An Empirical Analysis of Individual Fishing Quota Market Trading

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ABSTRACT

In the study, we investigate determinants of individual fishing quota (IFQ) lease price and transfer of permanent share in the General Category Scallop fishery of the Northeastern United States. A unique micro data set on individual IFQ transactions and related vessel-level fishing profit information for the six-year time period, fishing years 2010–2015, was used to estimate models of aggregate IFQ lease markets and individual transactions. We find that IFQ lease price is affected by the marginal profit of scallop fishing as well as macroeconomic conditions. Results of the analysis also suggest that the price for IFQ asset transfers captures the capitalized profits in the fishery over time. Overall, IFQ market performance is in general agreement with economic theory.

Key words: Individual fishing quota, IFQ, ITQ, quota market, scallop fishery.
JEL Codes: Q22, D40, L10.

INTRODUCTION

Since Christy's "tentative suggestion" in 1973 for individual transferrable quotas (ITQs) as a feasible solution to the common property market failure described by Gordon (1954), ITQ and similar programs (catch shares) have been increasingly incorporated into fisheries management around the world. Copes (1986) notes that individual fishing quotas (IFQs) are not a panacea for all the problems of fisheries management and describes both unintended consequences of an IFQ system and situations in which they are unlikely to increase economic efficiency.[1] Many empirical studies of the effectiveness of these programs have been conducted to characterize changes after catch share implementation, and, in some cases, draw a causal link between catch share implementation and changes in economic outcomes.[2]

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1. Multiple studies also examine non-efficiency concerns about ITQ management, including undesirable distributional impacts (Anderson 1991; Gauvin, Ward, and Burgess 1994; Matulich, Mittlehammer, and Reberte 1996; McCay, Apostle, and Creed 1998; McCay 2004; Brandt 2005; Anderson, Freeman, and Sutinen 2008; Yandle and Dewees 2008; Carothers 2013; Grainger and Costello 2016), effectiveness, or lack thereof, in stock conservation (Chu 2009; Acheson, Spencer, and Wilson 2015; Bromley 2015; Kahui, Armstrong, and Foley 2016).

2. These include focused studies of productivity and capacity (Weninger 1998; Shotton 2001; Dupont et al. 2002; Walden et al. 2012; Solís, Agar, and del Corral 2015; Färe, Grosskopf, and Walden 2015), output prices (Fox et al. 2003, 2006; Dupont et al. 2005), season length (Birkenbach, Kaczan, and Smith 2017), and resource rent (Anderson, Andersen, and Frost 2010). These also

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Different fisheries operate under different ecological, economic and operational conditions, and institutional arrangements. A clear understanding of the quota market is crucial for each specific fishery to achieve its ITQ management objectives. According to Arnason (1990), under certain conditions (e.g., perfectly competitive markets), the fishery manager needs only to monitor the quota market price and to adjust the total allowable catch (TAC) until the current total quota market value is maximized, which is the "minimum information management" scheme to achieve a socially optimal condition for the fishery. There are at least three functions of an efficient quota market to: allocate quota pounds (QP) to those who value them most, encourage efficient use and discipline inefficient use of QP, and provide information for business planning and policy decisions (Newell, Papps, and Sanchirico 2007; Holland 2016).

There is growing literature examining the performance of ITQ markets. Newell, Sanchirico, and Kerr (2005) examined the ITQ fisheries in New Zealand using a 15-year panel data set from New Zealand that covers 33 species and more than 150 markets for fishing quotas. They found that market activity was sufficiently high in the economically important markets and that price dispersion had decreased. They also found evidence of economically rational behavior through the relationship between quota leases and sale prices and between fishing output and input prices, ecological variability, and market interest rates. The relationship between the annual lease and sale prices in New Zealand's IFQ markets was the focus of a separate study by Newell, Papps, and Sanchirico (2007). They found that quota asset prices were negatively related to interest rates and risk levels, and positively related to future fish prices.

Market design and imperfections may be important in these new markets. Anderson (2004) illustrated how trading limitations could lead to very different final outcomes using a laboratory experiment. Lee (2012) found that institutional limitations led to bargaining power in the Northeast US multispecies days-at-sea market. Ropicki and Larkin (2014) found that informational differences, proxied by social network indicators, had similar effects in the Gulf of Mexico red snapper quota market. Kroetz, Sanchirico, and Lew (2015) assessed efficiency cost of restrictions on quota share (QS) trading. They estimated that restrictions led to reductions in resource rent in the Alaska halibut and sablefish fisheries by 25 and 9%, respectively. Holland (2016) reported the market imperfections in the Pacific groundfish QP market. Quota markets in multispecies IFQ fisheries develop slowly and may fail to perform efficiently even after several years.

In spite of the importance of information on IFQ markets, systematic studies of ITQ trading using empirical data have been developed for only a relatively small number of fisheries, because price information on catch share transfers is often limited or unavailable in many catch share programs (Holland et al. 2015). The Limited Access General Category Scallop IFQ program was implemented in 2010 and provides an opportunity to investigate new IFQ markets using empirical data. The program established QS that, when multiplied by the annual catch limit (ACL) for the IFQ fishery, determines the QP of scallop meats that may be harvested in a given year by any one entity holding QS. The IFQ program allows both permanent transfer of QS and short-term transfer of QP (leasing). Economic theory predicts that the price for QS (i.e., a permanent transfer of the IFQ share) is equal to the capitalized profits in the fishery over time, whereas the price for QP (i.e., an IFQ lease) reflects the marginal net return in the fishery. The objective of this study is to evaluate general economic performance of the QS and QP transactions in the General Category Scallop IFQ program and to test whether the market prices are consistent with economic theory.

include broad studies that examine many metrics of fishery performance (Arnason 2005; Costello, Gaines, and Lynham 2008; Grimm et al. 2012; Brinson and Thunberg 2016).

The vessels in this fishery typically take trips that target a single species, and thus, its quota market does not involve the many complexities associated with IFQs for multispecies fisheries. We compile a micro data set with information on individual transactions, as well as relevant vessel-level profit and fishing quota allocations. Following the general framework of Newell, Sanchirico, and Kerr (2005); Newell, Papps, and Sanchirico (2007); and Lee (2012), we estimate models of aggregate lease quota markets and individual transactions. We show that IFQ lease price is driven by the marginal profit from scallop fishing. We also investigate the relationship between IFQ lease and transfer prices, finding a positive relationship between the two. Our study is unique in that we directly investigate the relationship between quota lease price and marginal profit of fishing, as suggested by bioeconomic theory, while most existing analyses examine the relationship indirectly using fish price.

BACKGROUND

The study period covers fishing years 2010–2015; i.e., March 1, 2010 through February 29, 2016. During this period, the scallop IFQ lease market was quite active, with 1,852 lease (QP) transactions. In contrast, there were only 169 permanent IFQ share (QS) transfers. There were approximately 330 permits in the General Category Scallop fishery, and over 70% percent participated in the leasing market.[3]

The Atlantic sea scallop fishery is managed by the New England Fishery Management Council (NEFMC). Limited access (LA) was introduced in 1994; permit-holders who did not qualify for the LA fishery could fish under a general category (GC) permit, which remained an open-access fishery with a 400-pound trip limit (NEFMC 1993). Growth in the share of scallops landed in the GC fishery relative to the LA fishery led to the development of Amendment 11, which created the limited access-general category (LAGC) fishery and further divided it into the IFQ, Northern Gulf of Maine, and incidental fisheries. As with most US catch share fisheries, initial allocations for the IFQ fishery were based on catch history. The goal of Amendment 11 was to control fishing capacity and scallop mortality in the LAGC fishery. The NEFMC also adopted a vision for the LAGC fleet to "maintain the diverse nature and flexibility within this component of the scallop fleet" (NEFMC 2007).

The LA and IFQ fleets are affected by spatial closures to protect scallop habitat, groundfish habitat, and groundfish. A rotational access system also affects the LA and IFQ fleets. In this system, areas of the ocean with an abundance of juvenile scallops are closed to allow them to grow into larger sizes that fetch a premium price. Regulations for the IFQ fleet include a possession limit, currently 600 lbs., and a fleet-level aggregate limit on trips into scallop access areas. The access area limit was reached three times during the study period in Delmarva in 2010, Hudson Canyon in 2011, and the Mid-Atlantic Access Area in 2015. The life-history characteristics of sea scallops are favorable for spatial management: scallops grow quickly, adults have low levels of natural mortality, and scallops are relatively immobile after settling on the ocean floor (Hart and Rago 2006). Due to the importance of the rotational management system, finely detailed biomass data are collected to inform managers (see NEFSC 2014 and NEFMC 2015 for examples) and used to project future biomass using the scallop area management simulator (SAMS).

A few institutional limitations and peculiarities of the market are worth describing. When the IFQ program began, there were a few rules in place designed to lower the NMFS' burden of administering a new tradable rights program. Entities that made permanent transfers of QS were

3. There are an additional 40 fishing vessels that are dual permitted in the limited-access fishery (managed under days-at-sea) and the IFQ fishery. These vessels are not allowed to transfer or lease their QS or QP.

required to transfer their entire QS allocation prior to use of any IFQ, vessels that utilized any IFQ could not subsequently transfer QS later in the fishing year, and QP could be transferred only once per fishing year. An ownership cap of 2% per vessel and 5% per person was also imposed, with the explicit goal of limiting consolidation (*Federal Register* 2008). In 2011, permanent transfers of QS that were less than an entity's full QS allocation were allowed, and the vessel-level ownership cap was raised to 2.5% (*Federal Register* 2011). In 2013, vessels were allowed to make a within-season transfer of QS after using some QS, and QP could be transferred an unlimited number of times (*Federal Register* 2013).

There are also two "permit banks" that own QS and lease quota. The Cape Cod Fisheries Trust works with the Cape Cod Community Development Partnership to lease QP to local fishermen at below market rates. A similar permit bank is operated by the State of Maine. IFQ trades occur through both word of mouth and facilitation through brokers; no centralized market exists. Fishing right holders are required to report lease and transfer information to the Greater Atlantic Regional Fisheries Office (GARFO), including buyer and seller permit numbers, QS transferred or QP leased, and the total value of the transaction. Finally, the "Confirmation of Permit History" (CPH) program can be utilized by right holders. The catch history of a fishing vessel and, therefore, QS in the IFQ scallop program can be separated from the fishing vessel itself. Rights holders can then transfer this to a new vessel, sell this right, or lease out the corresponding amount of QP on an annual basis. Prior to approval, each transaction is reviewed by GARFO to verify that the seller has the available QP or QS to be transferred and that the buyer would not exceed the ownership cap.

Activity in the QP market has increased over time as traders gain experience, and some of the regulations regarding trades were removed; the total value (in constant 2015 dollars) of leases increased from $74 thousand per month in 2010 to $350 thousand per month in 2015, on average. Corresponding total lease quantity grew from 37 to 90 thousand pounds per month (figure 1). The actual monthly quantity of leased QP was even greater than that depicted in the figure, as over 30% of the lease quantity was excluded due to missing value information in the lease trade records (e.g., when quota was transferred between two vessels with the same owner). Significant seasonal variation existed in the lease market, and the number of lease transactions fluctuated between 10 and 60 per month. About half of the transactions involved CPH sellers. Spatial variation in lease trade was also evident, and most buyers and sellers were in Massachusetts and New Jersey.

Scallop prices rose from approximately $9 to $13/lb. during the study period. A similar trend was also present in IFQ lease price, increasing from about $2/lb. in 2010 to over $4/lb. in 2015 (figure 2). Changes in the IFQ transfer price generally followed the same pattern as the lease price (figure 3). Transfer prices for QS have been around $40/lb. in recent years (figure 3).

METHODS

THEORY

The classical bioeconomic fishery model is an optimal control problem in which the social planner selects a harvest level in order to maximize discounted net revenues from the stock of fish:

$$\max \int_0^\infty \pi(h)e^{-\delta t}dt \text{ with } \pi(h) = ph - c(h) \tag{1}$$

$$s.t. \frac{dx}{dt} = f(x) - h, \tag{2}$$

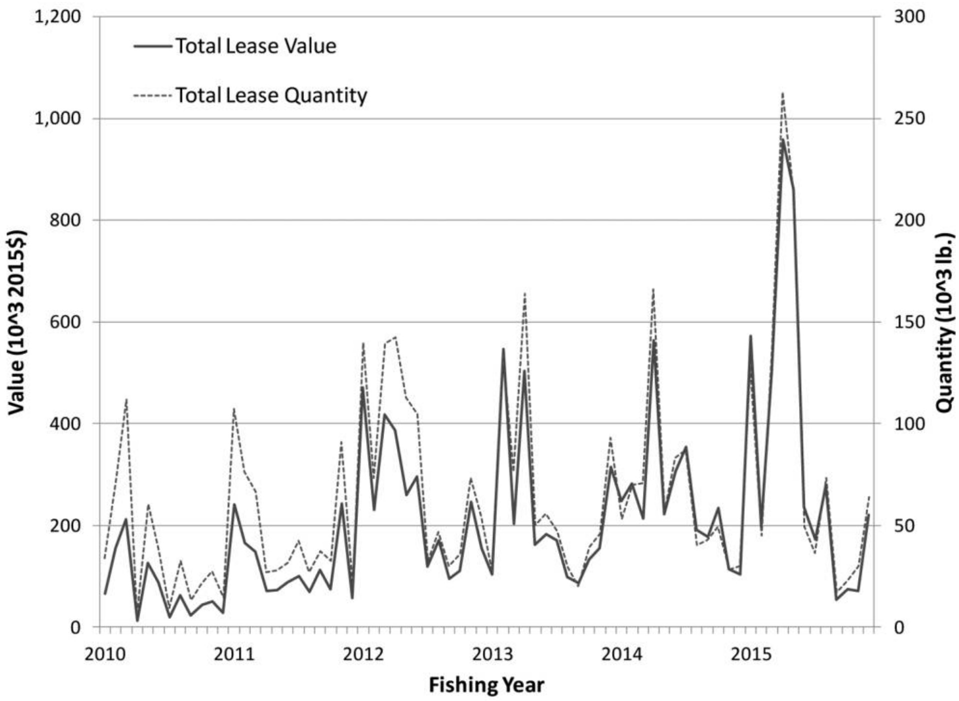

Figure 1. Monthly Total IFQ Lease Quantity and Value

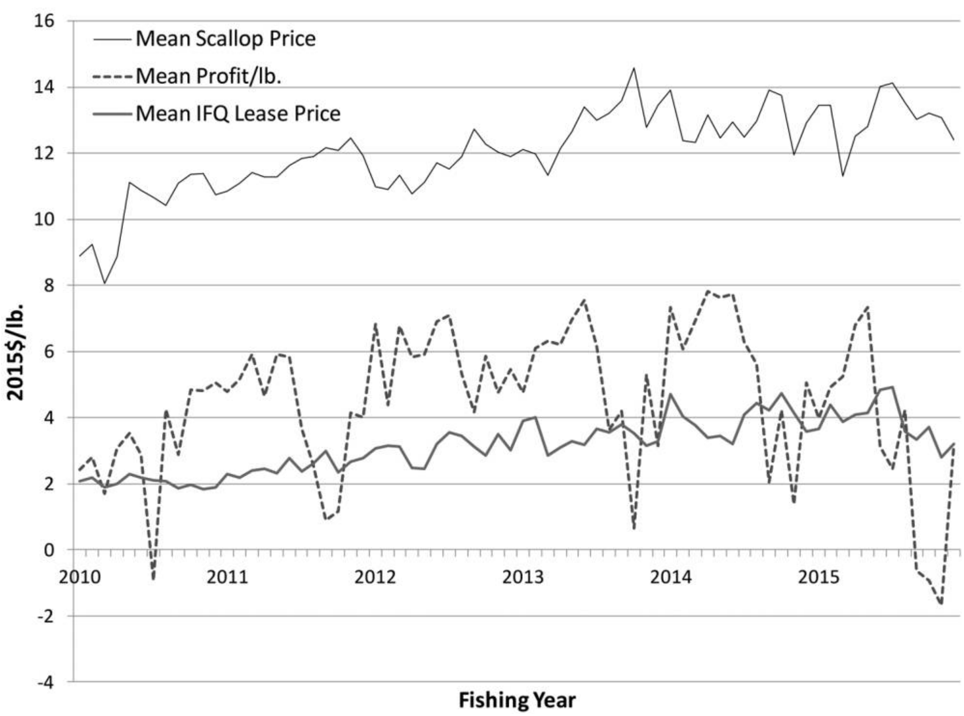

Figure 2. Monthly Mean IFQ Lease Price, Scallop Price, and Profit

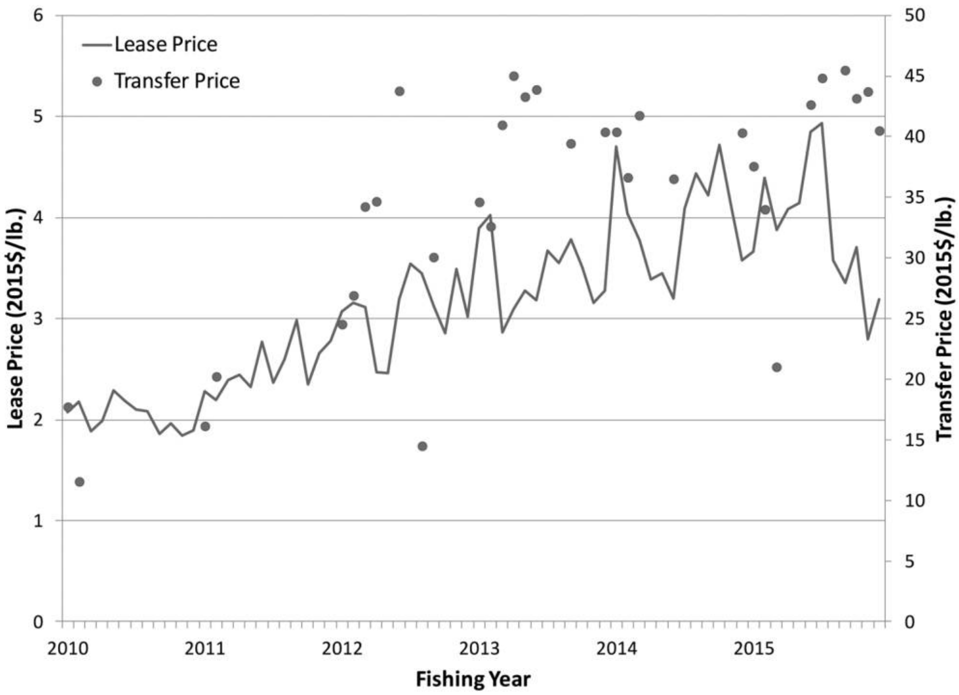

Figure 3. Monthly Mean IFQ Lease and Transfer Prices

where p is the price of fish, h is the harvest, $c(h)$ is the cost of fishing, π is the net revenue, δ is the discount rate, x is the fish stock, and $f(x)$ is the biological growth function (Clark 1976). The first-order condition of the optimal control problem (1) and (2) requires that:

$$\lambda^* = \frac{\partial \pi}{\partial h} = p - \frac{dc(h^*)}{dh}, \tag{3}$$

where λ is the costate variable, which represents the value of an additional unit of x (the shadow value of stock). Thus, when optimally harvesting fish, the shadow value is equal to the marginal profit of fishing ($\partial\pi/\partial h$). Equation (3) provides a solution to the inter-temporal problem in fisheries management.

Many fisheries are characterized by overcapitalization and derby fisheries. Economists have often prescribed property rights (usually IFQs) as a market-based solution that can, under certain conditions, solve this problem.[4] Clark (1980) investigated various regulatory instruments, including vessel quotas, using a disaggregate version of model (equations (1) and (2)) with N vessels being different in fishing costs:

$$\max \int_0^\infty \sum_{i=1}^{N} \pi_i(h_i)e^{-\delta t}dt \text{ with } \pi_i(h_i) = ph_i - c_i(h_i) \tag{4}$$

4. Under US law, IFQs are harvest rights.

$$s.t.\frac{dx}{dt} = f(x) - \sum_{i=1}^{N} h_i. \tag{5}$$

The solution to problems (4) and (5) includes the same optimality condition (3) for each vessel i in the fishery. Under quota management, vessel i will want to buy (sell) additional quota units from its given allocation, Q_i, if:

$$\frac{\partial \pi_i}{\partial h_i}(Q_i) > m \ (< m), \tag{6}$$

where m is the quota price. In a perfectly competitive market, a transferable fishing quota system will result in a social optimal equilibrium in which $Q = \Sigma_{i=1}^{N} Q_i = f(x^*)$ and $m = \lambda^*$. From prices, fisheries managers can infer information about stock status and appropriate catch limits (Arnason 1990; Batstone and Sharp 2003).

However, search frictions and bargaining power differentials may lead to less-than-perfect competition. For example, Harding, Rosenthal, and Sirmans (2003) illustrate how prices may be affected by relative bargaining power (measured by characteristics of buyers and sellers) in a thin market. Lee (2012) applies this model to the New England groundfish days-at-sea market. For an individual trade, j, the effect of bargaining can be modeled as:

$$m_j = g\left(\frac{\partial \pi_b}{\partial h_b}, \frac{\partial \pi_s}{\partial h_s}, \mathbf{D}_\mathrm{b}, \mathbf{D}_\mathrm{s}\right), \tag{7}$$

where s and b denote the individual seller and buyer, respectively. **D** is the vector of characteristics of the individual. With a thin market, the marginal net revenues ($\partial\pi/\partial h$) of both buyer and seller can affect the sale price. When two parties have unequal bargaining power, bargaining leads to the allocation that maximizes the joint surplus relative to the non-cooperative allocation; however, the surplus is divided according to individual bargaining power (Nash 1950; Blair, Kaserman, and Romano 1989). This particular market imperfection poses no particular problem for allocative efficiency: the most efficient producers will purchase quota (provided that quota can be traded multiple times, which has been allowed in this fishery since 2014). However, bilateral bargaining reduces the informational signal contained in quota prices, making the type of the inference about catch limits described by Arnason (1990) more difficult. In contrast, transaction costs make Pareto-improving trades less likely to occur (Stavins 1995; Newell, Sanchirico, and Kerr 2005).

Finally, quota transfer price is the capitalized value of quota leasing value. If quota leasing price reflects the marginal net revenue of fishing ($\partial\pi/\partial h$), transfer price (P) at time t is related to the expected future lease prices as (Newell, Papps, and Sanchirico 2007):

$$P_t = \sum_{k=0}^{\infty} \frac{E_t(m_{t+k})}{(1 + \delta_t)^k}. \tag{8}$$

If one assumes that expected future lease prices are constant, we have:

$$P_t = \frac{m_t}{\tilde{\delta}_t}, \tag{9}$$

where $\tilde{\delta} = r\delta$, r is an adjustment factor to capture a premium above δ that may reflect imperfections of the property right, risk premia, or anticipation of future stock declines (Scott 1996, 2000; Arnason 2005, 2012; Grainger and Costello 2014).

ESTIMATION

We develop three empirical models of scallop IFQ market trading. The first two models investigate IFQ lease price movement at the aggregate fishery and individual transaction levels, respectively. The third model examines the relationship between IFQ lease and transaction prices. We present two lease price models because they provide different perspectives and are complementary. Also, in applied analysis, data for the aggregate model are likely available for most IFQ programs, while complete data for the individual transaction model are typically unavailable.

One approach to examine general economic performance of IFQ markets is to investigate the determinants of quota price movement at the aggregate fishery level, as in the bioeconomic model specified in equations (1) and (2). As shown by Newell, Sanchirico, and Kerr (2005), quarterly average lease price may be affected by multiple factors including fish price, cost of fishing, and general economic conditions. For our analysis, we consider monthly average lease price (m), and the general specification of the aggregate IFQ lease model is:

$$m_t = \alpha_0 + \alpha_1 \pi_t^m + \alpha_2 D_t + \alpha_3 M_t + \varepsilon_t, \tag{10}$$

where α_is are coefficients to be estimated, ε is an error term, and t is time (month). π^m $(=\partial\pi/\partial h)$ is the marginal profit of scallop fishing, D is the number of permit bank sellers, and M is the macroeconomic condition (GDP). From the above discussion (equations (3) and (6)), m is positively related to π^m, and the expected sign of α_1 is positive. m is also affected by M, which captures economic conditions that are not measured by other variables (Wessells and Anderson 1992; Newell, Sanchirico, and Kerr 2005). Thus, the expected sign of α_3 is also positive. Equation (10) is estimated using time series (monthly) data and three different estimation methods: weighted least squares estimation using the number of transactions per month as weights;[5] Yule-Walker estimation for correction of autocorrelation (Chatfield 1984); and ordinary least squares (OLS), with Newey-West standard errors that are robust to heteroscedastic and autocorrelated errors (Newey and West 1987).

To investigate the effect of bargaining power, a micro-model of individual quota lease transactions is also estimated following Lee (2012). The general specification of the micro-model of IFQ lease price (m) is:

$$m_j = \beta_0 + \mathbf{D}_{bj}'\boldsymbol{\beta}_1 + \mathbf{D}_{sj}'\boldsymbol{\beta}_2 + \mathbf{Z}'\boldsymbol{\beta}_3 + u_j, \tag{11}$$

where β_is are coefficients to be estimated, and u is an error term. For transaction j, $\mathbf{D}_b$ is the vector of buyer characteristics, including marginal profit, quota allocation, and port state. $\mathbf{D}_s$ is the vector of seller characteristics, such as association with permit bank, being a frequent seller, and port state.[6] $\mathbf{Z}$ includes other variables that may affect price, such as macroeconomic condition (GDP) and time dummies.[7] As in the aggregate lease market model, the expected signs for marginal profit and GDP are positive, and a negative sign is expected for a permit bank seller. Unlike the above model of aggregate IFQ lease market (10), the data for individual transactions are not

5. When the dependent variable is monthly average lease price (m_t), the error variance of m_t is inversely related to the number of transactions in the month t (n_t). Using n_t as weight gives a large weight to an observation containing relatively more information than an observation with large error variance.

6. Seller's marginal profit is not included in model estimations due to missing values in the sellers fishing history data.

7. We included monthly, seasonal, and yearly dummies to capture possible time-specific effects in initial estimations. Model results reported in the next section include only statistically significant dummies. A list of all variables examined in the analyses is in appendix table A1.

time series (lease trades occur at irregular intervals). We employ the White estimator to calculate heteroscedasticity consistent standard errors (White 1980).

In the deterministic bioeconomic model described in equations (4) through (6) and no market imperfections, the price of quota is equal to the marginal profit of fishing. We construct marginal profit based on the trip that was taken immediately before the IFQ transaction. However, trip profit fluctuates due to various uncertainties, and the decision to lease may not be based on a single trip. Therefore, we estimate alternative models using vessel-level average profits at the monthly level as a robustness check.

Following Newell, Papps, and Sanchirico (2007), we estimate equation (9) in its double-log form using available monthly data and two-stage regression with scallop profit as an instrumental variable for the likely endogenous lease price. Note that the profit of scallop fishing (π^m) affects quota transfer price (P) through the lease price (m), and the transfer price is a function of the predicted lease price ($\hat{m}$):

$$ln\ P_t = \gamma_0 + \gamma_1\, ln\ \hat{m}_t + \gamma_2\, ln\ \delta_t + \mathbf{T}'\gamma_3 + \varepsilon_t, \tag{12}$$

where γs are coefficients to be estimated, and ε is an error term. Vector $\mathbf{T}$ includes variables that may shift transfer price, such as time trend and dummies. From (9), we see that P is positively related to m and negatively related to δ. The signs for γ_1 and γ_2 are expected to be positive and negative, respectively. Since the lease price (m) represents a stream of future profits, higher discount rate (δ) means lower present asset value (transfer price). As mentioned above (below equation (9)), the discount rate is affected by various risk factors (e.g., scallop stock and regulatory conditions), as well as macroeconomic conditions (Pindyck 1984; Newell, Papps, and Sanchirico 2007; Arrow et al. 2013; Fenichel et al. 2016).

DATA

Primary data sources for the study include separate data files on approved IFQ lease transactions, IFQ permanent transfers, vessel logbook (fishing trip records), scallop fishing quota base allocation, and vessel permits data from the National Marine Fisheries Service (NMFS). For convenience of data compilation, we identify buyers and sellers in an IFQ trade using their fishing permit numbers. Note that about 84% of the permit numbers were associated with the same hull number during the study period. Thus, IFQ trade among permits captures the general pattern of trade among vessels, and, in turn, vessel owners.

Fishing histories and other characteristics of buyers and sellers of an IFQ trade (e.g., catch quantities, revenues, and costs) are constructed through merging data on IFQ transactions, logbook, and other files by permit number. For aggregate market variables, trip-level information is merged by permit number for each month and fishing year. Prices and values are converted to real 2015 dollars using the Producer Price Index for unprocessed and prepared seafood.

The data sets for regression analyses exclude IFQ transactions without price information. We also exclude observations with prices that are likely to be data errors, "protest" answers, or nonresponse answers: lease transactions with prices between \$1.01 and \$10/lb. and transfers with prices between \$1.01 and \$100/lb. are used in the analysis.[8]

8. There are 1,853 IFQ lease transactions and 172 IFQ transfers in the raw data sets, and 1,148 and 94 are used in the analysis.

Table 1. Lease Market Data Descriptive Statistics

Variable	Mean	Std. Dev.	Minimum	Maximum
Dependent Variable				
Mean lease price[a]	3.152	0.810	1.846	4.933
Independent Variables				
Scallop profit[b]	4.477	2.216	–1.688	7.830
Number of permit-bank sellers[c]	3.403	3.931	0	20
GDP[d]	15.562	0.551	14.605	16.505

[a] Monthly average lease price in 2015$/lb.
[b] Monthly average scallop profit (2015$/lb.). The variable was constructed using trip-level data. Profit/trip = catch revenue/trip - trip cost - labor cost/trip, which may be either positive or negative.
[c] Number of permit-bank sellers by month.
[d] US quarterly real GDP in 10^{12} 2009$.

Vessel trip costs (fuel, food, water, ice, supplies, etc.) were estimated using a regression model for scallop dredge developed using NMFS sea sampling data and corresponding logbook information (Jin, Kitts, and DePiper 2016). In the model, trip cost is a function of vessel size (i.e., tonnage) and trip duration (days absent). Since relevant trip-level data are available for vessels involved in IFQ transactions, trip costs for those vessels can be easily computed.

Trip-level labor costs are constructed using vessel crew information in the fishing vessel data file, trip duration, and county-level labor cost data from the Bureau of Labor Statistics (BLS 2017). We use BLS weekly wage data for industry code 488330 (navigational services to shipping) to approximate captains' wages, and industry code 713930 (marinas) for crew wages.

Trip-level net revenues from scallop fishing are constructed by subtracting these trip and labor costs from catch revenues derived from vessel trip records.[9] For each permit (i.e., vessel), we then estimate profit per pound of scallops on each trip. We use profits from the trip prior to the transaction as one measure of marginal profit; we also average over the vessel's trips in a month as a robustness check. This provides a measure of marginal profit that is consistent with the theoretical model (equations (4) and (6)). Figure 2 depicts the movement of mean profit across all vessels.

We estimate equations (10) through (12) using project data sets. Tables 1 and 2 present definitions and descriptive statistics of variables in the models of aggregate lease market and individual lease transactions, respectively.

RESULTS

Table 3 reports the results from three separate estimations of the aggregate IFQ lease model in equation (10) using time series data with variables described in table 1. The explanatory variables are highly significant and with expected signs. Model I is the weighted least squares estimation. As noted above, the dependent variable is monthly average lease price, and we use the number of transactions per month as weights so that observations containing relatively more information get larger weights. The estimation results suggest that lease price is positively

9. Profit/trip = catch revenue/trip - trip cost - labor cost/trip. Also, vessels in the General Category Scallop IFQ fishery catch both scallop and other species. The scallop fishing profits were estimated using a subset of trips whose scallop catches accounted for at least 85% of the total.

Table 2. Lease Transaction Data Descriptive Statistics

Variable	Mean	Std. Dev.	Minimum	Maximum
Dependent Variable				
Lease price[a]	3.093	1.269	1.015	8.663
Independent Variables				
Buyer scallop marginal profit[b]	6.838	6.237	–73.395	16.953
Buyer scallop profit[c]	6.628	5.666	–33.640	14.571
Permit bank seller[d]	0.170	0.376	0	1
Frequent seller[e]	0.235	0.424	0	1
Buyer quota allocation[f]	0.012	0.011	–0.011	0.046
RI buyer[g]	0.006	0.080	0	1
ME buyer[g]	0.031	0.174	0	1
DE seller[g]	0.005	0.069	0	1
NC seller[g]	0.032	0.176	0	1
NY seller[g]	0.029	0.167	0	1
GDP[h]	15.632	0.520	14.605	16.505
August[i]	0.088	0.284	0	1

[a] Lease price of a specific transaction in 2015$/lb.
[b] Buyer scallop profit (2015$/lb.) of last trip prior to lease transaction.
[c] Buyer monthly average scallop profit in 2015$/lb.
[d] Seller is in permit bank.
[e] Seller sold more than 20 times in the study period.
[f] Buyer base quota allocation in 10^6 lb. The variable was constructed as the initial yearly "base" allocations + "carryover" - "overages" + "base adjustment." The "base adjustment" may cause a negative allocation. There were a few years in which the quota was revised down, and the adjustment could be large enough to put a vessel into a negative allocation. In addition, a vessel may have sold its entire allocation and subsequently experienced the downward quota revision, leading to a negative allocation in the data set.
[g] State dummy.
[h] US quarterly real GDP in 10^{12} 2009$.
[i] Monthly dummy.

related to the marginal profit of scallop fishing, which is consistent with theory. Lease prices are also inversely related to the number of permit-bank sellers that were active, which is consistent with the missions of these organizations to offer quota at below-market prices to encourage fishing activity in their communities. In addition, a positive relationship exists between IFQ lease price and macroeconomic condition (GDP).

Table 3. Model of Aggregate IFQ Lease Market: Monthly Mean IFQ Lease Price

	Model I		Model II		Model III	
Variable	Coefficient	Std. Error	Coefficient	Std. Error.	Coefficient	Std. Error
Scallop profit	0.085***	0.026	0.080***	0.025	0.106***	0.033
Number of permit-bank sellers	–0.038***	0.011	–0.044***	0.013	–0.053***	0.014
GDP	1.132***	0.087	1.168***	0.114	1.190***	0.119
Intercept	–14.725***	1.351	–15.239***	1.771	–15.656***	1.754
# of observations	72		72		72	
R-squared	0.73		0.78		0.75	

*** denotes significance at the 1% level.

Table 4. Model of Individual Transactions: IFQ Lease Price

	Model I		Model II		Model III	
Variable	Coefficient	Std. Error	Coefficient	Std. Error	Coefficient	Std. Error
Buyer scallop profit	0.0168***	0.0052	0.024***	0.006	0.0196**	0.0078
Permit bank seller	−1.4822***	0.0520	−1.490***	0.051	−1.4629***	0.0608
Frequent seller	−0.3167***	0.0620	−0.344***	0.060	−0.2738***	0.0708
Buyer quota allocation	−12.4404***	2.5936	−11.810***	2.765	−10.7975***	3.6228
RI buyer	–	–	−0.500*	0.268	–	–
ME buyer	−0.4361**	0.1969	−0.544***	0.209	–	–
DE seller	–	–	−0.572**	0.269	−0.6807**	0.2892
NC seller	0.4167***	0.1187	0.385***	0.111	0.3605**	0.1578
NY seller	0.6247***	0.1233	0.580***	0.126	0.5682***	0.1442
GDP	1.3319***	0.0532	1.355***	0.051	1.2756***	0.0707
August	0.2482***	0.0757	0.187**	0.073	0.2813***	0.1051
Intercept	−17.4348***	0.8142	−17.820***	0.789	−16.5474***	1.0839
# of observations	931		954		954	
R-squared	0.61		0.61		0.63	

*, **, and *** denote significance at the 10, 5, and 1% levels, respectively.

Model II is the Yule-Walker estimation, an autoregressive error model corrected for first-order autocorrelation (Chatfield 1984). Model III is the Newey-West estimator that corrects the standard errors for both heteroscedasticity and autocorrelation (Newey and West 1987). The results of Models II and III are consistent with those of Model I.

Table 4 reports the estimates of equation (11) using the data set on individual lease transactions (table 2). Models I and II show the White estimators, and Model III is a similar estimation with each observation weighted by the quantity (pounds) in the transaction.[10] In Model I, the buyer's scallop profit of the last fishing trip prior to the lease transaction is the measure of marginal profit. As a robustness check, the buyer's monthly mean scallop profit is used as a proxy for marginal profit in Models II and III. The results suggest that IFQ lease price is positively related to a buyer's marginal profit of scallop fishing and is expected to be lower if the seller is part of a permit bank or a frequent seller, or the buyer has large quota base allocation. Buyers with large quota allocations pay less to acquire additional fishing quota; we suspect that this is because they are experienced, skilled, and have more information about the state of the fishery.[11] The lease price is, on average, higher in August. Buyer and seller locations (states) also affect the lease price. As in the aggregate IFQ lease market, lease price is positively related to GDP. The results of all three models are consistent, except that the buyer effects (RI buyer in Models I and III and ME buyer in Model III) and seller effects (DE seller in Model I) are not statistically significant.

The coefficient on marginal profit is much smaller than one, as suggested by equation (3). There are a few reasons for this finding. First, equation (3) represents an optimal condition based on a simple deterministic model in continuous time. As shown in Pindyck (1984), with stock re-

10. For these models, multicollinearity is a concern (condition numbers are below 90) but not serious enough to affect estimates (Belsley, Kuh, and Welsch 1980).

11. Buyers with large quota allocations are likely to be experienced or skilled, because the initial allocations relied on historical catch. This experience or skill would cause these vessels to have higher returns from given quota.

Table 5. Model of IFQ Transfer Price[a]

Variable	Coefficient	Std. Error
ln(IFQ lease price) (instrumented)	1.234***	0.208
ln(T-note rate)	–0.282**	0.122
Spring	–0.156***	0.051
Fishing year 2013	0.199***	0.043
Intercept	1.021*	0.521
# of observations	31	
R-squared	0.81	

*, **, and *** denote significance at the 10, 5, and 1% levels, respectively.
[a] Dependent variable is *ln*(IFQ transfer price).

cruitment uncertainty, λ is affected by the uncertainty (i.e., variance in stock growth). Given that IFQ leases are for the rest of a fishing year, one would expect lease prices to be affected by stock and other uncertainties in the year. A higher average profit is required to cover a risk premium for stock and other uncertainties. Newell, Sanchirico, and Kerr (2005) confirmed a negative relationship between increasing quota prices and ecological uncertainty. Second, the cost data for the study include trip (variable) and opportunity costs of labor, and we do not have vessel fixed- or quasi-fixed cost data. If fixed costs were added in the profit calculation, the difference between lease prices and average profit would be smaller. Note, however, that fixed costs are typically considered sunk and not expected to affect marginal decisions. Finally, the lay system in the fishery may affect the quota prices (McConnell and Price 2006). Under this system, crew are paid a share of the gross revenues minus a share of costs. The details of the lay system vary considerably across fishing vessels. We use the opportunity cost of labor as a measure of crew costs; however, this may be below the actual cost of hiring crew in this fishery. To the extent that this occurs, our profit measures are larger than true profits, and the estimated coefficient are smaller than the true value.

Table 5 reports the results of the estimation of equation (12), using available monthly data and two-stage regression with the marginal profit of scallop fishing as an instrumental variable for the likely endogenous lease price.[12] The results indicate that transfer prices are positively related to instrumented lease prices and negatively related to the T-note rate, as suggested by economic theory. From equation (9), we have $m/P = \delta$. Figure 4 shows that the general movement of the lease to transfer price ratio (m/P) follows that of the interest rate of the 10-year Treasury note. The mean T-note rate and mean price ratio are 2.4 and 9.9%, respectively.[13] On average, the price ratio is 4.3 times the T-note rate. Fishing, and investing in a newly created property right associated with fishing, is far riskier than investing in US Treasury securities. In particular, there is uncertainty about future stock levels, volatility in costs of fishing, and concerns about the

12. The data are not time series, as lease transfers occur irregularly. Also, we excluded two low-transfer price outliers (October 2012 and May 2015) in the estimation. These two data points are depicted in figure 4 as having high lease-transfer price ratios. Pearson correlation coefficient between the lease-transfer price ratio and the T-note rate = 0.484 ($p < 0.01$), excluding the two outliers.

13. The price ratio (roughly 0.1) is consistent with the discussion in Newell, Papps, and Sanchirico (2007) and Grainger and Costello (2014).

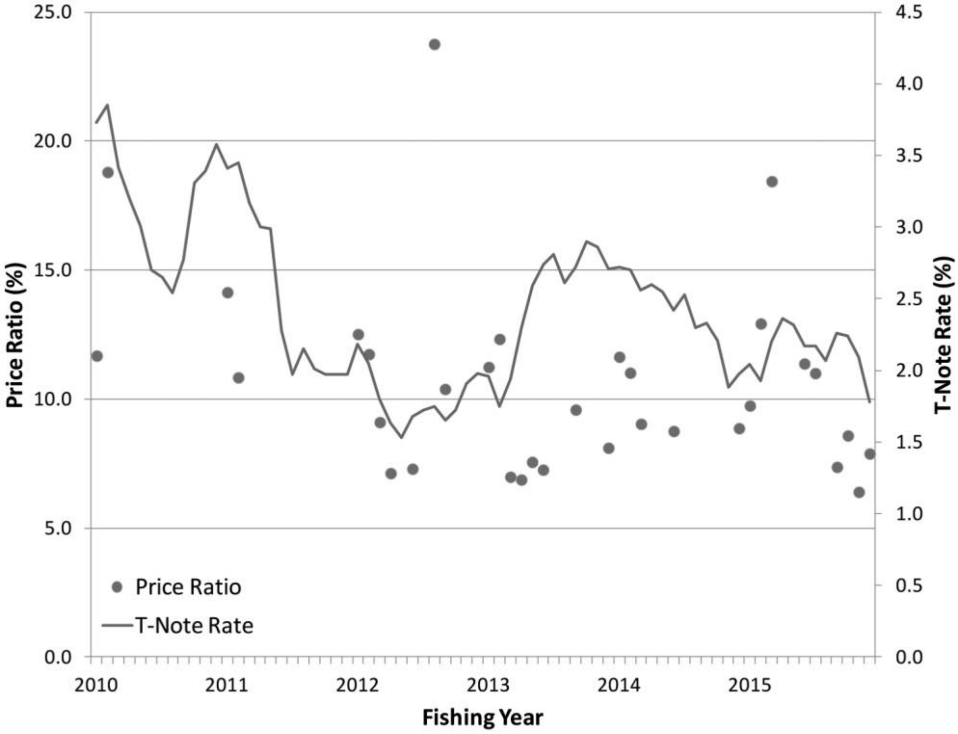

Figure 4. Monthly Lease-Transfer Price Ratio vs. T-Note Rate

quality of the newly established property rights (Scott 1996, 2000; Arnason 2005). Thus, the IFQ trader's discount rate is significantly higher.

CONCLUSIONS

This study investigated determinants of IFQ lease (QP) price and permanent transfer shares (QS) in the General Category Scallop fishery of the Northeastern US. Detailed data on individual IFQ transactions and related vessel-level profit information for the six-year time period, fishing year 2010–2015, were used to estimate models of quota lease market and individual transactions.

The estimation results suggest that IFQ lease price is affected by the profitability of the fishery as well as macro-economic conditions. Specifically, lease price is positively associated with marginal profit from scallop fishing and general economic condition. Lease price is negatively associated with permit-bank sellers. Significant spatial effects on lease price are also identified.

The number of permanent IFQ transfers is small due to ownership caps, high costs to obtain QS, and the convenience of a robust leasing market. Although QS trades are infrequent, changes in mean transfer price are related to movements in mean lease price. The results suggest that the price for IFQ transfers reflects the capitalized profits from fishing over time, adjusted for risks associated with the scallop fishery. Overall, scallop IFQ market performance has been consistent with economic theory.

APPENDIX

Table 1A. List of Variables Included in Model Analyses

Variable	Description	Lease Market Model	Individual Lease Transaction Model	IFQ Transfer Model
Dependent Variables				
Mean lease price	Monthly average lease price	x		
Lease price	Lease price of a transaction		x	
Mean transfer price	Monthly average IFQ transfer price			x
Independent Variables				
Scallop profit	Monthly average scallop profit per pound	x		
Buyer scallop marginal profit	Buyer scallop profit per pound of last trip prior to lease transaction		x	
Buyer scallop profit	Buyer monthly average scallop profit per pound		x	
Seller scallop profit	Seller monthly average scallop profit per pound		x	
Scallop price	Monthly average scallop price	x	x	
Price of other species	Monthly average price of other species	x	x	
Total scallop revenue	Monthly total scallop revenue	x	x	
Std. of scallop revenue	Standard deviation of monthly total scallop revenue	x		
Total lease value	Monthly total lease value	x		
Total lease quantity	Monthly total lease quantity	x		
Mean lease quantity	Monthly average lease quantity	x		
Lease quantity	Lease quantity of a transaction		x	
Trip cost	Monthly average trip cost	x	x	
Std. of trip cost	Standard deviation of trip cost across permits by month	x		
Number of sellers	Number of sellers by month		x	
Permit bank seller	Seller is in permit bank		x	
Frequent seller	Seller sold more than 20 times in the study period		x	
Buyer vessel gross ton	Buyer vessel gross tons		x	
Buyer quota allocation	Buyer base allocation		x	
Number of permit-bank seller	Number of permit-bank sellers by month	x		
Number of paper-boat sellers	Number of CFP sellers by month	x		
Percent of paper-boat sellers	Percent of paper-boat sellers in the number of trades by month	x		
Trade frequency	Number of trades by month	x		
Percent quota fished	Percent of TAC fished by month in a fishing year	x	x	
Cumulative scallop catch	Cumulative scallop catch in a fishing year	x	x	
Average scallop stock	Average scallop stock associated with all trips	x		
GDP	US quarterly real GDP	x	x	x
T-note rate	10-year treasury note			x
January	Monthly dummy	x	x	x
February	Monthly dummy	x	x	x
March	Monthly dummy	x	x	x
April	Monthly dummy	x	x	x
May	Monthly dummy	x	x	x

Table 1A (*Continued*)

Variable	Description	Lease Market Model	Individual Lease Transaction Model	IFQ Transfer Model
June	Monthly dummy	x	x	x
July	Monthly dummy	x	x	x
August	Monthly dummy	x	x	x
September	Monthly dummy	x	x	x
October	Monthly dummy	x	x	x
November	Monthly dummy	x	x	x
December	Monthly dummy	x	x	x
September	Monthly dummy	x	x	x
Spring	Seasonal dummy	x	x	x
Summer	Seasonal dummy	x	x	x
Fall	Seasonal dummy	x	x	x
Winter	Seasonal dummy	x	x	x
Fishing year 2010	Yearly dummy	x	x	x
Fishing year 2011	Yearly dummy	x	x	x
Fishing year 2012	Yearly dummy	x	x	x
Fishing year 2013	Yearly dummy	x	x	x
Fishing year 2014	Yearly dummy	x	x	x
Fishing year 2015	Yearly dummy	x	x	x
Fishing year	Time trend	x	x	x
CT buyer (seller)	State dummy		x	
DE buyer (seller)	State dummy		x	
MA buyer (seller)	State dummy		x	
MD buyer (seller)	State dummy		x	
ME buyer (seller)	State dummy		x	
NC buyer (seller)	State dummy		x	
NH buyer (seller)	State dummy		x	
NJ buyer (seller)	State dummy		x	
NY buyer (seller)	State dummy		x	
RI buyer (seller)	State dummy		x	
VA buyer (seller)	State dummy		x	

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