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Do Property Rights Lead to Sustainable Catch Increases?

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Abstract

Individual transferable quotas (ITQs) assign property rights in fisheries by granting individual fishers a tradable share of the total allowable catch (TAC). ITQs were originally proposed to enhance profitability and safety, but may also provide incentives for more conservation-minded fishing practices. Indeed, recent empirical evidence shows a reduction in the likelihood of stock collapse and a threefold increase in catches two decades after ITQ implementation. Yet these spectacular catch increases follow modest 20% reductions in reported catches. We used standard fisheries models to analyze whether these catch trends are consistent with the theory underlying conservation benefits from property rights. We find that it appears unlikely that catch increases are attributable to ITQs alone. Improved catch reporting systems are often enacted concurrent with ITQs and may plausibly explain sustained catch increases. The existence of this alternative explanation warrants caution about claims that property rights are the cause of sustainable catch gains.

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Perspectives

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Abstract   *Individual transferable quotas (ITQs) assign property rights in fisheries by granting individual fishers a tradable share of the total allowable catch (TAC). ITQs were originally proposed to enhance profitability and safety, but may also provide incentives for more conservation-minded fishing practices. Indeed, recent empirical evidence shows a reduction in the likelihood of stock collapse and a three-fold increase in catches two decades after ITQ implementation. Yet these spectacular catch increases follow modest 20% reductions in reported catches. We used standard fisheries models to analyze whether these catch trends are consistent with the theory underlying conservation benefits from property rights. We find that it appears unlikely that catch increases are attributable to ITQs alone. Improved catch reporting systems are often enacted concurrent with ITQs and may plausibly explain sustained catch increases. The existence of this alternative explanation warrants caution about claims that property rights are the cause of sustainable catch gains.*

Key words   Individual Transferable Quota (ITQ), property rights, catch share, fisheries, economic efficiency, sample selection, catch reporting.

JEL Classification Codes   Q22, Q58.

Introduction

Individual transferable quotas (ITQs) are among the most actively debated policy options for addressing problems with the world's fisheries. These licenses provide each holder with a set share of the total allowable catch (TAC) and can be sold. By doing so, ITQs assign full property rights to the fishermen that own them. They were originally proposed to increase fisheries' profitability. With ITQs, fishers can time their catch to maximize market prices, and the most productive fishermen can buy the licenses from the less productive fishers. Another benefit is enhanced safety, because the fixed catch shares prevent incentives to "race to fish" early in the season (Clark 1990; Branch 2009). The property rights associated with ITQs have also been suggested as incentives for better stewardship. Two highly visible recent papers examined the conservation performance of ITQ-based fisheries using a global data set on fisheries performance (The Sea Around Us Project

2007) and concluded that ITQs reduce the chance of stock collapse (Costello, Gaines, and Lynham 2008), while leading to much higher catches (Heal and Schlenker 2008).

In their influential paper, Costello and co-authors (2008) compared the historical performance of 121 ITQs relative to over 11,000 non-ITQ fisheries. ITQs were associated with a reduced chance of stock collapse, defined by an annual catch falling to 10% of the recorded maximum for that fish stock. They argued that ITQs are a "win-win" proposition: fishermen can increase their profitability while halting, or even reversing, the global trend towards widespread collapse. In a discussion of this paper, Heal and Schlenker (2008) provided supporting evidence by examining catch trends before and after ITQ implementation. On average, catches increased threefold over the two decades following ITQ implementation, with a limited initial catch reduction of approximately 20% (figure 1).[1]

Driven by industry interest, initial scientific findings like these, and initial empirical evidence that ITQs have led to quota lease and sale markets that operate reasonably well (Newell, Sanchirico, and Kerr 2005), fisheries managers in the United States and worldwide have taken keen interest in the implementation of ITQs as an economic and conservation tool (NOAA 2009; World Bank 2009). Therefore, it is important that we be confident about the conservation value of ITQs before advocating them. This article addresses the following main question: are the observed catch increases in ITQs consistent with the theory underlying conservation benefits from property rights? Using standard and widely adopted fisheries models, we find that the observed catch trends appear to be inconsistent with this theory unless we make additional assumptions. In particular, the data contradict one possible explanation—that ITQs are implemented in highly depleted fisheries. We do find plausible a hypothesis that catch trends reflect improvements in catch monitoring and reporting, concurrent with ITQ implementation. It cannot be ruled out that different models reach different conclusions. However, the results herein demonstrate that
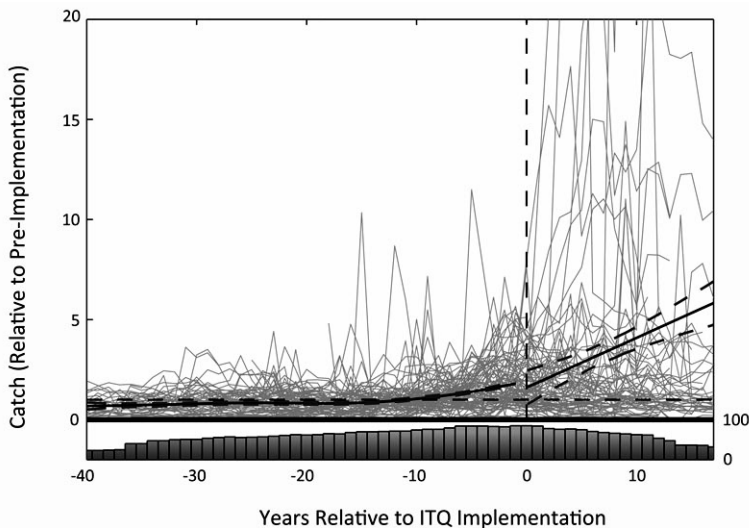
Figure 1. Catch Trends Before and After ITQ Implementation

Notes: Source: Heal and Schlenker (2008). The upper panel shows time series of individual fish species, where average catches before ITQ implementation are normalized to 1. The solid line results from a non-parametric regression. The lower panel shows a histogram of how many fisheries had catch data available for each time period. Reprinted by permission from Macmillan Publishers Ltd: *Nature* 455, 1044–1045, 2008.

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[1] Heal and Schlenker (Columbia University, pers. comm.) tested whether the drop in catches was statistically significant using polynomial time trends, and found that it typically was.

the conclusion that ITQs prevent fisheries collapses may not be correct in a widely adopted class of fisheries models. Therefore, catch monitoring and reporting deserve more attention in the current policy process, which is mainly focused on establishing property rights.

Fishery Management Regimes

To answer our main question, whether catch trends are consistent with the theory of conservation benefits from property rights, it is critical that we be clear about the characteristics of ITQs compared to other management practices. While there is a strong theoretical underpinning for why assigning property rights should lead to profit maximization, the theory behind conservation benefits is far more subtle. Fisheries management regimes span a spectrum ranging from no property rights (open access) to full property rights (ITQs), with many variants in between. Below, we describe this spectrum and its implications for conservation incentives and economic efficiency.

In the absence of any property rights, individuals utilizing an open-access resource will overuse it if the immediate individual benefit they get from doing so outweighs their share of the collective cost (Gordon 1954; Hardin 1968). In a fisheries context, this causes stocks to be exploited to inefficiently low levels. In its most extreme, the rational, profit-maximizing incentive may be to drive the stock to extinction (Clark 1973).

This conflict can be addressed, in theory, by setting catch limits (TACs), widely adopted by government agencies. However, if TACs are not allocated among fishers, they still have no property right to the resource. While a TAC has large conservation benefits in theory (with truthful catch reporting, full enforcement, and a government striving to maximize social welfare), it can lead to an overcapacity problem where too many people are unprofitably chasing too few fish.

In response, policy makers will often enact limited licensing programs (combined with a TAC), where a set number of people are granted the right to fish. This can be viewed as a crude and incomplete form of property rights. One of the problems with limited licensing programs is a potential race to catch fish early in the season even among a limited number of license holders, causing them to invest in too much individual capacity, use environmentally destructive fishing gear, and catch fish at suboptimal times from an efficient market perspective. A standard policy response to this 'race for fish' is to establish monthly or bimonthly trip limits for each vessel, which again is a crude policy instrument and does not fully eliminate the 'race for fish.'

A much more complete form of property rights is the allocation of catch shares (fixed percentages of the TAC) among the license holders. This form of catch shares is known as an individual fishing quota (IFQ). The race for fish and overcapacity issues can both be addressed simultaneously with IFQs (Copes 1986). IFQs establish property rights in a given fishing season. Since fishers may lose their license upon leaving the industry or retirement, IFQs fall short of providing full property rights.

To achieve full property rights, one only needs to allow for the resale of catch shares. This policy is referred to as an ITQ. Fishermen are now owners of a fixed share of the fishery. Thus, ITQs consist of three distinct policy elements: a TAC, individual catch shares, and transferability of licenses. Yet, transferability is the only unique element that distinguishes an ITQ from an IFQ.[2]

The term "catch shares" is often used to describe both IFQs and ITQs[3], and possibly IVQs (individual vessel quotas: a property right, sometimes transferable, that is assigned

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[2] Another characteristic of ITQs is that the licenses are typically fully divisible, but this is not central to our analysis.

[3] In fact, while Costello, Gaines, and Lynham (2008) use the term ITQs repeatedly, most have restrictions on transferability and whether shares can be traded on an open market (University of California at Santa Barbara, pers. comm.).

to vessels; [Grafton 1996]). In this article, we distinguish between these forms of catch shares, since the strength of the property rights associated with them is not exactly the same. For instance, upon retirement a fisherman can monetize the net present value of his catch share in an ITQ, but would instead lose his license in many IFQs.

While ITQs will certainly be more profitable than open-access fisheries without catch limits, they often evolve from fisheries that already have TACs, possibly combined with limited licensing, or even IFQs. Without distinguishing fisheries by their management characteristics (*e.g.*, catch limit, limited licensing, individual quotas, transferability), comparisons between catch share (or ITQ) fisheries and other fisheries are imprecise and potentially misleading. To isolate the effect of catch shares, these fisheries should be compared to fisheries with limited licensing plus TACs. However, including open-access fisheries in the control group (as Costello, Gaines, and Lynham (2008) do) would confound the effect of catch shares with the effect of establishing a TAC. Likewise, to isolate the impact of license transferability, a comparison of ITQs to IFQs would be most informative. Identification is further complicated by imperfect enforcement of existing management systems.

Conservation Benefits from Property Rights

It is not immediately obvious why catch shares (IFQs or ITQs) would lead to more *conservation* benefits than any other policy that includes a catch limit. After all, both are restricted by a TAC that, if set responsibly, should take care of the ecological concern about overfishing. Arnason (1990) shows that, with fully secure property rights, the market value of outstanding catch shares equals the present value of expected future fishery rents. Moreover, if industry expectation is the best predictor of the future state of the fishery, then adjusting the TAC to maximize the market value of outstanding catch shares is equivalent to profit maximization. Hence, each individual fisherman should have an incentive to lobby for the value-maximizing TAC. Without ownership of the future value of a fishery, fishers may sacrifice long-term productivity for short-term profits and pressure government agencies into setting TACs too high. For that reason, ITQs may be expected to lead to more responsible TACs and healthier fisheries (Grafton 1996; Environmental Defense 2007; Heal and Schlenker 2008).

Arnason's argument applies to a situation with full property rights. This implies that the property rights are permanent and can be sold, at least when a fisherman wants to retire from the fishery. It can be argued that the lack of transferability of catch shares in IFQs leads to weaker ("lower quality") property rights for fishermen that are planning to retire or quit. When such fishers do not view their quota as an exclusive and permanent harvesting right, they face short-term incentives, thereby removing the uniform incentive among participants to lobby for the value-maximizing TAC (Arnason 1990; Grafton 1996). Therefore, ITQs may have stronger conservation incentives than IFQs.

Other sources of conservation benefits from property rights (besides lobbying for economically efficient TACs) are the adoption of less destructive fishing methods, such as trawling. In addition, there is anecdotal evidence that if fishers own a share of the fishery, they have stronger incentives to fund scientific research and assist in improving data collection necessary to make the correct management decisions (Neher, Arnason, and Mollett 1989; NRC 1999; Branch 2009).

The argument that property rights lead to economic and conservation benefits has inspired relatively few fisheries to utilize ITQs, primarily in Australia (Wesney, Scott, and Franklin 1985), New Zealand (Clark, Major, and Mollett 1988; Annala 1996), Iceland (Arnason 1993), the United States (Gauvin, Ward, and Burgess 1994), and Canada (Casey *et al.* 1995). New Zealand has implemented ITQs for 636 fish stocks (Ministry of Fisheries 2010). Since the 1970s, about 1,000 fisheries worldwide have adopted ITQs, a limited fraction of the total (Arnason 2002).

If ITQs indeed lead to fishers lobbying for more conservative quotas in the short-run, we expect to observe that overexploited fisheries would show an initial *decline* in catches followed by a build up, following the adoption of an ITQ. This article argues that the spectacular threefold increases in long-run catches suggest that previous analyses may suffer from strong sample selection bias or a severe data quality issue. To illustrate our critique, we set up simple fisheries models to determine the degree of initial overfishing and the subsequent reduction in catches post ITQ implementation that would be necessary to explain a threefold long-run catch increase over 20 years.

In these standard models, a threefold catch increase is not possible in a typical fishery. Hence, to rationalize the catch trends, we need to make additional assumptions. One possible assumption is that ITQs were implemented in badly depleted fisheries. We argue that this is unlikely. A plausible alternative explanation is that improved catch monitoring and reporting concurrent with ITQ implementation drove the observed catch patterns. Given that commonly used fisheries models suggest that the increased catches may not be causally related to ITQ introductions only, policy makers should take care not to attribute the entire impact to (transferable) catch shares, but also consider direct means of improving catch reporting.

A Simple Fisheries Model

The data on catches pre- and post-ITQ implementation presented in Heal and Schlenker (2008) show an initial catch reduction of about 20%, followed by a threefold long-run catch increase. If a fishery were overfished initially (a key motivating circumstance for discussing conservation benefits of catch shares), a period of reduced catches would have to precede strong sustained long-run catch increases.

We now present a simple model to assess the degree of initial overfishing and the subsequent reduction in catches immediately following ITQ implementation that would be necessary for ITQs to explain the threefold long-run catch increases observed in the data.[4] In doing this, we compare the sustained catch levels at two equilibria—before ITQ implementation and after. It is even harder to interpret the threefold catch increases as the success of the ITQ if we relax the assumption that the adoption of an ITQ moves fisheries from one steady-state equilibrium to another. Those high catches may then also reflect unsustainable fishing practices.

For the initial equilibrium, we assume that effort levels lie somewhere between the competitive equilibrium with no property rights (*i.e.*, unregulated open access fishery) and the social optimum with full property rights (*i.e.*, the profit maximizing effort level that would occur with a single owner or a government agency managing the fishery optimally for sustained profits). For the post-ITQ equilibrium, we assume that the social optimum

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[4] This simple model has two distinguishing characteristics. First, it operates on aggregate fish biomass using a range of standard assumptions about the relationship between biomass and production. This approach is the norm in fisheries analyses, which form the basis of the data used in our article and those we are critiquing. There certainly are more complex models, for example those with Allee effects, age/size structure, or spatial dynamics. As explained at the end of the introduction, some of these alternative models may result in a threefold increase in catches following ITQ implementation. However, since we establish that the most commonly used models are not consistent with this threefold increase, our conclusion that causal claims about the effectiveness of ITQs may be misguided remains valid. Second, we assume stocks are in equilibrium prior to ITQ implementation. This is the appropriate assumption for causally attributing catch increases to ITQs. Suppose that a pre-ITQ stock were out of equilibrium because of other recent regulations (*e.g.*, restricted fishing activity or a tighter TAC). If the stock has not yet equilibrated and ITQs were implemented at the same time that other restrictions were relaxed, then the resulting catch increases would be (at least partially) attributable to those regulations and not to ITQs. Alternatively, if a stock were out of equilibrium because of changing oceanographic conditions, a large increase in catches may be more accurately attributed to better conditions. Either way, it would be inappropriate to attribute such catch increases to ITQs.

occurs. These assumptions are conservative in that they identify conditions under which threefold catch increases are possible at some point in the future (not necessarily in a 20-year timeframe) and presume that ITQs perfectly achieve the socially optimal effort level.

Consider a standard Gordon-Schaefer model with logistic stock growth and a simple catch function (Gordon 1954; Schaefer 1954):

$$\frac{dn_t}{dt} = rn_t\left(1 - \frac{n_t}{K}\right) - h_t \tag{1}$$

$$h_t = qE_t n_t, \tag{2}$$

where n_t is stock level at time t, K is the biological carrying capacity, r is the intrinsic population growth rate, h_t is annual catch, q is a catchability parameter, and E_t is fishing effort. Without loss of generality or flexibility, we can normalize stock levels to $N_t = n_t/K$, so that N_t is expressed as a fraction of carrying capacity. Equation (1) then becomes:

$$\frac{dN_t}{dt} = rN_t(1 - N_t) - h_t. \tag{3}$$

In equation (2), n_t is replaced by N_t. The steady-state conditions with constant effort, E^*, become:

$$N^*(E^*) = 1 - \frac{qE^*}{r} \tag{4}$$

$$h^*(E^*) = qE^*\left(1 - \frac{qE^*}{r}\right). \tag{5}$$

We can solve for the socially optimal effort using first-order conditions on profits, $\partial\pi/\partial E^* = 0$, where p is the unit price of fish and c is the unit cost of effort, as follows:

$$max_{e^*}\,\pi = \ ph^* - cE^*$$
$$max_{e^*}\,pqE^*\left(1 - \frac{qE^*}{r}\right) - cE^* \tag{6}$$
$$\Rightarrow E^{SO} = \frac{r}{2q}\left(1 - \frac{c}{pq}\right).$$

Solving for the competitive equilibrium simply requires no net profits, or $\pi = 0$:

$$ph^{CE} = pqE^{CE}\left(1 - \frac{qE^{CE}}{r}\right) = cE^{CE}$$
$$\Rightarrow E^{CE} = \frac{r}{q}\left(1 - \frac{c}{pq}\right). \tag{7}$$

Note that this value is twice the socially optimal level.[5] In many cases, we expect that the regulator can at least partially restrict effort directly (or indirectly through setting a TAC). We can represent their relative ability to do so using a parameter $\theta \in [0,1]$ to index their effectiveness at achieving the social optimum pre-ITQ as follows:

$$E_0(\theta) = \left(1 - \frac{\theta}{2}\right)\frac{r}{q}\left(1 - \frac{c}{pq}\right).$$

(8)

Here θ ranges from 0 (unregulated open access effort) to 1 (socially optimal effort), where a value near 0 means poor management control and a value near 1 means more efficient management control (potentially aided by enlightened lobbying). Note that all $\theta < 1$ correspond to economically inefficient effort levels.[6] In order to see a k-fold or larger increase in catches, we need to satisfy:

$$kh_0(\theta) \leq h^{SO},$$

(9)

or, equivalently:

$$kqE_0(\theta)\left(1 - \frac{qE_0(\theta)}{r}\right) \leq qE^{SO}\left(1 - \frac{qE^{SO}}{r}\right).$$

(10)

Simplifying, the only solution for a non-negative θ becomes:

$$\theta \leq \frac{1 - 2\frac{c}{pq} + \sqrt{\frac{(k-1)}{k} + \frac{1}{k}\frac{c^2}{p^2q^2}}}{\left(1 - \frac{c}{pq}\right)}.$$

(11)

Note that c/pq represents the competitive equilibrium population size. This ranges from 0 to 1. We restrict our attention to values of θ greater than or equal to 0, since lower values would indicate fisheries with effort levels even higher than what we would expect under unregulated open-access conditions. The feasible parameter combinations for a tri-

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[5] We assume that an individual fishery is small relative to world output, and therefore that p and c are exogenous and the same for all θ. If this assumption does not hold, sole-owner fisheries may have a lower per-unit cost, c, and a higher ex-vessel price, p, than open-access fisheries. In addition, inefficient fishery regimes may lead to too many fishermen using too much equipment: c is higher than in the efficient regime.

[6] According to the World Bank (2009), efficiency losses from non-property rights based fisheries (such as limited licensing) are large. In terms of our model, this case corresponds to θ being far below 1. In fact, when taking into account the additional loss to society from environmental damage and subsidies to the fishing sector, certain fisheries may have a *negative* social rent: not fishing would be more efficient than fishing!

pling of catch after ITQ implementation are shown as the grey Gordon-Schaefer region in
figure 2. The dotted lines are level curves for either lower or higher catch increases.
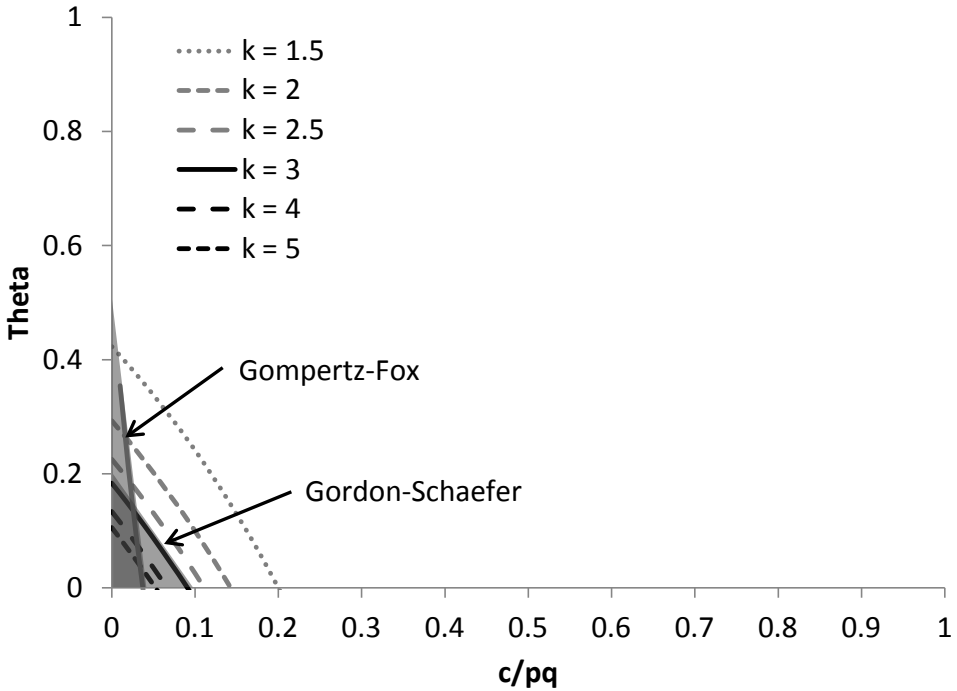

Figure 2. Feasible Conditions for Observing Threefold Catch Increases in Equilibrium
using the Gordon-Schaefer and Gompertz-Fox Models (grey areas)

Notes: The equilibrium population size under competitive equilibrium is shown on the horizontal axis. The ver-
tical axis represents the parameter *θ*, which varies from 0 (unregulated open access effort) to 1 (socially optimal
effort for maximizing profits). Only parameter combinations in the shaded region are capable of explaining
threefold catch increases. The dotted curves indicate the feasible region for higher or lower *k*.

To examine a broader range of possible fisheries, we examined the effect of using a
Gompertz-Fox production function instead of the Gordon-Schaefer model in equation (1).
Again, we normalize it so that abundance levels range from 0 to 1, yielding:

$$\frac{dN_t}{dt} = -\gamma N_t ln(N_t). \tag{12}$$

This production function differs from a Gordon-Schaefer model in having a skew
to the left, such that maximum production occurs at a lower biomass level (0.368 as op-
posed to 0.5). The skew also means production is higher at low population levels. As
such, the Gompertz-Fox production function provides a useful and standard contrast to
Gordon-Schaefer (these two models are commonly compared in fisheries stock assess-
ment exercises).

The analysis of this model is provided in the Appendix. The result is that a *k*-fold increase in catches is possible if:

$$k \leq \frac{\left\{ln\left(\frac{c}{pq}\right) + \varphi\left(\frac{c}{pq}\right)\right\} exp\left\{\varphi\left(\frac{c}{pq}\right)\right\}}{\left\{ln\left(\frac{c}{pq}\right) + \theta\varphi\left(\frac{c}{pq}\right)\right\} exp\left\{\theta\varphi\left(\frac{c}{pq}\right)\right\}}$$

$$\varphi\left(\frac{c}{pq}\right) = 0.0612\left(ln\left(\frac{c}{pq}\right)\right)^2 - 0.5244 ln\left(\frac{c}{pq}\right) - 0.0129.$$

(13)

The region defined by this relationship is shown in figure 2. It is a small triangle of feasible parameter values, approximately the same area as the region of feasible parameter values under Gordon-Schaefer production, but with more latitude in θ, the management control variable, and less in the competitive equilibrium abundance level, *c/pq*. The most relevant finding is that even under a quite different assumption regarding production, conditions for a tripling of catch remained highly restrictive.

These highly restrictive conditions are not likely to be common in real-world fisheries (see below). The low values of *c/pq* represent fisheries with extremely low initial biomass levels. In many fisheries, a threefold catch increase would be impossible even if they had unregulated open access conditions ($\theta = 0$) prior to ITQ-implementation.

The analysis above compares two steady states, but does not investigate the transition dynamics. However, the transition path matters. It may further restrict the feasible parameter space, but also has important economic implications. In order to simulate these changes over time, we used a discretized version of the Gordon-Schaefer model in equation (1). To ensure clarity of this approach, we now refer to the growth parameter as the λ, the standard symbol for the annual population growth potential, rather than the instantaneous growth rate, *r*.

First, we examined unconstrained optimal paths. To do so, we solved numerically for transition paths that maximize net present value ($NPV = \sum_{t=1}^{\infty} (1 + i)^{-t}(ph_t - cE_t)$). These optimal paths eliminate all fishing until the stock has rebuilt to sufficient levels to sustain optimal catch levels (figure 3). This finding is consistent with earlier literature, which found that net present value is maximized by policies that eliminate fishing when stocks are depressed below optimal abundance levels (Clark 1990). When a tripling of catch is possible in our model, it typically happens within 20 years. However, consistent with our equilibrium analysis, tripling of catches only occurs if the *c/pq* ratio is less than or equal to 0.1 (figure 3). While this analysis does not pose any further constraints on the feasible parameter space except for the slowest growing populations ($\lambda < 0.2$), it does pose a challenge to the empirical observations. Specifically, real-world catches were not eliminated following ITQ implementation.

Dichmont *et al.* (2010) found the same unconstrained optimal path, but argued that this path is rarely observed in reality because closing a fishery is costly. Continued fixed costs and frictions in labor markets make temporary closure practically unacceptable. In addition, borrowing constraints and lack of savings can make it impossible for fishers to survive long periods of fishery closure. We therefore follow their focus on "practical," constrained optimal solutions. First, we solved for optimal paths with the constraint that catches could not drop any more than 20% below initial values. We found that rebuilding

once again took place sufficiently quickly for most species (those with $\lambda \leq 0.25$). How-ever, catches still failed to match observed patterns. In these constrained-optimal paths, catches were held at 80% of initial values until the stock rebuilt sufficiently to sustain optimal catches. In contrast, observed catches dropped 20% momentarily and began in-creasing immediately.
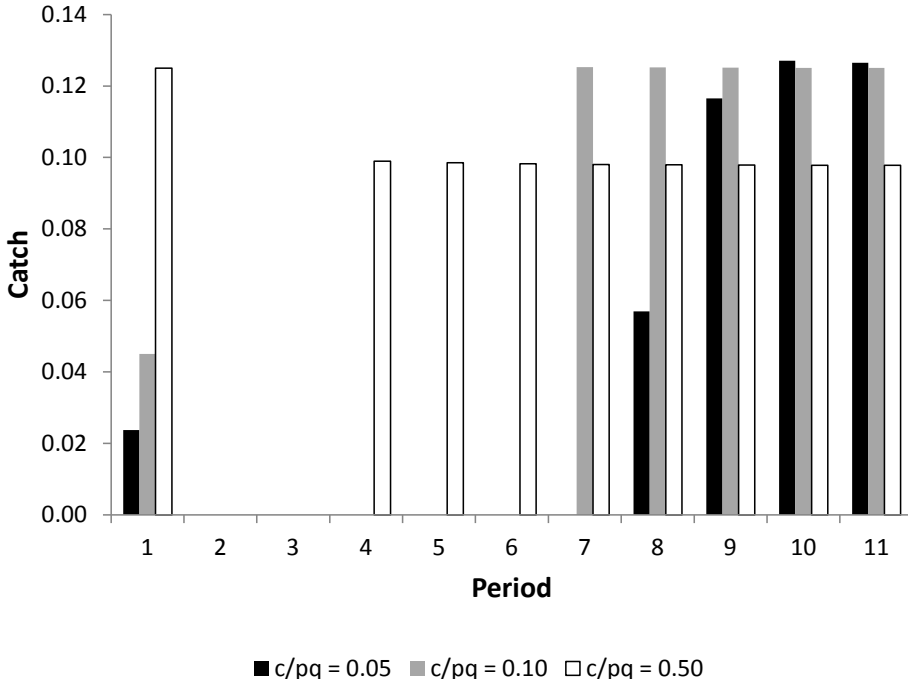

Figure 3. Optimal Catch for Different Effort Price Levels *c*
following ITQ Implementation

Notes: ITQ is implemented after period 1. Growth function: Gordon-Schaefer. Parameter setting: $\lambda = 0.5$ and $i = 0.05$.

To mimic the observed pattern, we examined simulations where *effort* was constrained to 80% of initial levels. In these simulations, catch trends qualitatively match observed pat-terns. Here, the conditions that allow for a tripling of catch within 20 years are restricted further (figure 4). In a highly productive stock ($\lambda = 1$), a tripling is only possible in 20 years if the c/pq ratio is less than 0.04 and θ is smaller than 0.08. In a moderately produc-tive stock ($\lambda = 0.75$), the parameter space is further restricted to c/pq values less than or equal to 0.03 and values of θ below 0.06. In a moderately slow-growing stock ($\lambda = 0.5$), a tripling is not possible in the timeframe provided, regardless of these parameter values.

We conclude that using standard fisheries models, the threefold catch increase in 20 years could only be observed when the pre-ITQ fishery was overfished to levels near extinction, and in species with relatively high population growth potential. Despite media reports to the contrary, actual statistics on the state of fisheries would suggest that most are not imperiled by extinction (FAO 2009; NMFS 2009). Thus, explaining the observed

data requires additional assumptions. We explore two main options: that ITQs are implemented in a highly skewed sample of all fisheries, and that catch data were reported more completely after ITQ implementation.
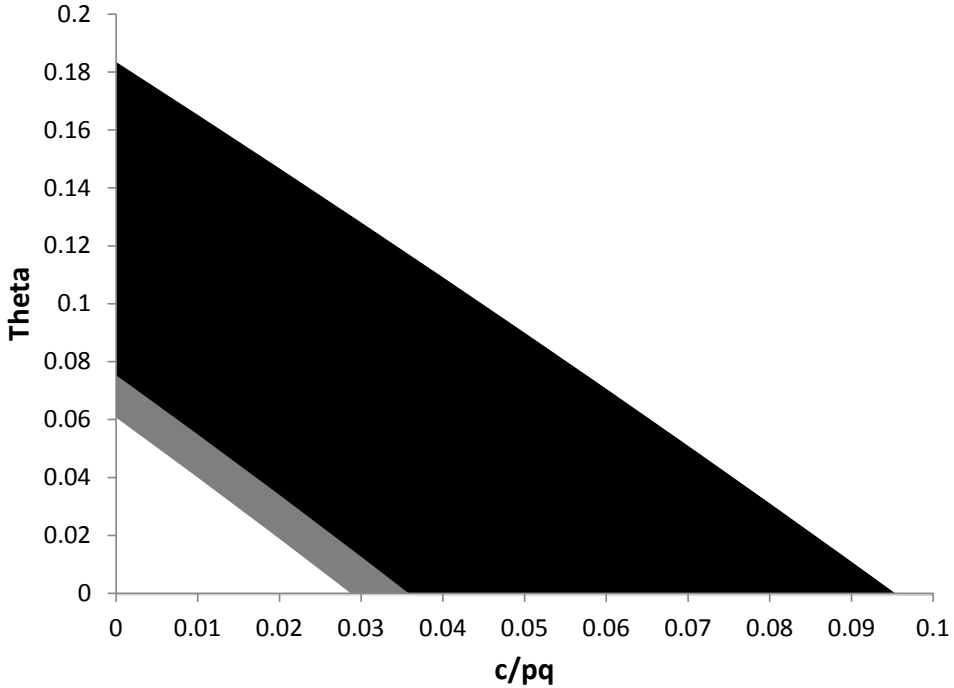

Figure 4. Feasible Conditions for Observing Threefold Catch Increases in 20 Years with Effort Constrained to at Least 80% of Initial Levels

Notes: The horizontal axis shows the steady-state population size under competitive equilibrium, while the vertical axis shows the parameter θ, which varies from 0 (unregulated open-access effort) to 1 (socially optimal effort for maximizing profits). The collection of the white triangle and two shaded regions shows the feasible parameters that allow a tripling of catches without a time limit. The white triangle and lighter-shaded region show the feasible parameters that allow tripling within 20 years if $\lambda = 1$. The white triangle shows the feasible parameters that allow a tripling within 20 years if $\lambda = 0.75$. If $\lambda = 0.5$, tripling is not possible within 20 years.

Exploring Additional Assumptions

Is it possible that a selection bias could explain the observed patterns if ITQs were preferentially implemented at the reopening of collapsed fisheries? This explanation seems unlikely for two reasons. Most importantly, the data suggest that catches were actually stable or increasing, on average, prior to ITQ implementation (figure 1). Thus, if they were depleted, the overfishing would have had to occur many decades in the past. Moreover, Costello and colleagues (2008) made substantial efforts to test for a selection bias and could never reject the null hypothesis that ITQ fisheries were representative of fisheries as a whole.

Instead, could the observed catch trends be explained by improved monitoring and reporting of catches that happened simultaneously with the adoption of an ITQ? We find

this hypothesis plausible. In negotiations around the implementation of ITQs, conservation groups have often successfully pressed for expanded catch monitoring, including the use of onboard observers to account for retained and discarded fish (discards are notoriously difficult to track otherwise). This coverage appears to lead to improvements in compliance with catch limits in ITQ fisheries (R. Fujita, Environmental Defense Fund, pers. comm., 26 March 2009). In addition, Grafton (1996) documents that New Zealand adopted a much stricter monitoring system for fishers' landings concurrent with establishing ITQs. This means that it becomes more difficult to underreport catches or discard less profitable catches, such as (typically dead) undersized fish. In other words, reported catch becomes more similar to actual catch. This effect cannot be attributed to the establishment of property rights, since incentives for underreporting and catch discarding remain even in ITQ fisheries (NRC 1999).

The improved catch data would have two effects. First, it would effectively reduce the TAC, since more discards will be counted against it. Thus, what appears to be a 20% drop in the catch data may represent a larger reduction in catches following the implementation of ITQs. Hence, enhanced reporting could lead to a rebuilding of a fish stock. The rebuilding will likely lead to real increases in reported catch per unit effort, which is viewed as the best indicator of stock abundance for most fisheries. Hence the regulator will increase the TAC. This is consistent with the catch trends for ITQs observed in the data. Second, improved catch reporting would potentially create an appearance of higher catch per unit effort, since fishers would hit their limit with less effort considering that previous unreported discards would now be counted against them.

If the regulator naively fails to recognize the distinction between actual and reported catches, the improved catch reporting would look to the assessment model like a sudden stock rebound. If the reporting change were addressed explicitly, though, we might expect improved stock assessments because of the more accurate measure of catch per unit effort resulting from more complete catch records.

There are other potential explanations of the observed catch patterns. Catch increases may reflect other concurrent changes that are correlated with the adoption of catch shares (*e.g.*, ITQs or IFQs), such as improved timing of catch (*e.g.*, avoiding the breeding season); management reform prompted by policy shifts or litigation; or extra-regulatory efforts, such as consumer campaigns (*e.g.*, sustainable seafood guides). However, such changes would seemingly result in catch reductions like those predicted by a conservation theory of property rights. Alternatively, catch shares might have selectively been implemented in developing fisheries that have not yet reached their full economic potential. We cannot rule out this explanation, although it would certainly contradict the conventional wisdom of fish stocks in peril. If it were true, then the observed patterns would not reflect conservation benefits from property rights. If these changes, rather than establishing property rights through catch shares, have indeed led to better conservation, policy makers should employ them directly even in regimes without catch shares (such as a TAC with limited licensing).

Previous studies have neither convincingly estimated the impact of establishing catch shares (property rights) on the probability of fishery collapse nor the differential effect of ITQs versus IFQs. Costello, Gaines, and Lynham (2008) compared a mix of ITQ and IFQ fisheries to all other fisheries, though these fisheries varied in what policy elements were used in their management. A more complete analysis would separately test the importance of the key characteristics along the fisheries management regime spectrum—open access, TACs, TACs plus limited licensing, IFQs, and ITQs. The main specification in Costello, Gaines, and Lynham (2008) is the following logit model in which each fishery is a cross-sectional observation:

$$C_{it} = \beta_0 + \beta_1 D_{ITQ_i} + \beta_2 D_{ITQ_i} ITQ_{year,it} + \beta_3 year_t + \gamma'^{z_{it}} + \theta_i + \varepsilon_{it}, \quad (14)$$

where the dependent variable, C_{it}, is a binary variable that indicates whether or not fishery i was collapsed in year t. D_{ITQi} is a binary variable to indicate if a fishery implemented an ITQ at some point in time. $ITQ_{year,it}$ is the number of years that the fishery has been an ITQ fishery by year t. θ_i is a fishery fixed effect. Z_{it} is a matrix of control variables.

For a more relevant comparison between fisheries management regimes, it is crucial to classify fisheries into the following categories: (1) ITQ (TAC, catch shares (CS), transferability (TF)); (2) IFQ (TAC, CS); (3) limited licensing (TAC, LL); (4) TAC; (5) open access (none of the above). Then one can estimate:

$$C_{it} = \beta_0 + \beta_1 D_{TAC_i} + \beta_2 D_{TAC_i} D_{LL_i} + \beta_3 D_{TAC_i} D_{CS_i} + \beta_4 D_{TAC_i} D_{CS_i} D_{TF_i}$$
$$+ \beta_5 D_{TAC_i} TAC_{year,it} + \beta_6 D_{TAC_i} D_{LL_i} LimLic_{year,it} + \beta_7 D_{TAC_i} D_{CS_i} IFQ_{year,it}$$
$$+ \beta_8 D_{TAC_i} D_{CS_i} D_{TF_i} ITQ_{year,it} + \beta_9 year_t + \gamma' Z_{it} + \theta_i + \varepsilon_{it}. \tag{15}$$

The open-access fishery is the new control group. We assume for simplicity that limited entry and catch shares are mutually exclusive fisheries management regimes.[7] For example, the coefficient β_8 indicates the effect of an ITQ over and above an IFQ (measuring the impact of license transferability). β_7 indicates the effect of IFQs relative to TAC fisheries. $\beta_7 - \beta_6$ measures the effect of going from a limited license (plus CAT) fishery to an IFQ.

These comparisons are more informative about the true relative performance of different fishery management regimes than a simple comparison of ITQs to all other fisheries. For instance, if β_7 is large relative to β_8, and β_6 is small relative to β_7, one could conclude that establishing catch shares is what drives the reduction in collapse rates, but not transferability (a move from IFQs to ITQs). In that case, policy focus should be shifted towards establishing more IFQ fisheries in places where there had previously only been a catch cap. However, if β_6 is large relative to β_7, the focus on catch shares may be misplaced, and establishing limited licensing (possibly in combination with trip limits) already leads to most of the observed conservation benefits.

Conclusion

In conclusion, it is certainly a possibility that establishing catch shares or, specifically, ITQs has led to much improved and more conservation-minded management practices which, in turn, have led to higher catches and more profit. However, our analysis indicates that attributing these conservation benefits to the enhanced property rights associated with catch shares may be premature. Standard fisheries models suggest that a plausible alternative explanation would be that better catch reporting and monitoring are responsible for the observed catch trends. It may be possible to design a different model that leads to higher catches as a result of ITQs. Nevertheless, the existence of a plausible alternative explanation using the most commonly used fisheries models warrants caution about strong causal claims regarding the effectiveness of ITQs in sustaining substantially higher catches. Also, previous empirical work has not convincingly estimated the effect of the license transferability element of ITQs on conservation incentives. Only further data analysis will help to illuminate the true explanation behind the observed catch patterns. In the meantime, we need to be cautious about conclusions regarding the conservation benefits of catch chares based solely on catch data.

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[7] While this simplification has no impact on the conceptual regression framework suggested above, it needs to be mentioned that there are fisheries with both catch shares and limited licensing. For example, fishers in the red snapper fishery in the Gulf of Mexico need separate catch shares and fishing permits (Gulf of Mexico Fisheries Management Council 2008).

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Appendix

In the case of a Gompertz-Fox production function, it is not possible to derive an explicit solution for the socially optimal effort level, E^{SO}, as a function of the competitive equilibrium effort level, E^{CE}. Instead, we approximated an explicit equation based on the implicit relationship between these two variables. The first step was to solve for steady-state abundance ($dN_t/dt = 0$) and catches as a function of a constant effort level, E^*:

$$N^*(E^*) = exp\left(-\frac{q}{\gamma m} E^*\right) \tag{16}$$

$$h^*(E^*) = qE^* exp\left(-\frac{q}{\gamma m} E^*\right). \tag{17}$$

We then solved for the effort, abundance, and catch levels associated with maximum sustainable yield by maximizing over h^*. These values serve as useful reference points:

$$E^M = \frac{\gamma m}{q} \tag{18}$$

$$N^M = \frac{1}{e} \tag{19}$$

$$h^M = \frac{\gamma m}{e}. \tag{20}$$

The competitive equilibrium levels, determined by solving for a zero profit condition, are:

$$E^{CE} = -\frac{\gamma m}{q} \ln\left(\frac{c}{pq}\right) \tag{21}$$

$$N^{CE} = \frac{c}{pq} \tag{22}$$

$$h^{CE} = -\gamma m \frac{c}{pq} \ln\left(\frac{c}{pq}\right). \tag{23}$$

We then divided the competitive equilibrium effort level by the maximum sustainable effort level for algebraic convenience:

$$\frac{E^{CE}}{E^M} = -\ln\left(\frac{c}{pq}\right). \tag{24}$$

Finally, we derived the social optimum effort level by maximizing profits, yielding:

$$\frac{E^{SO}}{E^M} - \frac{E^{CE}}{E^M} = \ln\left(1 - \frac{E^{SO}}{E^M}\right). \tag{25}$$

Implicitly solving this relationship for ratios of E^{CE}/E^M ranging from 0 to 4 (which correspond to c/pq values ranging from approximately 0.018 to 1), the explicit quadratic equation $\frac{E^{SO}}{E^M} = -0.0612\left(\frac{E^{CE}}{E^M}\right)^2 + 0.4756\left(\frac{E^{CE}}{E^M}\right) + 0.0129$ produced an excellent fit ($R^2 = 0.9994$). Substituting in the relationship (24), we were able to express E^{SO} in terms of E^{CE} as follows:

$$E^{SO} = E^{CE} - \frac{\gamma m}{q}\varphi\left(\frac{c}{pq}\right)$$

$$\varphi\left(\frac{c}{pq}\right) = 0.0612\left(\ln\left(\frac{c}{pq}\right)\right)^2 - 0.5244\ln\left(\frac{c}{pq}\right) - 0.0129. \tag{26}$$

We can think of fisheries in feasible equilibrium as existing on a continuum ranging from E^{CE} to E^{SO}, indexed by $\theta \in [0,1]$, such that initial effort is:

$$E_0(\theta) = \left(-\frac{\gamma m}{q}\right)\left\{ln\left(\frac{c}{pq}\right) + \theta\varphi\left(\frac{c}{pq}\right)\right\}. \tag{27}$$

Initial catch would then be $h_0(\theta) = qE^0N^0$, and our criteria for evaluating the 're-covery potential' of the fishery would be comparing this catch to the catch at the social optimum level. Specifically, we ask whether $kh_0(\theta) \leq h^{SO}$ or $k \leq (qE^{SO}N^{SO})/(qE^0N^0)$, where k is the magnitude of potential catch increase, or:

$$k \leq \frac{\left\{ln\left(\frac{c}{pq}\right) + \varphi\left(\frac{c}{pq}\right)\right\}\exp\left\{\varphi\left(\frac{c}{pq}\right)\right\}}{\left\{ln\left(\frac{c}{pq}\right) + \theta\varphi\left(\frac{c}{pq}\right)\right\}\exp\left\{\theta\varphi\left(\frac{c}{pq}\right)\right\}}. \tag{28}$$