An Empirical Analysis of New Zealand's ITQ Markets

Richard G. Newell, *Resources for the Future, Washington, DC*
James N. Sanchirico, *Resources for the Future, Washington, DC*
Suzi Kerr, *Motu Economic Research, Wellington, New Zealand*

Abstract. Fisheries worldwide continue to suffer from the negative consequences of open access. In 1986, New Zealand responded by establishing an individual transferable quota (ITQ) system that by 1998 included 33 species and more than 150 markets for fishing quotas. We assess these markets in terms of trends in market activity, price dispersion, and the fundamentals determining quota prices. We find that market activity is sufficiently high to support a competitive market. Using a 15-year panel dataset, we also find evidence of economically rational behavior through the relationship between quota lease and sale prices and fishing output and input prices, ecological variability, and market interest rates. Controlling for these factors, our results show an increase in quota prices, consistent with increased profitability. Overall, the results suggest these markets are operating reasonably well, implying that ITQs can be effective instruments for efficient fisheries management.

Keywords: tradable permits, individual transferable quota, fisheries, policy

1. INTRODUCTION

Economists Gordon (1954) and Scott (1955) identified the "common pool" problem of fisheries almost 50 years ago, predicting that open access would lead to excess fishing effort, dissipation of rents, and inefficient depletion of fish populations. Individual transferable quota (ITQ) systems are a promising means to correct this market failure. They limit fishing operations by setting a total allowable catch (TAC), which is typically allocated in perpetuity to fishing participants based on historical catch. Because the aggregate catch is capped and fishermen have access to a guaranteed share of the TAC, this approach significantly reduces the likelihood that fish stocks are overfished and the incentives to engage in a race to fish. In addition, when transferability of the shares is permitted, the least efficient vessels will find it more profitable to sell their quotas rather than fish them. Over time, this should both reduce excess capacity and increase the efficiency of vessels operating in the fishery.

Since the late 1970s and early 1980s, when countries began to "enclose the commons" by establishing exclusive economic zones in the ocean off their coasts, more than 15 countries followed New Zealand's and Iceland's lead in establishing ITQ systems. To date, ITQs are used to manage over 60 species, including 4 in the United States (OECD 1997). New Zealand alone has over 30 species within their ITQ system. For ITQs to deliver an efficient solution to the common pool problem in practice, it is critical that fisherman can buy and sell quotas in a competitive market and that quota markets convey appropriate price signals. Assuming competitive markets, rational asset pricing theory suggests that quota prices should reflect the expected present value of future rents in the fishery. Price signals sent through the quota market are therefore an essential source of information on the expected profitability of fishing and an important criterion for decisions to enter, exit, expand, or contract individual fishing activity. Quota prices also send signals to policymakers about the economic and biological health of a fishery. Some have suggested quota prices could therefore be used as a measurement tool for the dynamic adjustment of TACs to optimize policy outcomes (Arnason 1990).

In theory, ITQ programs are analogous to other cap and trade programs, such as the U.S. tradable permit program for reducing sulfur dioxide emissions from power plants. However, there may be important differences between pollution permit markets and fishing quota markets in practice. For instance, controlling and forecasting emissions from a power plant is arguably easier than predicting both the level of catch on any trip and its composition. This is especially true in multi-species fisheries where fish populations cannot be directly targeted without incidental catch of other stocks. Thus, fishermen operating under a quota management system will likely need to rebalance their portfolio of quota holdings throughout the year to match catch levels—a task that some argue is simply too complex (Copes 1986; Squires et al. 1998).

Such skepticism is in part warranted by the limited number of opportunities for careful research on how well created markets have performed in general and particularly in fisheries. The existing literature on ITQ programs, although extensive, is dominated by description and anecdotal evidence of their effects (NRC 1999). There are, however, a few notable exceptions. Recent work by Grafton et al. (2000) uses firm-level data from the British Columbia halibut fishery spanning pre- and post-ITQ periods to estimate a stochastic production frontier, finding evidence of substantial gains in revenues and producer surplus. Other studies quantitatively assess ITQs using relationships estimated on either pre- or post-ITQ catch-effort data to predict changes in fleet restructuring, costs, and revenues (Squires et al. 1994; Wang 1995; Weninger 1998). Several studies also present descriptive statistics on annual quota prices and number of trades (Lindner et al. 1992, Arnason 1993, Batstone and Sharp 1999, Dinneford et al. 1999). For example, using two years of data on quota sale and lease prices from the New Zealand ITQ system, Lindner et al. (1992) attempt to measure economic rents, but conclude that a more thorough analysis of the determinants of quota prices is needed to properly assess market performance and rents.

To establish an empirical record on market performance for fishing quotas, we use the most comprehensive data set on ITQ markets gathered to date for the largest system of its kind in the world. The panel dataset from New Zealand covers 15 years of transactions across 33 species and includes price and quantity data on transactions in more than 150 fish stock markets (see Newell et al. (2002) for detail). Markets exist in New Zealand both for selling the perpetual right to fish a certain quota stock and for leasing quotas. A unique aspect of our data is the breadth of markets and the cross-sectional heterogeneity, as the market characteristics are diverse across both economic and ecological dimensions. The export value of these species currently ranges from about NZ$700 per ton for jack mackerel to about NZ$40,000 per ton for rock lobster. Throughout this paper, monetary figures are year 2000 New Zealand dollars, which are typically worth about half a U.S. dollar. Tons are metric tons.

We investigate how these markets have performed in a number of ways. First, by assessing the overall level and trends in market liquidity and participation across the markets, we establish whether the right conditions are in place for these markets to function well. If these markets have few participants and low liquidity, noisy price signals could ensue reducing the expected efficiency gains. Another aspect of well-functioning markets is that asset prices represent underlying fundamentals and behave in an economically rational way. If, as many claim, prices reported in these markets are fictitious and confounded by the inclusion of other assets (e.g., boats and gear), we should not find any meaningful relationship between quota prices and their underlying fundamentals (Lindner et al. 1992). Finally, if quota prices reveal relevant asset arbitrage information, we should expect the rate of return to fish quotas to be comparable with other financial assets in the New Zealand economy. We test this proposition by investigating the relationship between the prices of perpetual quota sales and annual quota leases relative to measures of the market rate of interest.

2. NEW ZEALAND'S INDIVIDUAL TRANSFERABLE QUOTA (ITQ) SYSTEM

Although the New Zealand fishing industry accounts for less than 1% of the world's fishing output, it contributes NZ$1.7 billion annually to the New Zealand gross domestic product. Seafood is the fourth largest export earner, and more than 90% of fishing industry revenue is derived from exports. New Zealand is currently considered a world leader in fisheries management, in both environmental and economic terms. Before 1976, New Zealand fishery policy focused primarily on the development of inshore fisheries, leaving offshore fisheries to Japanese, Soviet, and Korean factory trawlers. This focus began to shift, however, after New Zealand extended its exclusive economic zone (EEZ) to 200 miles in 1978, which had the effect of "nationalizing" the waters where the offshore fisheries reside. The government to promote domestic production in the offshore fishery used subsidized loans, duty-free imports of large fishing vessels, and price supports. In 1983, after a series of joint venture programs with foreign and domestic fishing interests, the New Zealand government established a quota-based system for nine companies fishing seven offshore species. Quotas were allocated to each company for a ten-year period based on investment in catch and processing capital, although as described below, this program was absorbed three years later by a more comprehensive ITQ system. Trading and leasing of shares are reported to have occurred (Sissenwine and Mace 1992), but the system did not provide an adequate mechanism for the transfer of quotas.

Inshore fisheries depletion, the development of the quota-based program for offshore fisheries, and the general orientation of the government in the 1980s toward deregulation, combined to create an atmosphere conducive for fundamental change in New Zealand fisheries management. After several years of consultation with industry, the Fisheries Amendment Act of 1986 passed, creating New Zealand's ITQ system. Modifying legislation has been passed several times since, but the basic structure of the system has remained intact. The ITQ system initially covered 17 inshore species and 9 offshore species, and expanded to a total of 33 species by 1998. Under the system, the New Zealand EEZ was geographically delineated into quota management regions for each species based on the location of major fish populations. Rights for catching fish were defined in terms of fish stocks that correspond to a specific species taken from a particular quota management region. In 1998, the total number of fishing quota markets stood at 157, ranging from 1 for hoki (*Macruronus novaezelandiae*) to 10 for abalone. We exclude region 10 from our analysis because this region was set up for administrative reasons (Yandle 2001) and is rarely if ever fished for any species. As of 1996, the species managed under the ITQ system accounted for more than 85% of the total commercial catch taken from New Zealand's EEZ.

Fishing quotas are generally tradable only within the same fish stock, and not across regions or species or years, although there are some minor exceptions (see Newell et al. 2002 for further detail). The quota rights can be broken up and sold in smaller quantities and any amount may be leased and subleased. The New Zealand Ministry of Fisheries sets an annual total allowable catch for each fish stock based on a biological assessment as well as other relevant environmental, social, and economic factors. The TACs are set with a goal of moving the fish population toward a level that will support the largest possible annual catch (i.e., maximum sustainable yield), after an allowance for recreational and other noncommercial fishing. Here we use the term TAC to refer to the total allowable commercial catch, which under the New Zealand system is referred to as the TACC. For many species (e.g., offshore fish stocks) there is no interest from recreational anglers and the entire TAC is allocated to the commercial sector. Compliance and enforcement is undertaken through a detailed set of reporting procedures that track the flow of fish from a vessel to a licensed fish receiver (on land) to export records, along with an at-sea surveillance program including on-board observers (Boyd and Dewees 1992).

Individual quotas were initially allocated to fishermen as fixed annual tonnages in perpetuity based on their average catch level over two of the years spanning 1982-1984 (Yandle 2001). The government allocated the quotas free of charge. The main reasons for introducing the system, however, were to rebuild the inshore fisheries and improve the economic conditions of the industry. By denominating quotas as fixed tonnages, the government was counting on its ability to purchase quotas on the open market if it wanted to reduce the total catch from a fishery. Because the initial allocations—which were based on past catch histories—exceeded the maximum sustainable yield in some fisheries, the government bought back quota on two occasions prior to the implementation of the program. Purchasing these quotas turned out to be expensive, however, as the government paid NZ$45 million for 15,000 tons of quotas from the inshore fisheries (Clark, Major, and Mollett 1988).

Faced with the prospect of spending another NZ$100 million to further reduce TACs (Sissenwine and Mace 1992), the government switched from quota rights based on fixed tonnages to denominating the quotas as a share of the TAC beginning with the 1990 fishing year. In doing so, the burden of risk associated with uncertainty over future TAC levels was moved from the government to the industry. At the same time, the industry received compensation payments over a period to 1994 for TAC reductions (Annala 1996). The New Zealand ITQ system is a dynamic institution that has had many refinements since its beginnings more than 15 years ago. Nonetheless, the basic tenets of the system—setting a total allowable catch and leaving the market to determine the most profitable allocation of fishing effort—have remained intact. For further history and institutional detail, see Clark et al. (1988), Sissenwine and Mace (1992), Boyd and Dewees (1992), Annala (1996), Dewees (1999), Batstone and Sharpe (1999), and Yandle (2001).

3. TRENDS IN MARKET LIQUIDITY

The ability of firms to buy and sell quotas in a well-functioning market is necessary for achieving efficiency gains. In this section we assess the operation of the New Zealand ITQ market along the quantity dimension, in terms of the number of market participants and the level of market activity. Thin markets with few participants can lead to high transaction costs because buyers and sellers may have difficulty finding trading partners. With high transaction costs, transactions are less likely to occur, which could lead to noisy price signals and little or no efficiency gains (Noll 1982; Stavins 1995).

Market Participation, Entry, and Exit. The number of quota owners in the New Zealand ITQ system has averaged about 1,500 over the history of the program. Individual markets have had a median of 45 quota owners, ranging from 418 to just 1 owner in some small fisheries of low importance. As illustrated in Figure 1, the total number of owners increased from a minimum of about 1,300 in 1986 to 1,800 in 1990, falling since then to 1,400 in 1998. To give some additional sense of the variation across fishing stocks, we also present ownership trends by grouping species according to whether they are inshore, offshore, or shellfish (see Newell et al. (2002) for details). The increase in quota owners from 1987 to 1990 was due to the addition of several shellfish species to the ITQ program, and the subsequent 22% overall decline was due to the exit of about 32% of inshore owners and 19% of shellfish owners from their peaks in 1989–1990. The median number of owners in individual fishing quota markets has fallen from 51 in 1986 to 42 in 1998. Why the difference in exit behavior between the offshore versus inshore and shellfish fisheries? As described in section 2, prior to the adoption of the full ITQ system, a subset of the offshore stocks were included in a quota-based system, which had the effect of limiting entry. At the same time, the inshore fisheries had excess capacity, especially near Auckland. One might therefore expect to find that rationalization in the form of exit from certain fisheries would be greater in the inshore and shellfish compared with the offshore fisheries, all else equal.

Market Activity. Markets exist in New Zealand both for selling the perpetual right to fish a certain quota stock and for leasing quotas. In practice, virtually all leases are for a period of one year or less. Although there are no official statistics, the general belief among government officials and quota brokers is that a majority of the transactions between small and medium-sized quota owners are handled through brokers. Larger companies, on the other hand, typically have quota managers on staff and engage in bilateral trades with other large companies. Brokers advertise quota prices and quantities for sale or lease in trade magazines, newspapers, and on the Internet. A brokerage fee between 1% and 3% of the total value of the trade to be paid by the seller is standard.

We find that the quota markets are very active with more than 120,000 leases and 30,000 sales of quotas as of the end of the 1998 fishing year—an annual average of about 8,700 leases and 2,000 sales. The mean lease and sale quantities are approximately 30 and 16 tons, respectively. The total number of leases has risen considerably, from about 2,000 in 1986 to 14,500 in 1998. To get a sense not just of the aggregate market activity, but also of the activity at the individual fishing quota market level, Figure 2 illustrates the historical trends in the quota lease and sale markets as measured by the annual median across fish stocks of the net percentage leased and sold by fishing year. (Fishing years run from October to September for all species except rock lobster, packhorse rock lobster, and scallops, which run from April to March.) The figure shows that the median percentage of quota leased in these markets has risen consistently, from 14% in 1987 to 40% in 1998.

The total number of quota sales has fluctuated, from highs of almost 3,250 sales in 1986 and 1990 to a low of 1,150 sales in 1998. The high years correspond to the large initial quota allocations for most species in 1986 and for rock lobster in 1990. The median quota market shows the same pattern, with the percentage sold being as high as 18% in years of initial allocation (1986 and 1990), gradually decreasing in subsequent years to around 4% of total outstanding quotas per year in the late 1990s. This pattern of sales is consistent with a period of rationalization and reallocation proximate to the initial allocation of quotas. Although the typical ITQ market exhibits a reasonably high degree of activity, some individual quota markets are thin. The number of leases in the individual ITQ markets from 1986 to 1998 ranges from about 30 to 3,500, the median being 645 leases. The number of sales ranges from 0 to 1,500 across quota markets, the median being 138 sales. Quota markets with low activity tend to be of low economic importance in the size and value of the catch. In many cases, these minor markets were designed more for political and biological reasons than for maximizing economic gains (Boyd and Dewees 1992; Annala 1996).

4. ANALYSIS OF FUNDAMENTALS DETERMINING MARKET PRICES

A crucial question in gauging the performance of quota markets is whether market prices behave in an economically reasonable manner. We assess quota price behavior in several ways. We begin by econometrically estimating the relationship between quota lease and sale prices and underlying fundamentals that theory would tell us should determine these prices. We also evaluate the relationship between quota lease and sale prices, which in an efficient market would be related to the market interest rate through arbitrage.

Empirical Specification of Quota Prices. In a competitive quota market, each fishing enterprise has an incentive to lease or trade quotas until it attains just enough quotas to cover a catch level that maximizes its expected profits. The price of a one-year lease on the right to catch one ton of fish should therefore equal the marginal flow of profit or rent from that enterprise, that is, the price of fish minus the marginal cost of fishing. The price of holding that right in perpetuity (i.e., the quota sale price) should likewise equal the discounted expected rent. Thus, as we explore further below, the quota sale price should roughly equal the lease price divided by the market rate of interest, assuming expected lease prices are relatively constant.

In a deterministic setting, quota prices would depend on fish prices, factor prices, and factors underlying the technical relationship between fishing effort and the amount of fish caught, such as gear types, species biological characteristics, and climatic conditions. The specific role played by these factors could be modeled by specifying functional forms for the fishing production function and the biological relationship between catch and the population of fish. In practice, however, the inherent uncertainty surrounding fishing activities, biological populations, and the evolving availability of information on demand in an ITQ market are very difficult to capture in a fully structural manner, especially if the ultimate desire is a basis for empirical estimation across many species, regions, and time.

We therefore take a reduced-form approach, employing a flexible functional form of key variables to approximate the relationship between quota prices and their determinants. We use a comprehensive panel dataset of information we constructed from New Zealand government agencies and other sources for the period 1986–1999. We have more than 170,000 individual transactions altogether, which resulted in 6,010 quarterly lease and 4,161 sale observations. We estimate separate equations for lease prices and sale prices using feasible generalized least squares (FGLS), wherein the covariance matrix of the disturbances is adjusted for stock-level heteroskedasticity, serial correlation, and weighted based on the number of observations underlying each quarterly average. All monetary figures were adjusted for inflation to year 2000 New Zealand dollars. A detailed description of the variables in the dataset and their sources along with details of the econometric specification, estimation, and results are provided in Newell et al. (2002). Table 1 gives descriptive statistics for the included variables, which exhibit a large degree of variation.

In addition to the variables described below, we also include fixed effects for each individual fish stock, as well as seasonal effects (by quarter). We also estimate a model without individual fixed effects, instead including regional effects which should to a certain extent control for fishing cost differences, especially those related to transportation. This alternative specification may be of particular interest if one is interested in prediction beyond the sample population, as well as better understanding the source of cross-sectional differences in quota prices.

Results. See Newell et al. (2002) for detailed estimation results. Overall, the results are consistent with economic expectations about the parameters. The estimated coefficients generally have the expected signs and reasonable magnitudes and are consistent across both the lease and the sale price equations. The qualitative results are also robust to changes in the functional form and the error structure employed.

We find that the value of fish, as measured by the logged export price of fish (greenweight), is positively associated with quota prices as evident by the result that the elasticity of the quota price with respect to the fish export price is positive and statistically significant in both lease and sale prices equations. As we would expect, species with higher export prices also tend to have proportionately higher quota prices. The magnitude of the export price elasticity is also consistent across the two quota price equations (about 1 at the mean export price in the model without fish stock fixed effects). Fishing costs as measured by a logged input price index for New Zealand fishing over time, including labor, fuel, and material costs is negatively correlated with quota sale and lease prices. The individual fish stock fixed effects we include control for much of the cross-sectional factors that affect costs, including differences in fishing techniques for different species (e.g., gear) and regional costs differences (e.g., transportation costs and oceanographic conditions). These are jointly significant at the 5% level.

In addition, we include variables that capture differences in relative quota demand within and between fish stocks over time. The first measure of quota demand is the prior year's percentage caught of the TAC. The second measure of quota demand updates the first by measuring the year-to-date percentage caught of the TAC *relative* to the prior year. In other words, the second factor measures the additional information available at some point within the fishing year that is incremental to what was available at the start of the fishing year. Since both higher demand and lower supply are associated with greater scarcity and higher prices, we would expect both of these variables to have a positive influence on quota prices. We also include an interaction effect between the percent caught and the export price to allow the relationship between the quota price and the export price to vary based on the degree to which the TAC is binding. When the percentage caught of the TAC is higher, we would expect the relationship between quota prices and export prices to be stronger, suggesting a positive sign for the parameter estimate on this variable. Regardless of specification, these relationships hold empirically and are statistically significant.

We include additional variables, depending on the specification, to assess the effect of ecological uncertainty on quota prices; one is biological and the other climatic. The biological variable is the mortality rate for each species, which gives the percentage of the fish population that dies annually of natural causes. It is included only in the specification without individual fixed effects because it is not identified in the other specification. Species with higher mortality rates have population sizes that are more variable, which leads to greater uncertainty in the amount of fish likely to be caught with a given level of effort. As a consequence, there is greater uncertainty in the profits from fishing high-mortality species, and we would expect the mortality rate to have a negative effect on quota prices due to curvature in the profit function and risk aversion. Our results show that species with higher mortality rates do have significantly lower quota prices, other things equal.

The climatic variable we include is the Southern Oscillation Index, a time-series measure of variability in water temperature and pressure. Water temperature significantly influences fish ecology and location and is an important variable used by the fishing industry when assessing the productivity of fisheries. We would expect that greater variation in the Southern Oscillation Index would be associated with more uncertain profitability of fishing and thus would have a negative effect on quota prices. The Southern Oscillation Index (SOI) had a negligible relationship with quota prices. A complexity with measuring the influence of the SOI is that each species is expected to respond differently and over different time frames to this index. This requires a more disaggregated approach and careful treatment of the relationship between individual species abundance and oceanographic variables—an analysis that is beyond the current exploration.

If the tradable quota system delivers on its most important promise—increased profitability of the fisheries through stock rebuilding and cost rationalization—we would expect the time effects in our model to be generally positive and increasing. That is, once we have controlled for changes in fish prices, fishing input prices, and other important factors in our analysis, the residual effect of time on quota prices should be positive as the system provides incentives for increased catch per unit effort and increased profitability. This should be particularly evident for fisheries that were plagued with excess capacity, were the most depleted, and therefore faced significant reductions in allowable catch at the outset of the ITQ program. Most of the fishing stocks included in the program did not in fact face significant initial reductions in catch, but rather had TAC levels set based on historical levels. We therefore estimate separate time effects in our model for fishing stocks that faced significant initial reductions, versus those that did not. We would expect the time effect to be significantly larger for the former, as these stocks should experience greater increases in profitability and quota prices, due to potential improvements in fish populations and the likelihood of significant gains from consolidation and trade. Therefore, even though we do not have a control group of fisheries operating fully outside the ITQ system, we nonetheless have a natural experiment in the form of different fishing stocks facing varying degrees of government constraint on catch levels through the setting of TACs.

Controlling for other factors, there is evidence of increased profitability of the included fisheries since the establishment of the ITQ system. The collection of stocks that faced initial reductions in allowable catch also experienced significant consolidation, with the median fish stock having a 38% reduction in the number of owners. For these stocks, we estimate that lease prices rose at an average rate of 4% and sale prices by 10% annually since the program started, holding other factors constant (based on the model with fixed effects). For the other collection of stocks, which saw only a median 12% reduction in the number of owners, we estimate that lease prices rose a more modest 0.6% annually and sale prices by 6% annually, all else equal.

Regardless of the specification employed, we found that quota sale prices have risen to a greater degree than quota leases prices. The greater increase in quota sale than lease prices can be at least partly attributed to decreases in the market interest rate, which fell from about 11% to 3% real over the relevant period. As mentioned earlier, increases in quota sale prices could also be driven in part by the perception of increased security of quota assets, although such an effect should not be important for quota lease prices. Caution is always in order when interpreting time effects, however, and there are other unmeasured factors that could plausibly influence quota prices over time. For example, there may also be an increase in the perceived security of quota assets over time, which could have a positive effect on quota sale prices but would not necessarily influence quota lease prices. There have also been policy changes over the history of New Zealand's ITQ system that could affect prices in both positive and negative ways. Finally, we include New Zealand's real GDP growth rate to control for changes in the general state of the New Zealand economy, which affects corporate profitability and tends to be correlated with asset prices. We found that higher quota prices were also significantly associated with periods of higher GDP growth.

We also explored the relationship between quota lease prices, sale prices, and the rate of interest by calculating an "expected rate of return" to quota by dividing each stock's average annual lease price by its sale price. Recall that in a competitive market the lease price should measure the annual profit flow, and the asset sale price should represent the present value of expected future profit flows. Assuming roughly constant expected future profit flows, the lease price divided by the sale price should be close to the market interest rate. The data supports the presence of this arbitrage relationship, with the computed expected rate of return tracking both the level and the trend in the market interest rate over the sample period. At the same time the expected rate of return fell by about half from 14% to 7%, the interest rate as measured by New Zealand Treasury bills fell from 11% to 3% real.

5. CONCLUSION

In the New Zealand ITQ markets, we typically observe both a sufficient number of market participants and high enough levels of market activity to support a competitive quota market. The level of activity has risen steadily over the years, consistent with the notion that the development of these markets takes time. Not all is rosy, however—some markets have relatively few transactions, although these tend to be economically and ecologically unimportant fisheries. Market thinness could be addressed through policy by aggregating illiquid quota markets into other quota markets. The advantages of such aggregation would of course have to be considered along with any positive or negative biological, social, and administrative implications.

Our estimates indicate that prices in these markets are related in an expected manner with underlying economic fundamentals, including measures of fishing value, relative quota demand, ecological variability, and market rates of return. Our analysis of the market arbitrage relationship between quota lease and sale prices, for example, shows that the expected rate of return for quotas follows the general historical level and trend of New Zealand's real rate of interest. Moreover, after controlling for relevant factors, our results show an increase in the value of quota prices over the history of the ITQ program, consistent with an increase in the profitability of the included fisheries. This is particularly true for fishing stocks that were initially overcapitalized and overfished and faced significant catch reductions from historic levels.

The results are also relevant for ongoing policy developments in the United States, where the debate focuses in part on whether shares should be transferable. We can infer from the revealed behavior in the New Zealand ITQ market that the overall flexibility of the system and the ability to transfer shares has high economic value. Furthermore, the flexibility provided to quota holders by having the option to lease appears to have significant value as revealed by the dramatic increase in leasing over time. In addition, the opportunity to arbitrage across the sale and lease market provides an additional dimension across which relevant market information can be exchanged and rationalized. Overall, the evidence to date suggests a reasonable level of economic sophistication in these markets, implying that market-based quota systems are potentially effective instruments for efficient fisheries management.

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APPENDIX

B.1 TABLES

Table 1. Descriptive Statistics for Determinants of Fishing Quota Prices

Variable	Mean	Std. dev.	Min.	Max.
Lease price ($/ton)	1,738	4,321	1	43,663
Sale price ($/ton)	21,216	48,585	22	358,586
Export price (greenweight) ($/ton)	7,592	11,246	311	60,263
Catch (tons/year)	3,992	20,814	0	268,633
Total allowable commercial catch (tons/year)	5,154	23,416	1	251,883
Percentage catch	0.76	0.35	0.00	5.09
Percentage cumulative catch over prior year	0.01	0.13	-1.07	3.11
Mortality rate	0.30	0.22	0.05	1.00
Southern Oscillation Index	-2.6	10.2	-23.7	15.47
Fishing cost index (index = 1 in Jan. 1986)	0.85	0.04	0.79	1.00
GDP annual growth rate	0.02	0.02	-0.02	0.07
Number of leases per quarter	14	17	1	192
Number of sales per quarter	4	5	1	75

Note: Monetary figures are year 2000 NZ dollars, which are typically worth about half a U.S. dollar. Tons are metric tons.

B.2 Figures

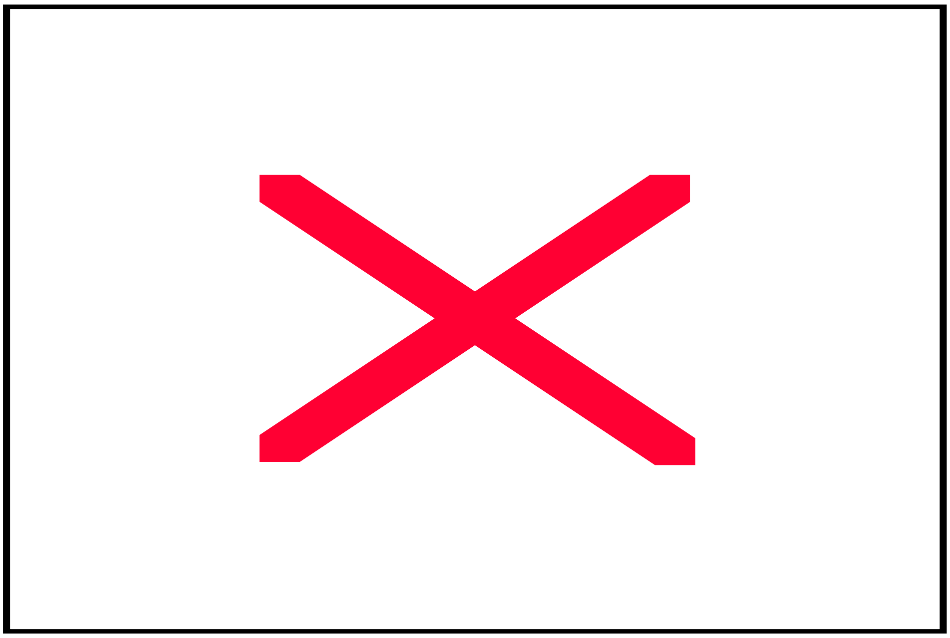

Figure 1: Trends in the Number of Quota Owners

Note: Number of quota owners, by fishing year.

Figure 2. Trends in the Portion of Quota that are Leased and Sold

Note: Annual median across fish stocks of the net percent of quota owned that is leased and sold by fishing year.