Capitalizing property rights insecurity in natural resource assets*

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Abstract

Property rights are commonly touted as a solution to common pool resource problems. In practice, however, the security of property rights over natural resources varies substantially, which may affect returns to ownership as well as asset values. We examine theoretically the capitalized asset market effects of weakened property rights to natural resources. We then assemble a unique dataset of global fisheries to examine empirically how differences in property right strength affect market outcomes. Consistent with our theoretical predictions we find significant asset market capitalization of insecurity arising from: (1) ownership disputes, (2) illegal extraction from resource stocks, and (3) the possibility of government revocation of rights. Overall, these results suggest important pecuniary effects of weakened property rights to natural resources.

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To overcome the problems associated with common pool resources (e.g. Gordon, 1954; Hardin, 1968), property rights approaches to management are increasingly employed globally. Across resources, strong evidence of increased economic and ecological performance from rights-based approaches has emerged (Grafton et al., 2000; Costello et al., 2008), and the policy debate has shifted away from the effectiveness of these approaches toward questions of design. While it seems self-evident that design elements may affect the security of a property right, this link has not been adequately explored. For example, so-called "sunset clauses" after which rights are revoked and redistributed will affect stewardship and value (Costello and Kaffine, 2008) and assignment of rights to only a portion of the resource stock may erode conservation and investment incentives (Deacon et al., 2012). Other fundamental design parameters include limits on ownership or transferability (Grafton et al., 2000), revocability, and geographic or temporal control over resource stocks. Despite their ubiquity and importance for design, to our knowledge the extent to which these limitations on property rights security affect behavior and economic value has not been carefully studied. The purpose of this paper is to develop and analyze a model linking insecure property rights to asset markets, and to employ that model to empirically examine these effects for a globally significant common pool resource.

Our empirical application concerns the movement to property rights for global fisheries, but this story is not unique to fisheries. The deleterious consequences of common pool management of resources such as timber, air, water, and biodiversity are increasingly realized. These declines have lead to the establishment of property rights over these resources. In so doing, governments inevitably wrestle with equity-efficiency tradeoffs in determining how much control to cede to private resource owners, where more control typically confers a stronger property right to its owner. Loosely speaking, when the government retains more control over the resource, it weakens the property rights held by individuals; this may or may not be transmitted through market prices for the natural resource asset. We explore three general classes of property right insecurity that are chosen to capture a large set of

Table 1: Examples of natural resource property rights and sources of insecurity.

Natural Resource	Location	Class of Insecurity	Citation
Agriculture	Ghana	Expropriation Risk	Besley (1995)
Forestry, Agriculture	Brazil	Expropriation Risk	Alston, Libecap and Mueller (2000)
Fisheries	New Zealand	Illegal Harvest	Ministry of Fisheries Annual Plenary Reports
Agriculture, deforestation	Nicaragua	Expropriation Risk, Ownership Dispute	Liscow (2012)
Fisheries	USA	Revocation Risk	Magnuson-Stevens Act
Water	Somalia and Ethiopia	Ownership Dispute	Flinton and Tamrat (2002)
Grazing	American West	Revocation Risk	Libecap, 1981

the real-world circumstances under which property rights are weakened. The first concerns uncertainty over future ownership and is modeled as an ownership dispute that will be resolved once-and-for-all at a known date in the future, the second involves illegal harvest activity, and the third examines the effects of a perpetual threat that the property right will be revoked. Table provides several real-world examples of natural resources managed by property rights that are subject to one or more of these sources of asset insecurity.

While the structure of property rights surely differs across natural resources, a common model is the so-called "cap and trade" model where the level of extraction from resource stocks is set by a regulator, extraction rights are owned by individual firms, and those firms divide, buy, sell, and lease those rights as assets. These "quota markets" offer an ideal opportunity to study the effects of property right security on asset values because the relationship between lease price and sales price of asset will be dictated by market fundamentals. For example, among the examples given in Table , some fisheries managed by tradable quota are prone to illegal harvest or whose underlying property rights are legally revocable.

The details of quota markets and property right security for natural resources are well described in the literature, but only few papers examine directly the effects of property right security on asset values. It is well documented that property rights and institutions can have a profound impact on investment and economic growth, yet it is difficult to empirically disentangle the effects of institutions on economic outcomes. In considering economic development, there is wide acknowledgement of the critical role of institutions (see, e.g. Acemoglu and Johnson, 2005; Besley and Burgess, 2000, Alston et al., 1996; Alston and Mueller, 2010; Banerjee et al., 2002; Besley, 1995; Goldstein and Udry, 2008; Jacoby et al., 2002). Yet few papers empirically study the effects of property rights security on economic outcomes in common pool resources. We contribute to this broader literature by examining the pecuniary market effect of stronger property rights. In fisheries, Newell et al (2005) study individual transferable quota (ITQ) markets in New Zealand and find that markets are sufficiently "thick" to operate well; the relationship between lease and sales prices approximately follows market interest rates, and asset values in fisheries that experienced significant rebuilding showed large gains. In a follow-up paper, Newell et al (2007) extend this analysis to a more formal model of asset pricing for "created markets". They find that asset prices are higher when interest rates are lower, and asset values are lower for stocks with higher biological fluctuation. They also find that stocks that had large decreases in costs or high growth rates in output prices have higher quota asset prices. These papers contribute significantly to our understanding of quota markets and asset pricing, though they do not address the issue of property rights security or institutional design.

We begin by developing an analytical model of a natural resource managed with property rights. Harvest rights are owned and can be divided, bought, sold, and leased among a competitive set of resource users. We consider three general ways that institutional design may affect the security of property rights over natural resources: disputes over ownership, instances where extraction may be (partially) uncontrolled by the regulator, and cases where the right may be revoked entirely. We use the model to generate predictions about the impact of property rights design on asset values and lease prices. Because many forms of property right insecurity involve uncertainty over future rent capture, we follow the literature on asset pricing and use the dividend price ratio to capture future expectations. This measure accomplishes two goals. First, it measures the market's capitalized belief's about the future returns on the asset (this is the denominator or "price"). Second, it controls for a whole suite of potentially unobservable resource-specific characteristics by incorporating the current period return on the asset (via the numerator, or "dividend"). While this is an attractive measure, the extent to which it can be relied upon to reflect changes in property rights security for natural resources has not been carefully studied. For example, some changes in property rights may affect both the current returns (the dividend) and future expectations (the price) which may dampen, or even cancel out completely, any measurable effect on the dividend price ratio. We derive a number of concrete theoretical predictions that directly link capitalized asset values and dividend price ratios to property right insecurity.

We use these theoretical insights to examine the effects of property right insecurity on global fisheries asset values. To do so, we exploit differences in property rights within and across countries to determine the market implications of secure ownership of these assets. We find that property rights security has a significant effect on asset values in fisheries. In accordance with theoretical predictions, markets appear to be capitalizing ownership disputes (in our application market participants behave as if there is a 45% chance of rights being modified), illegal harvest (where market outcomes suggest that the problem is worsening over time), and the possibility of revocation of the right (where markets behave as if this effect is more significant than the discount rate itself). Overall, our results suggest that the security of property rights has a profound impact on economic outcomes in (previously) common pool resources.

1 Theoretical Background

We begin by developing a simple analytical model to examine the role of property rights on lease and sales prices of a natural resource asset.[1] We begin by assuming that a natural resource asset is owned, divisible, leasable, and transferable in a market. We denote by π_t the competitive market rental rate (equivalently, lease price) of the asset. If rights are secure and held in perpetuity, the sales price of the asset will capitalize the expected discounted

[1] A famous application of this type of reasoning outside of natural resources is in Fogel and Engerman (1974), who examine slave price trends leading up to the end of the Civil War.

rent stream as follows:

$$V_\tau = \sum_{t=0}^{\infty} \pi_{\tau+t}\delta^t = \pi_\tau + \sum_{t=1}^{\infty} \pi_{\tau+t}\delta^t, \tag{1}$$

where δ is the discount factor. Dividing the period-0 rental rate by the capitalized asset value gives

$$R_0 = 1 - \delta \frac{V_1}{V_0}. \tag{2}$$

This ratio is commonly used in finance to test future expectations about earnings, to compare measures of asset value across geographically distinct markets, and to test for bubbles in asset markets (see, e.g., Campbell and Shiller, 1988; and Cochrane, 1991; Poterba, 1991). In that literature, it is referred to as the *dividend price ratio*, to which we will conform here.

Modifying this simple model can yield sharp analytical predictions about the effects of property rights security on dividend price ratios. Property right insecurity over natural resource assets can occur for numerous reasons. We focus on: (1) Ownership disputes, where some fraction of the asset may be transferred to another owner without compensation, (2) Illegal harvest, where the owner captures only a fraction of the resource's rent, and (3) Possible revocation, where the government or other party poses a credible and perpetual threat to revoke all rights to the asset. Ultimately, theoretical analysis of each issue will result in a prediction that is empirically testable.

1.1 Ownership disputes

We first analyze the effect of an ownership dispute on the ex-ante and ex-post dividend price ratio. We model the ownership dispute as follows: The initial asset owner holds a secure right to access the resource in the current period (so π_0 is not affected by the dispute), but the ownership is under dispute so future ownership is uncertain. In water rights, for example, this may take the form of a dispute over agricultural vs. in-stream flows that will be resolved by court decision on a particular day. We assume that the dispute will be resolved prior to period 1. We further assume that the policy function being pursued (which need not be the result of a dynamic optimization) is independent of the resolution of asset ownership.[2] In the absence of an ownership dispute, the dividend price ratio is given by Equation 2.

[2] The policy function determines the time paths of extraction and resource stock levels.

Now suppose that some fraction $(1-\alpha)$ of the asset is under dispute that will be resolved once-and-for-all prior to period 1. With probability p the dispute will disadvantage the asset owner, so the right will be modified. With probability $1-p$ the dispute is settled in the owner's favor so the right remains unaltered. Under this setup, the expected present value of the asset prior to dispute resolution is:

$$J_0 = \pi_0 + \delta V_1(1-p+\alpha p) = V_0 - (p-\alpha p)\delta V_1, \tag{3}$$

where V_τ is as defined in equation 1. The dividend price ratio prior to the dispute resolution is:

$$R_0 = 1 - \frac{\delta V_1(1-p+\alpha p)}{V_0 - \delta V_1(p-\alpha p)}. \tag{4}$$

This ratio clearly depends, for example, on the proportion of the asset under dispute $(1-\alpha)$ and on the probability of alteration of the right (p). However, once period 1 arrives, the uncertainty over the dispute will have been resolved. This gives rise to the following result:

Result 1. *Following the dispute resolution, the dividend price ratio is given by:* $R_1 = 1-\delta\frac{V_2}{V_1}$, *regardless of the outcome of the dispute. If the resource is in steady state,* $R_1 < R_0$.

The first clause of Result 1 follows directly from the identity: $V_1 \equiv \pi_1 + \delta V_2$, and says that, while the dividend price ratio will change following dispute resolution, it will always change to the same level, regardless of the outcome of the dispute. The second clause states that if the resource is in steady state (so $\pi_t = \pi_{t+1}\ \forall t$), then the sign of the change is also independent of the outcome: resolving the dispute will always decrease the dividend price ratio.[3] Result 1 presents an empirically relevant finding: suppose we observe the dividend price ratio before and after a dispute is resolved. Result 1 says that the sign of the change reveals nothing about how the dispute is capitalized into asset values. However, the magnitude of the change in dividend price ratio does reveal important information. It will become useful to define the expected fraction of the asset that is revoked as $\beta \equiv p - \alpha p$. Employing the set of equations above, and assuming steady state, we can immediately calculate the decrease in the dividend price ratio following the dispute resolution, as follows:

$$\Delta R \equiv R_1 - R_0 = \delta\beta\left(\frac{\delta - 1}{1-\delta\beta}\right) \tag{5}$$

[3] We thank Larry Karp for pointing this out.

We can rearrange this expression to back-out the implied property right insecurity preceding the dispute resolution, as follows:

Result 2. *The market's expectation of the fraction of the asset that will be revoked is given by:* $\beta = \frac{\Delta R}{\delta(\delta - 1 + \Delta R)}$.

Result 2 implies that we can use the change in dividend price ratio - before vs. after the dispute resolution - to estimate the ex-ante market capitalization of the dispute. In our empirical application we will make use of Result 2 by observing the change in the dividend price ratio (ΔR) surrounding a legal dispute, and calculating the implied expectation of asset alteration, β.

1.2 Illegal or uncontrolled extraction

A second important class of property rights insecurity involves illegal or uncontrolled exploitation of the natural resource. A common example from forestry concerns private landholders in developing countries who manage their lands under a perpetual barrage of illegal timber extraction. Harvest outside of the owner's control obviously weakens the ability of the owner to capture resource rents, and consequently would be expected to lower the value of the asset. On the other hand, illegal harvest would also presumably reduce the dividend (i.e. rental rate) to the righful owner of the resource. Thus, care is required to develop testable hypotheses about the effects of illegal extraction on the dividend price ratio.

We begin by assuming that both the illegal and managed extraction levels are in steady state - they remain constant over time,[4] though we allow the level of extraction would clearly depend on the amount of illegal activity taking place. Let $\bar{\pi}(f)$ be the steady state dividend to the asset owner where f measures the level of illegal harvest taking place and $d\bar{\pi}/df < 0$. The dividend price ratio with illegal harvest is denoted $\bar{R}(f)$. The following result is straightforward but instructive:

Result 3. *Provided the system is in steady state, the dividend price ratio is independent of the level of illegal harvest, and is given by:* $\bar{R}(f) = 1 - \delta$.

[4] We will relax this shortly.

Provided rental rates are in steady state, the level of illegal harvest has *no effect on the dividend price ratio* because both the dividend and the price are equivalently affected; the market effect of illegal harvest is exactly cancelled out.

However, in the presence of illegal activity it is possible that the system is out of steady state; illegal harvest might be increasing or decreasing over time. To proceed, we need not a assume a functional form describing how illegal harvest changes over time, but we do assume that, over time, it has a monotonic effect on rental rates. Here, we denote the period t asset value by $\bar{V}_t$, the rental rate by $\bar{\pi}_t$, and the rental rate change by: $\Delta\bar{\pi}_t \equiv \bar{\pi}_{t+1} - \bar{\pi}_t$. As stated above, we will assume that $\Delta\bar{\pi}_t$ is either: (1) $> 0 \; \forall t$, (2)$< 0 \; \forall t$, or (3) $= 0 \; \forall t$. Letting the change in asset value be $\Delta\bar{V}_t$, we will make use of the following lemma:

Lemma 1. $sgn(\Delta\bar{\pi}_t) = sgn(\Delta\bar{V}_t)$

For example, if illegal harvest is increasing, so the rental rate is decreasing over time ($\Delta\bar{\pi}_t < 0$), then Lemma 1 says that the asset price is also decreasing over time ($\Delta\bar{V}_t < 0$). This is intuitive since the asset value is nothing more than the discounted sum of future rental rates.

Ultimately we are interested in whether illegal harvest will have any predictable effect on the dividend price ratio. Result 3 shows that if the system is in steady state ($\Delta\bar{\pi}_t = 0$) then the dividend price ratio is independent of the level of illegal extraction. The following result shows how this conclusion is generalized when the system is out of steady state:

Result 4. *The presence of illegal harvest has the following effects on the dividend price ratio:*

$$\frac{\delta\bar{R}}{\delta f} \begin{cases} < 0 & \textit{iff } \Delta\bar{\pi} > 0 \\ = 0 & \textit{iff } \Delta\bar{\pi} = 0 \\ > 0 & \textit{iff } \Delta\bar{\pi} < 0 \end{cases} \tag{6}$$

Result 4 presents a testable hypothesis. Consider two resource assets that are otherwise identical, but where asset A is plagued by illegal harvest while asset B is not (so f is larger for A than for B). If the dividend price ratio for A exceeds that for B ($\bar{R}_A > \bar{R}_B$) then we can conclude that the economic consequences of illegal extraction are getting worse over time. If $\bar{R}_A < \bar{R}_B$ the we can conclude that the illegal activity is abating over time. And if $\bar{R}_A = \bar{R}_B$, then the market perceives no future changes in the amount of illegal activity. In our dataset, we will control for other factors and will estimate the effect of the "presence of illegal activity", noted in management reports, on dividend price ratios. We will then make use of Result 4 to interpret the implied expectation about its future effects.

1.3 Revocation possibility

Finally, we consider the case where the property right itself is perpetually in jeopardy. We assume that the asset owner faces a fixed annual probability (θ) of losing the right. This could reflect, for example, a government who wishes to preserve the right to change institutional design which may involve revoking the right from the current owner. Alternatively, governments may reallocate land to squatters, as in the case of Brazil (Alston, Libecap and Mueller, 2000). This class of property right insecurity is common, particularly in developing countries that face high government turnover. We allow for the system to be out of steady state and develop a Bellman equation formulation. The policy function need not be optimized, though we assume it is independent of θ. Conditional on owning the asset in period τ (i.e. it has not yet been revoked), the expected asset value in period τ is given by:

$$\tilde{V}_\tau = \pi_\tau + \sum_{t=1}^{\infty} \pi_{\tau+t}(1-\theta)^t \delta^t. \tag{7}$$

Rewriting and solving for the period-0 asset value gives:

$$\tilde{V}_0 = \pi_0 + \delta(1-\theta)\tilde{V}_1 \tag{8}$$

which leads to the following period-0 dividend price ratio:

$$\tilde{R}_0 = 1 - \frac{\delta(1-\theta)\tilde{V}_1}{\tilde{V}_0} \tag{9}$$

Here, revocation risk enters as an additional discounting term in a manner similar to risk premia in asset markets (Mehra and Prescott, 1985). This gives rise to our next result:

Result 5. *Regardless of whether the system is optimized or in steady state, but provided that the policy function is independent of θ, the dividend price ratio is increasing in the annual revocation probability, θ.*

Differentiating Equation 9 with respect to θ gives: $d\tilde{R}_0/d\theta = \delta\tilde{V}_1/\tilde{V}_0$ which is always positive, is increasing in δ and in the ratio $\tilde{V}_1/\tilde{V}_0$. Result 5 suggests that we can use the dividend price ratio to test the market response to differences in revocation probabilities: Consider two assets A and B that are otherwise identical, but which may face different revocation probabilities. It is straightforward to show (by manipulating Equation 9) that the difference in revocation probabilities is proportional to the difference in dividend price ratios. That is, we can back out the market's implied difference in revocation probability by simply knowing the difference in dividend price ratios, as follows:

Result 6. *The difference in revocation probability between two otherwise identical assets is given by:*

$$\theta^A - \theta^B = \frac{\tilde{R}_0^A - \tilde{R}_0^B}{\delta Y} \tag{10}$$

where $Y \equiv \frac{\tilde{V}_1^B}{\tilde{V}_0^B} = \frac{\tilde{V}_1^A}{\tilde{V}_0^A}$.[5]

We will make empirical use of this result by controlling for other relevant factors and comparing the dividend price ratios in countries with different legal mandates to preserve the right to revoke the asset.

Armed with these theoretical insights, the remainder of the paper presents an empirical application to global fisheries assets, where property rights are increasingly used to overcome the negative consequences of open access. Using a mix of within-country analysis (to examine the effects of ownership disputes and illegal fishing) and cross-country analysis (to isolate the effects of revocation possibility), we are able to examine empirically each of the results developed above.

2 Global Fisheries Assets

In fisheries, where the common pool feature has led to broad-scale fisheries (e.g. Worm et al., 2006; Costello et al. 2012), there is an increasing global trend toward property rights-based approaches. Fisheries in developed countries have largely transitioned from open access to limited entry, where the number of vessels is restricted, and often an overall quota is set for

[5] The equality holds by the assumption of the assets being "otherwise identical".

all licensed fishermen. Under such management, resource rents may still be dissipated in the race to fish and overcapitalization (Homans and Wilen, 1997). In an attempt to allow the capture of resource rents, many fisheries have adopted catch shares or other rights-based management.

In this paper, we focus our empirical analysis exclusively on fisheries managed by tradable quota shares. Individual Transferable Quota (ITQs), a form of catch shares, are the most prevalent form of fishery property right in the industrialized world, where the holder of an ITQ owns an asset which confers the right to harvest a share of the total allowable catch in the present year and into the future. ITQs have been hailed by economists as a means to capture the rents in fisheries. But in practice, the design of ITQ systems varies significantly across fisheries; these design idiosyncracies may affect property rights security, and as analyzed above, the resulting insecurity may be transmitted through asset values, lease prices, or a combination (dividend price ratios). We will utilize our model to interpret empirical findings regarding this link.

Under ITQ management, shares of the total allowable catch (TAC) are allocated to individuals (or firms or cooperatives), who then hold the right to harvest their share each year. Typically, the holder of an ITQ can exercise that harvest right, lease it to another fisherman, or sell it. This has been shown to help achieve allocative and technical efficiency (Grafton et al, 2000), which adds significant value in a fishery. In addition to eliminating the "race for fish," ITQ management has been shown to reverse the collapse of fisheries (Costello et al, 2008).

Since the introduction of the first ITQs in the mid-1980s in Iceland and New Zealand, ITQ fisheries have been established in many countries (prominently the United States, Canada, Peru, Chile, and Australia; lesser known examples exist in Namibia, South Africa, and Estonia); today, ITQs account for about 25% of global fish catch (Arnason, 2012). The general structure of ITQ management has been adopted widely, but ITQs as property rights are viewed very differently by governments around the world. In New Zealand, ITQs are viewed as perpetual rights to fish. There, an ITQ is a legal asset whose owner can use as collateral in establishing credit with banks. On the other hand, in Canada and the United States ITQ ownership is considered a revocable privelege, and the future of ITQ property rights (at least in the long run) is uncertain.

There is also important variation in the security of property rights *within* countries. Beyond differences in design features, some stocks are prone to significant illegal harvest due to high enforcement costs, while highly migratory species are subject to harvest by neighboring jurisdictions or in international waters. Ownership of quota shares in these stocks is arguably less secure than stocks with good enforcement and/or species that stay within the waters of the managing jurisdiction. And in some cases the ownership of the asset itself may be disputed, as is the case in New Zealand where the native Maori challenged the allocation of fishing assets to non-Maori.

Regulators in every country impose idiosyncratic limitations on trades, duration, and use of ITQ shares, including (but not limited to) caps on ownership of shares, restrictions on ownership by foreign fleets, vessel capacity or gear restrictions, and sunset provisions.[6] In the empirical analysis we control for fishery- and country-specific characteristics and estimate the effects of various sources of insecurity on asset market outcomes.

2.1 Adoption of ITQs

Experience with ITQ management has varied widely, beginning with New Zealand as an early adopter in 1986. Species have been subsequently added to New Zealand's Quota Management System (QMS) over the past few decades, and there are currently 98 species (or species groups) under quota management, with 690 separate management stocks.

North America has taken a more cautious approach toward ITQ adoption. Canada's Pacific Sablefish and Halibut ITQs were introduced in 1990, and the United States implemented its first ITQ program in the mid-Atlantic surf clam and ocean quahog fishery in the same year. Since the introduction of the first ITQs, several stocks have transitioned to ITQ management in the United States and Canada. While the general principle behind ITQs is the same in these countries, the governments have very different laws underlying the quota

[6] Arnason defines what he calls a "Q-Value", which is a measure of the quality (or strength) of property rights in fisheries. The Q-Value is a weighted index of assigned values for exclusivity, security, durability, and transferability, but in the current empirical setting the practical use of this index has limitations.

share held by individuals; these imply palpable differences in property rights security on which we will focus here.[7]

2.2 ITQs as Property Rights

In the United States, the resources in a marine fishery are deemed "common property," and are held in trust by the government for the community at large. Such resources cannot be transferred to or owned by individuals. The Magnuson-Stevens Act[8] holds that quota shares "shall be considered a permit;" "may be revoked, limited, or modified at any time;" "shall not confer any right of compensation to the holder...if it is revoked, limited, or modified;" and "shall not create, or be construed to create, any right, title, or interest in or to any fish before the fish is harvested by the holder."

As a result of this insecure property right, there is uncertainty about the future of the program, and holders of quota shares are generally unable to use their holdings as collateral at banks.[9] As anecdotal evidence, when asked why this is the case, a fisherman in the Red Snapper fishery in the Gulf of Mexico stated that "we don't really own anything. In the legal language, it's a privilege. There's always a danger that the government can change its fishery policy down the road, and then the quota would be worthless."[10] Another expressed his concern that the ITQ management would disappear after the five-year review.

A similar situation exists in Canada. Under Canadian law, ITQ shares are considered a revocable privilege, and a resistance to ITQs has led to other catch share systems (called Enterprise Allocations) in the Atlantic Provinces. Although fish are considered "Property of the Crown" in Canada, in 2008 the Supreme Court ruled that fishing quota are "property" for the purposes of the federal Banking and Insolvency Act[11]. ITQs are in place in several

[7] Prominent papers examining the effects of property rights on resource use include Watts and LaFrance (1994) and Libecap (1981) who look at grazing permits; Rucker, Thurman and Sumner (1995) who examine agricultural quota transfers; and Johnson, Gisser, and Werner (1981) who focus on water rights transfers in the Western United States.

[8] 16 U.S.C. 1801, 1996.

[9] This is not due to legal constraints, but rather the bank's willingness to accept a quota share as collateral. A recent exception in the United States is the ability of Alaskan fishermen to leverage against IFQ holdings with some Seattle-based banks.

[10] Personal communication with Keith "Buddy" Guindon, April 6, 2009.

[11] Saulnier v. Royal Bank of Canada 2008 SCC 58.

fisheries in British Columbia (see Appendix, Table 4), but restrictions on trading were cited as a constraint on potential efficiency gains in the halibut fishery. Grafton, Squires and Fox (2000) argue that "substantial long-run gains in efficiency can be jeopardized by preexisting regulations and the bundling of the property right to the capital stock" (pg. 679).

In New Zealand, property rights are explicitly established in the creation of ITQs, and over the past 25 years nearly all commercial fisheries have shifted to ITQ management. The right to a share of the catch is held in perpetuity, and when a program is discontinued, or where the allocation is changed by the regulator, fishers are entitled to financial compensation. Indeed, in the initial allocation of quota under the QMS, allocations were in terms of tonnes, and the TAC was fixed. When fishery managers subsequently decided to lower the TAC, quota were bought back in an expensive scheme.[12] Tables of the fisheries included in this analysis are provided in the appendix for North America (Table 4) and New Zealand (Table 5).

3 Data Description

We have compiled a unique panel dataset spanning hundreds of ITQ fisheries in three countries from 1986-2008. The primary variables of interest involve ITQ asset and lease prices. Because data on individual transactions are generally not available, we use annual average prices for sales and lease transactions of quota shares. Variables that can affect the price of quota shares include the total allowable catch (TAC), ex-vessel prices, the market interest rate, and biological characteristics of the species.[13]

New Zealand is arguably the most advanced country in the world with respect to rights based management of its fisheries. Data from New Zealand are the most comprehensive and come from FishServe, the New Zealand Seafood Industry Council, and the Ministry of Fisheries. For each species under quota management and for each management area, our data consist of average annual prices for sales and leases, average greenweight tonnage prices,[14] the total allowable commercial catch, and biological data from the Ministry of

[12] For a detailed overview of the history of the Quota Management System, see Rees, 2005.
[13] A detailed description of the data sources is available from the authors.
[14] In New Zealand, ex-vessel prices are not available for the entire time period. Following

Fisheries and FishBase.[15] Because of its extensive coverage of ITQ fisheries, all of our within country analysis takes place in New Zealand. Early in the ITQ adoption a famous legal challenge provides an opportune natural experiment to apply Results 1-2 concerning ownership disputes. The comprehensive management reports in New Zealand allow us to distinguish between fisheries that suffer from illegal harvest and those that do not. Thus we can apply Results 3-4 regarding the effect of illegal harvest on dividend price ratios.

While more limited in their adoption, fisheries from the United States and Canada will also prove useful in the analysis. Canadian quota prices were extracted from management reports, Department of Fisheries and Oceans consulting reports from Nelson Bros., and Individual Fishing Quota reports from Munro & Associates. Canadian fisheries included in the analysis are British Columbian halibut, sablefish coastwide hake, gulf hake, arrowtooth flounder, and "uncut" groundfish, all of which operate under an ITQ.

Finally, United States data come from the National Marine Fisheries Service (NMFS) and regional management councils. Fisheries under ITQ management included in the analysis are the Alaskan Halibut and Sablefish, the Gulf of Mexico Red Snapper, and the Virginia Striped Bass fishery.[16] By controlling for other factors, we conduct a cross-country analysis to apply Results 5-6 concerning the effects of a revocation possibility on asset values and dividend price ratios.

4 Within-Country Analysis

We begin by testing the predictions from our model using data from New Zealand. Because ITQ programs are generally subject to federal laws defining catch shares, most within-country

Newell et al (2005), we calculate greenweight tonnage prices using export price data for each year, and conversion factors from Clement and Associates.

[15] In consultation with FishServe, a small number of observations are omitted from the analysis because they are believed to contain significant errors. Including these observations does not qualitatively change our results.

[16] At this time, data from the Alaskan Crab fishery are not available. Furthermore, we are unaware of any historical data on quota prices in the Atlantic Surf Clam / Ocean Quahog fishery.

features of property rights are similar across fisheries.[17] However, because of its rich and diverse set of fisheries managed with property rights, New Zealand is an ideal place to exploit several sources of within-country heterogeneity. We begin by analyzing a dispute between incumbent asset holders and the Maori people of New Zealand to examine the ex-ante market consequences of an ownership dispute on asset values. We then exploit variation in the exclusivity of the property right across fisheries in New Zealand resulting from illegal harvest and highly migratory behavior of several fish stocks.

4.1 Ownership Disputes and the Treaty of Waitangi

Two important policy changes in New Zealand between 1989 and 1992 may plausibly have impacted beliefs about ITQ security within New Zealand. In 1986, the initial allocations in the QMS system were in terms of tonnes, rather than as a percentage of the annual total allowable catch. Subsequent analysis by the Ministry of Fisheries revealed that some allocations were too generous and would need to be reduced based on the available fishstock. This possible policy change (which was later ratified) was interpreted by fishery asset holders as a dispute that may affect ownership. Indeed, the Ministry of Fisheries proceeded to redefine the right as a percentage of the total allowable catch, rather than a nominal right.[18] After much debate, the government honored the property rights by issuing a buyback of quota where the initial allocation was too high. The buybacks began in 1989 and were finalized over the next two years.

Around the same time, there was a debate about how the Maori people, native New Zealanders, were being treated under the QMS system. The Maori people had traditionally relied on the ocean's resources, and there was a concern that the quota system did not take into account the significance of the fisheries to them. A legal dispute ensued, citing the Treaty of Waitangi of 1840. If resolved in the Maori's favor, some fraction of the fishery assets would be redistributed to tribes. In the end, the Maori people were allocated 20% of the TAC for some key stocks. Results 1-2 will be used to interpret the market outcome of

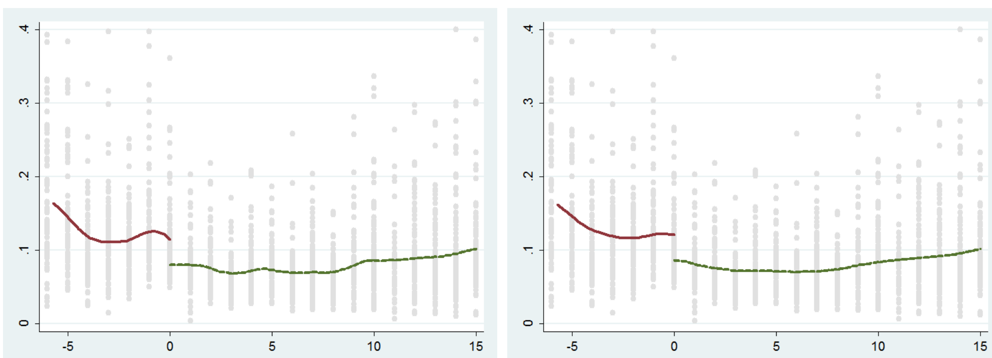
[17] There is some variation within the United States in how catch shares have been implemented by regional management councils, but due to data limitations, we focus our attention on New Zealand.

[18] This approach has since been adopted by nearly all countries.

these disputes.

Our model predicts an immediate drop in the dividend price ratio ($\tilde{R}$) of ITQ assets upon the resolution of the ownership disputes. As described above, the Treaty of Waitangi serves as an interesting natural experiment. As an initial exploration, we present local linear regression plots in Figure 1 (for ownership disputes). Figure 1 shows local linear regression estimates for alternative bandwidths for the dividend price ratio, $\tilde{R}$, in New Zealand fisheries over time. Estimates suggest that $\tilde{R}$ decreased markedly (approximately 3.5 percentage points) upon resolution of the disputes in 1992. We will subsequently expand this analysis to a more formal regression model to help control for other variables that may plausibly affect the dividend price ratio.

Figure 1: Local Linear Regression Plots



Notes: The vertical axis is the dividend price ratio of quota shares in New Zealand, and the horizontal axis shows the years since 1992 (1992=0). The scatter plot in light grey represents the fishery-by-year observations, and the plots show the local linear regression estimates for bandwidths 1.62 and 3.24. The estimated decrease at 1992 is approximately 3.5 percentage points in each case.

4.2 Illegal and Uncontrolled Harvest of New Zealand Fish Stocks

While property rights characteristics such as disposition, use, and possession do not vary significantly across New Zealand fisheries, there is substantial variation in exclusivity. This variation is not policy-induced, but rather is a function of the characteristics of the species. While some species do not move significantly across space, several "highly migratory" species move in and out of New Zealand waters, where they are subject to fishing pressure outside

New Zealand's exclusive economic zone.

But even for local stocks, there is some evidence of illegal harvest. For each commercial species in the Quota Management System in New Zealand, the 2008 Plenary Report from the Ministry of Fisheries discusses any known evidence of illegal harvests. Of the 75 species with sufficient data for the analysis here, there are six instances where significant illegal takes are believed to occur due to high monitoring costs. Thus, for each stock in New Zealand we are able to identify those that are highly migratory and those that suffer from illegal take (or both).[19] These will be modeled as dummy variables in the regression analysis and results will be interpreted using our theoretical Results 3-4.

Our model predicts that asset values would be lower in fisheries that migrate out of New Zealand's waters or are prone to illegal harvest. If the uncontrolled harvest in either case is not changing over time, though, the dividend price ratio $\tilde{R}$ would not be impacted, as the annual dividend is also affected by illegal harvest (Result 3). Only if exclusivity is weakening over time would the dividend price ratio decline (Result 4). As preliminary evidence, Figure 2 provides a plot of the median sales and lease price of ITQ assets for each New Zealand species under ITQ management since 2002.[20] Each dot represents the median lease and median sales value (in 2008 NZ dollars) for a particular New Zealand species under ITQ management between 2002 and 2008. Species above and to the left have higher dividend price ratios, $\tilde{R}$. We distinguish between stocks with high illegal take (upward triangle), highly migratory stocks (downward triangle), and other stocks (open circle). Under this simple graphical analysis, the mean $\tilde{R}$ for the latter category is about 8%, and is graphed by the lower line. The mean $\tilde{R}$ for the former categories is about 12% and is graphed by the upper line, possibly suggesting a worsening of the problem over time.

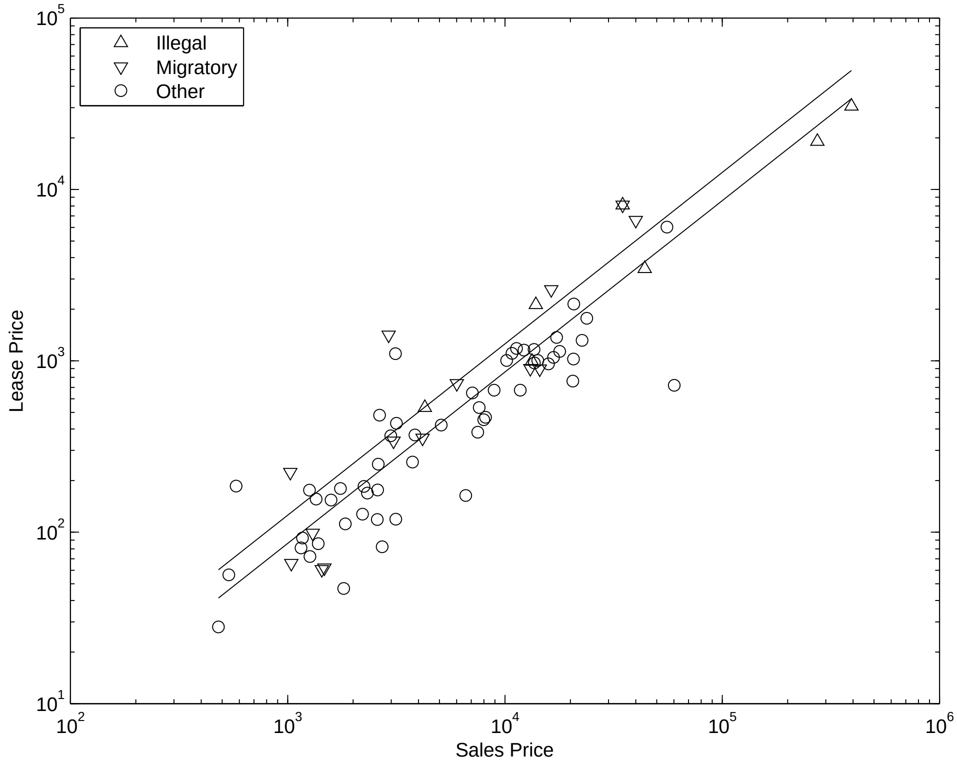
4.3 Within-New Zealand Empirical Strategy

In order to test the predictions from our analytical model, we need to estimate econometric models with two alternative outcome variables: 1) the asset value of an ITQ and 2) the ITQ

[19] See Appendix Table 5.

[20] Newell, Sanchirico and Kerr (2005) provide similar plots in their study, but focus on market functionality and liquidity, not the value of stronger property rights.

Figure 2: ITQ Lease and Sales Prices for New Zealand Fisheries.



Notes: Each dot represents the median annual sales and lease price for ITQ shares in New Zealand for an individual species group between 2002 and 2008.

dividend price ratio.

First, we are interested in the determinants of asset values in ITQ fisheries. Because the annual value of the fishery is clearly an important indicator of the present value of the fishery, we control for the lease price of quota. However, because lease markets and sales markets operate in tandem, lease prices of quota are jointly determined with asset values. Thus we instrument for the lease price using contemporaneous greenweight prices of that individual species following Newell, Papps and Sanchirico (2007). As they discuss, over 90% of commercial catch is exported in New Zealand, and most species constitute only a small share of the world market, so exogeneity is plausible. Greenweight prices are an excellent predictor of lease values. The first stage coefficients, shown in the Appendix, suggest that a 10 percent increase in the ex-vessel price leads to approximately a 7 percent increase in the lease price. The F-Statistics confirm that this is a strong instrument.

The main outcome variable for our within-New Zealand analysis is the quota's dividend price ratio, given by the annual lease price of quota for a fishstock and year divided by its sales price. We are able to control for a host of factors, including 5-year Treasury yields, trends for catch and greenweight prices,[21] time to maturity, length at maturity, maximum age, fishery type (inshore, offshore, or shellfish)[22] and whether or not the Ministry characterizes a species as recreationally or customarily "significant." In addition, we control for stock-specific revenue volatility, which captures both inter-annual fluctuations in total harvest and product prices. In some specifications (columns 2 and 5) we include year fixed effects instead of the interest rate to control for unobserved contemporaneous shocks.

4.4 Within-New Zealand Results

As described above, using within-country variation we can test two general predictions regarding asset prices and dividend price ratios from our analytical model: the impact of the resolution of the ownership dispute regarding the Treaty of Waitangi, and the impact of uncontrolled harvest. The econometric results within New Zealand are shown in Table 2. Columns (1)-(3) show the results for the specifications with the asset value as the dependent variable (instrumenting for the lease price with the greenweight value). The dependent variable in columns (4)-(6) is the dividend price ratio of quota at the fishery level.

The results suggest that uncontrolled harvest (from illegal harvest or due to harvest outside of New Zealand's national waters) have a significant, negative impact on the dividend price ratio. Depending on the control variables included, $\tilde{R}$ is between 0.8 and 1.1 percentage points higher for highly migratory species. A much stronger conclusion holds for stocks prone

[21] New Zealand's fish production constitutes less than one percent of worldwide production, and exports (in terms of value) make up about two percent of overall international trade in fish products. Some stocks, however, are large on a worldwide basis. In these fisheries the ex-vessel price is arguably endogenous. While we do not have a plausible instrument for ex-vessel prices, in alternative specifications (available from the authors) we exclude these fisheries. All of our results are robust to the exclusion of these fisheries from the analysis.

[22] In addition we have included fish categories used by the United Nations Food and Agriculture Organization (ISSCAAP) categories in some specifications to hold species group effects fixed. In this specification we do not include ISSCAAP category fixed effects because they are collinear with one of our key explanatory variables, the indicator for Highly Migratory Species.

to illegal harvest for which the dividend price ratio is roughly 3 percentage points higher than for other stocks. The impact on asset values is large and significant for stocks facing illegal harvest, but the effect is less robust for migratory stocks. Interpreting these results in light of our analytical model suggests that the market behaves as if illegal harvest is increasing over time, while external pressure on highly migratory stocks may be closer to steady state.

In columns (3) and (6) of Table 2, we estimate regression equations with the same controls as in column (1), but also including an indicator variable that equals one for all years including 1992 and thereafter as well as linear time trends for pre- and post-periods. As predicted by the theory, the asset value increases (column (3)) and the dividend price ratio decreases (column (6)) following dispute resolution. The point estimate suggests that post-resolution there was a 3.9 percentage point decrease in the dividend price ratio, controlling for interest rates and fishery-specific characteristics. Using Result 2 this result suggests that the market behaved (prior to dispute resolution) as if it expected at least 50% of the asset to be modified as a consequence of the two concurrent disputes.

5 Revocation Risk from Cross-Country Evidence

We now turn to cross-country evidence of the effects of revocation risk on asset values. In practice, ITQ rights are rarely revoked. Yet as described above, the three countries in our analysis treat fishery asset security in very different ways and thus there is substantial variation in the property rights underlying ITQs across countries. It may be possible to qualitatively describe each property right characteristic for each fishery, but comparing these property rights characteristics across fisheries and countries is difficult. Here we take a more agnostic approach, estimating reduced-form equations to test for systematic differences in property rights across countries. Because most ITQ-harvested fish are traded in global markets, and similar species are harvested using similar fishing technologies, it is reasonable to think that we can control for characteristics other than asset security that affect dividend price ratios. We attempt to carefully control for relevant fishery- and country-specific characteristics. Once again we make use of the observation that by dividing lease price by sales price, the dividend price ratio washes away many fishery and country specific factors that

Table 2: Within-Country Evidence: New Zealand Regressions

Dependent Variable:	Log Sales Price of ITQ			Lease/Sales Price of ITQ		
	(1)	(2)	(3)	(4)	(5)	(6)
Log Lease Price	1.0012***	0.9747***	1.0359***			
	(0.0587)	(0.0580)	(0.0634)			
Migratory Spp.	-0.1209	-0.1187	-0.1541*	0.0081*	0.0111**	0.0078
	(0.0838)	(0.0789)	(0.0851)	(0.0049)	(0.0047)	(0.0047)
Significant Illegal Harvest	-0.2794***	-0.2408**	-0.3404***	0.0300***	0.0293***	0.0309***
	(0.1034)	(0.1015)	(0.1069)	(0.0073)	(0.0072)	(0.0075)
Revenue Volatility	-0.0982	-0.1673*	-0.0828	0.0097	0.0159*	0.0103
	(0.0842)	(0.0856)	(0.0875)	(0.0087)	(0.0090)	(0.0086)
Significant Spp.	0.0599	0.0885*	0.0920*	-0.0074	-0.0106**	-0.0091*
	(0.0499)	(0.0468)	(0.0526)	(0.0048)	(0.0046)	(0.0048)
5 Year Treasury Rate	-3.9002***		1.4116	0.3851***		-0.1235
	(1.0305)		(2.1573)	(0.0993)		(0.2188)
Pct. Change Harvest	0.0280	-0.0077	0.0254	-0.0015	0.0010	-0.0007
	(0.0451)	(0.0416)	(0.0463)	(0.0046)	(0.0044)	(0.0046)
Pct. Change Ex Vessel Price	-0.0749	-0.0038	-0.1085	0.0014	-0.0068	0.0030
	(0.0881)	(0.0891)	(0.0933)	(0.0091)	(0.0096)	(0.0094)
Age at Maturity	-0.0066	-0.0058	-0.0069	0.0013*	0.0013**	0.0012*
	(0.0063)	(0.0057)	(0.0064)	(0.0007)	(0.0006)	(0.0007)
Length at Maturity	0.0008	0.0011**	0.0009	-0.0001	-0.0001**	-0.0001*
	(0.0006)	(0.0005)	(0.0006)	(0.0001)	(0.0001)	(0.0001)
Maximum Age	-0.0002	0.0002	-0.0007	-0.0002	-0.0002	-0.0002
	(0.0017)	(0.0016)	(0.0018)	(0.0002)	(0.0001)	(0.0001)
Post-1992			0.4692***			-0.0391***
			(0.0840)			(0.0113)
Year Fixed Effects	No	Yes	No	No	Yes	No

The dependent variable is the ratio of the average lease price to the average sales price of quota in a management area. There are 992 observations in each regression. Heteroskedastic-robust standard errors are in parentheses, and ***, ** and * denote significance at the 1, 5 and 10 percent levels, respectively. Each specification also includes "type" fixed effects, corresponding to offshore, inshore and shellfish (freshwater excluded), as well as the time trends for number of years (and years squared) since an individual fishery has been managed by ITQs. Revenue volatility is calculated as the standard deviation in real total revenue for that fishery over all years in our dataset.

affect the value of the fishery. For example, highly-productive fisheries or high-value species should have high annual values, and normalizing with the dividend price ratio allows us to isolate discounting behavior. Our model predicts that a higher probability of revocation will affect the dividend price ratio of quota by decreasing the asset value (Result 5). The main outcome variable of interest is the mean dividend price ratio of a fishery in a given year. Comparing across fisheries, we can also use Result 6 to back out the implied difference in revocation probability across countries.

5.1 Results from Cross-Country Analysis

As an introduction to the cross-country results, consider a graph of the median dividend price ratio across time for New Zealand, Canada, and the United States (Figure 2). While this simple graph fails to control for other factors (e.g. the interest rate, fishery characteristics), it suggests there might be a systematic difference across countries. The median dividend price ratio in New Zealand always falls below that of the United States, and typically falls below that of Canada. Furthermore Canada's median ratio is typically below that of the United States. This is consistent with our theory and descriptive accounts that property rights are most secure in New Zealand, somewhat less secure in Canada, and substantially less secure in the United States. A few details are worth noting about the data. The spike in 2007 for the United States includes only the first year of ITQs in the Red Snapper fishery. In 2008, both the Red Snapper and Virginia Striped Bass are included. These ratios tend to be significantly larger than US halibut and sablefish, which are included in earlier years in the figure.[23] In New Zealand, there is a downward trend from the first year of the Quota Management System (QMS) until present. The median ratio in the first year of the program was about 15%, whereas that rate in 2008 was near 8%. As is clear from Equation 2, the interest rate is expected to play a key role in determining this ratio.

It is useful to further motivate our approach with an example. Consider two similar fisheries in the United States and New Zealand: the Gulf of Mexico Red Snapper fishery, and the New Zealand Snapper (SNA) fishery. The Snapper fishery in New Zealand was first

[23] Data for Alaskan Halibut and Sablefish ITQs leases are not available past 2006.

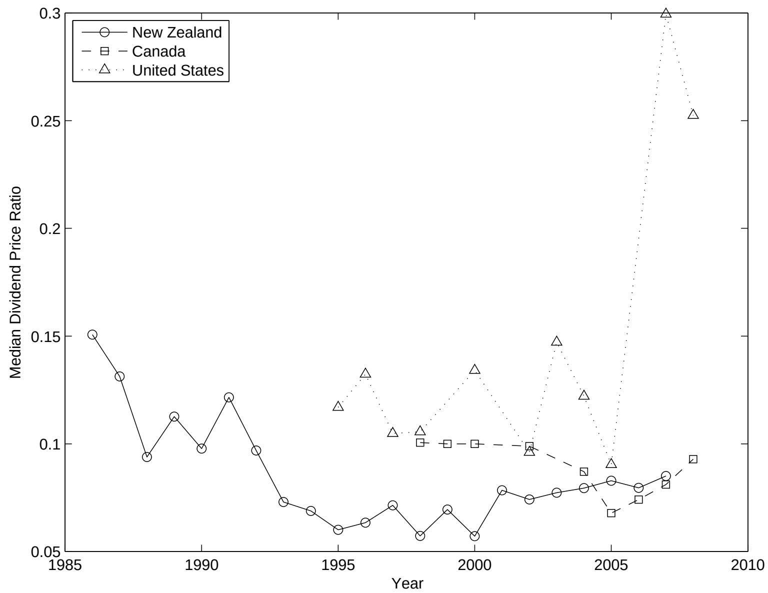


Figure 3: edian dividend price ratios for New Zealand, Canada, and United States.

put under quota management in 1986, and the median dividend price ratio ($\tilde{R}$)[24] for that species group for the first three years of the program (a period of extremely high interest rates) was about 17%, and over the entire series the median $\tilde{R}$ is about 8.8%. On the other hand, the Red Snapper fishery in the Gulf of Mexico had a mean $\tilde{R}$ of about 27% during the first two years of the ITQ program. Though biologically similar and traded in the same global market, the implicit revocation probability in the US fishery is much higher, anecdotally supporting our hypothesis that weaker property rights raise the dividend price ratio. Of course, a host of factors could affect the dividend price ratio, which we consider below.

The dependent variable throughout this section is the dividend price ratio of ITQs.[25] We exploit the panel-structure of the data and estimate country fixed-effects, which we use

[24] We use the tilde notation to conform with our theoretical notation concerning the dividend price ratio when the asset in question may be revoked.

[25] This variable was constructed using average annual sales and lease prices, which may introduce some measurement error into our dependent variable. Because our data are on an annual basis, we cannot take into account intra-year fluctuations in lease or sales prices. Furthermore, because we are not constructing the ratio from individual transactions, we cannot observe whether any outliers (which may not represent arms-length transactions, for example) are included. To the extent that any measurement error is random (and uncorrelated with the independent variables), our estimates will be unbiased.

to test the null hypothesis that there is no systematic difference in dividend price ratios across countries. We estimate several equations, including controls for market conditions, biological characteristics, fixed effects for species groups, and year fixed effects to control for time-varying unobservables.

The most basic specification regresses $\tilde{R}$ on country fixed effects, species group fixed effects,[26] and the market interest rate (in this case that country's 5-year Treasury rate in that year). The results are in column (1) of Table 3. Result 6 provides a concrete interpretation of these estimates. If we assume returns in each fishery are roughly constant over time, so $Y = 1$, then for a discount factor of δ the difference in revocation probability is simply $(\tilde{R}^A - \tilde{R}^B)/\delta)$. Using a discount factor of $\delta = 0.9$, these results suggest that, on average, the revocation probability in the United States is about 6.3 percentage points larger than in New Zealand. The revocation probability in Canada is also significantly larger than in New Zealand (1.7 percentage points), and the difference between the United States and Canada is significant. In the second specification (column 2), we add year fixed effects to control for unobserved contemporaneous shocks.[27] In this case, the revocation probability in the United States is about nine points higher than in New Zealand. These results are economically significant. The implied revocation probability is approximately as important as discounting itself.

Other factors, such as expectations about the future harvest and ex-vessel prices, would dictate future profitability and hence quota sales prices. We attempt to control for these expectations by including trends for harvest and ex-vessel prices. Specifically, we control for the percentage change of this year's harvest from last year (in that fishery), and the percentage change of this year's average ex-vessel price from last year.

Although species group fixed effects are included in every specification, we also add biological characteristics of each fishery, which could influence the horizon over which stocks rebuild. We control for years to maturity, length at maturity, and the maximum age of a species. Inclusion of these variables does not affect the main results, perhaps unsurprisingly because there is little variation in these variables within the species groupings used by the

[26] We use ISSCAAP species group classifications to hold constant species-specific effects; there are 18 groups in the baseline specification.

[27] The results are robust to the inclusion of a quadratic function of interest rates.

United Nations Food and Agriculture Organization (ISSCAAP categories). Finally, the dynamics of a ratio within a fishery over time suggest that the ratio of lease to sales prices decrease with the tenure of an ITQ program. For each fishery, we include the number of years since the first year of ITQ management. We also include a quadratic term to account for nonlinear relationships, and each of these variables is interacted with country fixed effects to allow this effect to vary across countries. Column (3) of Table 3 includes these control variables and suggests the revocation probability in the United States is about 12 points larger than in New Zealand. In Canada, the point estimate indicates that the revocation probability is nearly eight points larger than in New Zealand.

As discussed above, New Zealand's Quota Management System includes many species not managed by ITQs in the United States or Canada. In column (4), we restrict the sample to include only New Zealand species with "comparable" counterparts in the United States or Canada.[28] These results are shown in column (4) of Table 3. In this case, the point estimate rises still further so the implied revocation probability in the United States is 14 points higher than in New Zealand.

Our cross-country results suggest that the dividend price ratio of ITQs is significantly higher in the United States and Canada, where property rights governing ITQs are relatively weak. Rather than picking up the desired effect of property rights security, these results could be reflecting a higher risk of collapse in US and Canadian fisheries. While we have no empirical or anecdotal evidence that this is the case (stock assessed ITQ fisheries in all three countries tend to be in good health (Worm et al., 2009), we can test for it in our analysis. In columns (5) and (6) we include a dummy variable for stock collapse; our results are robust to the inclusion of this variable, as well as alternative definitions of collapse or measures of stock health.[29] In column (6), our preferred specification, the dividend price ratio in Canada is about seven points higher than in New Zealand, and that ratio in the United States is nearly 14 points higher than in New Zealand. These correspond to differences in implied

[28] Specifically, we restrict the sample to include only species in ISSCAAP groups 25, 31, 32, 33 or 34.

[29] Specifically, we include an indicator variable equaling one if the stock is below ten percent of historical harvest levels, a common measure of fishery "collapse" developed by ecologists (Worm et al. 2006).

revocation probabilities of 8 and 16 percentage points, respectively.

The cross-country regression results suggest that ITQ fisheries in the United States have a significantly higher $\tilde{R}$ than in Canada, which, in turn, is higher than New Zealand (though the results for Canada are not robust across specifications). By Result 6, these suggest that ITQ fishing asset markets have an implied probability of revocation that is perhaps of greater economic significance than the discount rate itself. Because we are controlling for fishery-specific characteristics and market factors, we argue that property rights strength explain the difference in dividend price ratios across these countries.[30]

6 Conclusion

This paper provides the first theoretical and empirical exploration of how property right insecurity will affect marketable natural resource asset values. Our theoretical model provides general predictions about how various forms of property right insecurity (ownership disputes, illegal harvest, and revocation possibility) will affect lease prices, asset values, and dividend price ratios for natural resource assets.

Our initial empirical tests exploit important differences in the exclusivity of fisheries property rights within New Zealand. We find that the resolution of two important ownership disputes led to a decrease in the dividend price ratio, as predicted by our model (Result 1). Applying Result 2, our empirical finding suggests that the quota asset market behaved as if it expected a substantial (perhaps >50%) erosion of asset values. We also explored the effects of illegal and uncontrolled harvest and found evidence that fisheries where the exclusivity is limited by illegal harvest have higher dividend price ratios, which suggests that illegal harvest may be growing over time. We find only weak evidence that the negative consequences of migratory behavior are worsening. To our knowledge, this is the first attempt to use market-level natural resource prices to derive implied dynamic biological phenomena.

[30] Our results are robust to a variety of additional controls, including revenue volatility and quadratic functions of the control variables. Furthermore, when estimating these regressions excluding the Red Snapper and Virginia Striped Bass fisheries (both of which have very high dividend price ratios), the difference between the United States and New Zealand remains significant.

Table 3: Cross-Country Regression Results

	(1)	(2)	(3)	(4)	(5)	(6)
United States	0.0572***	0.08119***	0.1097***	0.1344***	0.1092**	0.1354***
	(0.0124)	(0.0189)	(0.0405)	(0.0426)	(0.0407)	(0.0429)
Canada	0.0150**	0.0217	0.0684***	0.0701***	0.0677***	0.0699***
	(0.0071)	(0.0153)	(0.0186)	(0.0174)	(0.019)	(0.0175)
5 Year Treasury Rate	0.5521***	1.3513*	0.8550	0.6120	0.8484	0.6257
	(0.0872)	(0.7798)	(1.1099)	(1.0829)	(1.1132)	(1.0858)
Pct Change in Harvest			0.0047	0.0010	0.0048	0.0011
			(0.0046)	(0.0045)	(0.0047)	(0.0046)
Pct Change in Ex-Vessel Prices			-0.0040	-0.0031	-0.0042	-0.0031
			(0.0107)	(0.0103)	(0.0107)	(0.0103)
Time to Maturity			0.0005	0.0023**	0.00050	0.0024**
			(0.0008)	(0.0010)	(0.0008)	(0.0010)
Length at Maturity			0.0000	0.0002*	0.0000	0.0002*
			(0.0001)	(0.0001)	(0.0001)	(0.0001)
Maximum Age			0.0000	-0.0005*	0.0000	-0.0005*
			(0.0002)	(0.0003)	(0.0002)	(0.0003)
Collapsed					0.0164	0.0216*
					(0.0393)	(0.0123)
Year Fixed Effects	No	Yes	Yes	Yes	Yes	Yes
ISSCAAP Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
N	2,097	2,097	1,059	670	1,059	670

The dependent variable is the ratio of the average lease price to the average sales price of quota in a management area. Each specification also includes, for each country, the number of years (and years squared) since an individual fishery has been managed by ITQs. Collapsed equals 1 if that fishery has current harvest levels less than ten percent of the historical maximum in our dataset. Standard errors (in parentheses) are clustered on country-year, and ***, ** and * denote significance at the 1, 5 and 10 percent levels, respectively.

Our cross-country evidence is based on the dramatically different legal definitions of ITQs as property in New Zealand, Canada and the United States. In our cross-country regressions, the point estimates suggest that $\tilde{R}$ for quota in the United States is nearly twice as large as in New Zealand. The average $\tilde{R}$ for quota in Canada is larger than in New Zealand in some specifications, but these results are not as robust. These results are consistent with the general view that ITQs as property rights are more secure in New Zealand than in North American fisheries.

Several caveats should be mentioned. First, across countries, we have not quantified the effects of component characteristics of property rights on asset values. Instead, we rely on country fixed-effects and dummy variables to capture differences in property rights security across fisheries. However, our focus on fisheries and the use of the dividend price ratio allows us to isolate the effect of country-specific institutions on investment in common pool resources. Second, our cross-country results could be consistent with systematic differences in the probability of fishery collapse across countries. To attempt to rule out this possibility, we control for trends in harvest and ex-vessel prices in our main specifications and we control for whether an individual fishery was "collapsed" in any given year. Our results are robust to the inclusion of controls for the state of the fish stock as well as market conditions and trends, but, as in any cross-country regression, other unobserved heterogeneity may still be influencing our results. Third, our cross-country results could be consistent with credit constraints and non-collateralizable assets. The dividend price ratio could be higher in the United States because of credit constraints and the inability to secure a loan for ITQ shares. This would simply be a mechanism through which insecure property rights affect asset prices. Finally, our results suggest that there is a pecuniary effect of property rights security, and if this result is present elsewhere (such as capital investment) the security of property rights are critical to fisheries management. On the other hand, if the only impact of property rights security is through quota asset values then the impact on social welfare is unclear, though the security of property rights would clearly affect the distribution of wealth.

Property rights-based management of previously common-pool resources can lead to significant economic gains by eliminating the tragedy of the commons and providing private incentives to steward the resource. Our theoretical results suggest that market-level prices can reveal important insights about: (1) the market's expectation about the outcome of ownership disputes, (2) whether illegal resource extraction will likely increase or decrease in the future, and (3) the implied probability of revocation for an insecure property right asset. Our empirical results suggest that stronger property rights lead to greater quota asset values. A closely related question concerns how property rights strength will affect different dimensions of investment in common pool resources (e.g. physical capital, environmental recovery, investment in self-enforcement, etc.). Indeed, these changes in investment may be partially responsible for the changes in asset values we observe. One implication may be that weak property rights decrease the incentive for good stewardship of the resource by increasing the average implicit discount rate. While we can only speculate on the underlying mechanisms, this research may help motivate future work on the effects of property rights security on the management, biological status, and sustainability of the resource itself.

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Appendix

Table 4: US and Canadian ITQ Fisheries in the Analysis

Country	Species	Area	First Year Under ITQ	First Year With Data
USA	Halibut	Alaska	1995	1995
USA	Sablefish	Alaska	1995	1995
USA	Red Snapper	Gulf of Mexico	2007	2007
USA	Striped Bass	Virginia	1998	2008
Canada	Sablefish	B.C.	1990	1996
Canada	Halibut	B.C.	1990	1996
Canada	Groundfish (uncut)	B.C.	1997	1999
Canada	Arrowtooth Flounder	B.C.	1997	2006
Canada	Coastwide Hake	B.C.	1997	1997
Canada	Gulf Hake	B.C.	1997	1999

Table 5: New Zealand ITQ Fisheries in the Analysis

Common Name	QMS Code	First Year	Migratory Species	Illegal Harvests
Freshwater Eel	ANG	2000		
Barracouta	BAR	1986		
Blue Cod	BCO	1986		
Bigeye Tuna	BIG	2004	Yes	
Bluenose	BNS	1986		
Butterfish	BUT	2002		
Blue Shark	BWS	2004	Yes	
Alfonsino	BYX	1986		
Black Cardinalfish	CDL	1998		
Spiny Lobster	CRA	1990		Yes
Elephant Fish	ELE	1986		
Blue Mackerel	EMA	2002		
Flatfish	FLA	1986		
Frostfish	FRO	1998		
Garfish	GAR	2002		
Green-lipped Mussel	GLM	2004		
Grey Mullet	GMU	1986		Yes
Giant Spider Crab	GSC	2005		
Dark Ghost Shark	GSH	1998		
Pale Ghost Shark	GSP	1998		
Red Gurnard	GUR	1986		
Hake	HAK	1986		Yes
Hoki	HOK	1986		
Groper	HPB	1986		
John Dory	JDO	1986		
Jack Mackerels	JMA	1987		
Kahawai	KAH	2004		
Kingfish	KIN	2003		
Lookdown Dory	LDO	2004		
Leatherjacket	LEA	2003		
Freshwater Eel	LFE	2004		
Ling	LIN	1986		
Mako Shark	MAK	2004	Yes	
Blue Moki	MOK	1986		
Moonfish	MOO	2004	Yes	
Oreo	OEO	1986		
Orange Roughy	ORH	1986		
Dredge Oyster Nelson/Marlborough	OYS	1996		
Dredge Oyster Foveaux Strait	OYU	1997		Yes

Table continued on next page.

Table Continued

Common Name	QMS Code	First Year	Migratory Species	Illegal Harvests
Paddle Crab	PAD	2002		
Parore	PAR	2004		
Paua	PAU	1987		Yes
Pilchard	PIL	2002		
Porae	POR	2004		
Porbeagle Shark	POS	2004	Yes	
Ray's Bream	RBM	2004	Yes	
Rubyfish	RBY	1998		
Red Cod	RCO	1986		
Ribaldo	RIB	1998		
Rough Skate	RSK	2003		
Red Snapper	RSN	2004		
Southern Blue Whiting	SBW	1999		
Scallops coromandel	SCA	1992		
School Shark	SCH	1986		
Freshwater Eel	SFE	2004		
Gemfish	SKI	1986		
Snapper	SNA	1986		Yes
Spiny Dogfish	SPD	2004		
Sea Perch	SPE	1998		
Rig	SPO	1986	Yes	
Arrow Squid	SQU	1987		
Smooth Skate	SSK	2003		
Stargazer	STA	1986		
Southern Bluefin Tuna	STN	2004	Yes	Yes
Kina	SUR	2003		
Silver Warehou	SWA	1986	Yes	
Swordfish	SWO	2004	Yes	
Tarakihi	TAR	1986		
Pacific Bluefin Tuna	TOR	2004	Yes	
Trevally	TRE	1986		
Trumpeter	TRU	1998		
Blue Warehou	WAR	1986	Yes	
White Warehou	WWA	1998	Yes	
Yellow-Eyed Mullet	YEM	1998		
Yellowfin Tuna	YFN	2004	Yes	

Species and species groups in the dataset for New Zealand. First Year denotes the first year under the Quota Management System. Highly Migratory is determined by the Ministry of Fisheries. Illegal harvests denotes species that the Plenary Reports discuss the problem of evidence of illegal harvests for that species.

Table 6: First Stage Regression Results

	(1)	(2)	(3)
Log Green Weight Price	0.6948***	0.6613***	0.6920***
	(0.0512)	(0.0606)	(0.0520)
F-Stat	183.88	119.15	177.24

First stage regression results are shown for the specifications (1)-(3) in Table 2. The dependent variable is the sales price of quota shares in New Zealand. Coefficients on the instrumental variable, greenweight price, are shown for the three specifications.