PERSPECTIVES

Development of the Pacific Groundfish Trawl IFQ Market

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ABSTRACT

In-season transferability of quota plays an important role in multispecies individual fishing quota (IFQ) systems since fishermen often need to acquire quota to balance incidental catch. The optimal utilization of quotas is thus dependent on development of an efficient quota market, but markets in multispecies IFQ fisheries develop slowly and may fail to perform efficiently even after several years. In 2011 an IFQ system was implemented for the Pacific groundfish trawl fishery in the US. After four years, the quota market does not appear to be yielding efficient prices for many species or distributing quota efficiently. I explore the structure and performance of the QP market and discuss the impediments to market efficiency. Drawing from theory and experience in other multispecies IFQ systems, I discuss other quota distribution and catch-balancing mechanisms that can supplement and perhaps improve inefficient markets and enable higher quota utilization rates.

Key words: IFQ, ITQ, catch shares, quota markets, multispecies fishery.
JEL Codes: Q22, D40, L10.

INTRODUCTION

Individual fishing quota (IFQ) systems promote economic efficiency by substituting simple individual output controls for what had often become a complex, inefficient set of rules governing fishing or a rent-dissipating race-for-fish (e.g., Homans and Wilen 1997). IFQs provide fishermen with incentives and more flexibility to decrease costs and increase the value of landed catch. Most IFQ programs also allow both permanent transfers of quota shares (QS) and leases or transfers of an annual form of quota defined in absolute weight, which I refer to hereafter as "quota pounds" (QP).[1] Transferability offers the means and incentives for catch privileges to move to the fishermen who can produce the most value with them. QP transfers play a particularly important role in multispecies fisheries where individual fishermen may have limited abil-

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1. In New Zealand and the New England sector program the annual form or quota is referred to as "annual catch entitlement" (ACE). In some other US IFQ programs, it is referred to as "quota allocation." In all cases these are functionally similar to leasing the permanent quota share, but the quota pounds are a separable, tradable commodity not directly tied to the quota share once issued.

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ity to control the species composition of their catch and may need to acquire QP during the season to balance portfolios or to cover unexpected catches.

"In mainstream economic theory, the firm and the market are, for the most part, assumed to exist and are not themselves the subject of investigation" (Coase 1984, p. 5). However, efficient QP markets in multispecies IFQ systems are not automatically created when the IFQ is implemented. They mature slowly and, even when mature, may fail to efficiently price or distribute QP (Holland 2013). Efficient markets are generally characterized by large numbers of buyers and sellers and low transactions costs (i.e., a low cost means of matching up buyers and sellers and negotiating fair terms of trade), and they generally require readily available price information to enable prices to converge to efficient levels (Coase 1960; Fama 1970; Liski 2001; Squires et al. 1998; Stavins 1995; Swinkels 1999; Williamson 1985). These characteristics are often absent in multispecies IFQs for which markets are often thin, with few trades and traders, and a lack of publicly available price information (Holland et al. 2015).

Using a case study of an IFQ program implemented in the Pacific groundfish trawl (PGT) fishery in 2011, I explore how the multispecies QP market developed, its apparent failure to price and distribute QP efficiently, and how these failures might be mitigated. I discuss the structure and performance of the QP market in this fishery as well as other mechanisms for distributing QP that have emerged to address perceived market failures or inadequacies. I then discuss alternatives or supplements to markets in other IFQ systems and multispecies fisheries managed with cooperatives. The analysis suggests that markets in multispecies IFQ systems face serious challenges that may require supplementary or alternative mechanisms or institutions for redistributing quota within the fishing year to enable full, efficient use of fishery resources.

THE PACIFIC GROUNDFISH TRAWL FISHERY

The PGT IFQ system includes 30 different quota stocks comprised of both individual species (e.g., sablefish, petrale sole, canary rockfish, etc.) and a number of quota stock aggregates (e.g. "minor slope rockfish" and "other flatfish").[2] Each year QS owners are allocated QP which individuals can use to balance their own catches or can trade or sell. QP must be transferred from a QS account to a vessel account in order to be used to balance catches, and can also be transferred between vessel accounts. The QS itself was not initially transferable, but became so in 2014.

The IFQ program was a major change from the previous management system, which set species quotas on what an individual could land each two-month period but allowed fishermen to continue fishing and discard species for which they had reached their landings limits. IFQ rules require fishermen to balance all IFQ species catch with QP, whether the fish is landed or discarded. The fishery has 100% observer coverage to ensure all catch is accounted for. Fishermen whose catches exceed their QP holdings must acquire QP from other quota holders or cease fishing and potentially face fines. Since fishermen have limited ability to control the species composition of their catch, a well-functioning QP market is essential to enable them to match QP with catches. Transferability of QP also offers the possibility for fisherman to adjust their catch and quota pound portfolios to better fit their business plans. Businesses can now buy and sell QS to adjust

2. The IFQ was implemented for vessels that deliver groundfish to dealers and processing plants on shore. There is also a sector of this fishery that solely targets Pacific whiting with catcher-processors or vessels that deliver to floating processors called motherships. This at-sea sector is managed with cooperatives rather than as part of the IFQ program.

their annual QP allocations, but I focus on the QP market here since QS trading was only allowed as of 2014, and little QS trading took place before 2015.

QS for most species were allocated to fishermen based on catch history, but QS, and consequently QP, for several overfished rockfish species (bocaccio, canary rockfish, cowcod, dark-blotched rockfish, Pacific Ocean perch, widow rockfish, and yelloweye rockfish) and Pacific halibut, were allocated by applying bycatch rates to allocations of target species. Although these species are sometimes referred to as "bycatch," the catch can be and is landed and sold. One exception is Pacific halibut, which is purely a bycatch quota—catch must be counted against QP but the fish must be released. Allocating QS for these species based on bycatch rates was intended to provide everyone with a fair share of quota to cover catch of species that fishermen had generally been asked to avoid in the years leading up to the IFQ. This allocation formula avoided rewarding fishermen that had high bycatch rates during the IFQ qualification years with higher QS allocations. As a result, allocations of QS for these species were broadly distributed, but most fishermen received relatively small allocations. In the most extreme case, the median allocation of yelloweye rockfish QS provided fishermen with only four pounds of QP in 2011.

When the IFQ program was implemented, there was widespread concern that very small total quotas for several overfished rockfish species might constrain catches of other IFQ species. These concerns were due, in part, to worries that overall catches of some bycatch species would exceed available QP, but also that individuals who exceeded their initial allocations would be unable to acquire QP from others who would be holding back their own QP in case they needed it themselves. Catches for many of these "bycatch" species tend to be rare, highly uncertain, and concentrated, creating the potential for mismatches between allocations and catches and the need to redistribute and aggregate dispersed QP holdings (Holland and Jannot 2012). For example, in 2011 only 14 vessels caught any yelloweye rockfish in the IFQ fishery, while QP was dispersed to over 120 vessel owners. Several of the 14 vessels that caught yelloweye exceeded their initial QP allocation, though total yelloweye catch was only 10% of the total QP allocated.

In response to concerns about being constrained by bycatch quotas, a number of fishery participants formed risk pools in which they pooled QP for the overfished rockfish species and Pacific halibut (Holland and Jannot 2012). The risk pools reduce the risk that an individual fisherman will be shut down by an unexpected bycatch event and failure to find anyone to sell them QP. However, to ensure that pool members take due care to avoid bycatch, the risk pools also require members to follow a number of rules designed to reduce bycatch; for example avoiding certain areas with high bycatch risk and moving if bycatch is encountered (Holland and Jannot 2012). Risk pools are not regulated entities, and it is unclear how many fishermen joined them or exactly how they operated. It appears that most fishermen did not join risk pools and were thus reliant on the quota market or personal trading networks to acquire QP to cover deficits.

Total catches of IFQ species during the first four years of the program (2011–2014) were in fact far below the total QP allocated for all but a few species (see table A1 in the web appendix). Catches exceeded 90% of allocated QP for only three stocks (Pacific whiting, petrale sole, and sablefish north of 36° latitude). Catches did not exceed 50% of total QP in aggregate for any of the overfished rockfish species or Pacific halibut.[3] Yelloweye catches were only 10% of QP

3. Catches of widow rockfish reached 66% of total QP in 2014, but the widow rockfish stock was no longer considered overfished at this point and the TAC had been substantially increased, which motivated some people to begin targeting this stock with midwater trawl gear.

in 2011 and only 6% in 2012, 2013, and 2014. For canary rockfish, which was frequently mentioned by fishermen as one of the biggest concerns, catches did not exceed 28% of total QP between 2011 and 2014.[4] Although aggregate catches have been far below QP, catches tend to be very uneven, so some individuals have caught more than the QP they were originally allocated and had to acquire additional QP. Anecdotal reports indicate that many other fishermen may have opted not to pursue certain species in shallower "shelf" areas[5] because of the risk of exhausting QP allocations for species like yelloweye and canary rockfish, which are more prevalent on the shelf, forcing them to tie up if they could not find QP on the market. This suggests a failure of the market to distribute QP effectively and a lack of confidence in the QP market as a source of QP should an individual need to acquire more. My analysis can neither confirm nor dispute this hypothesis explicitly, but I do present evidence that suggests the market is highly complex and was arguably inefficient during its first four years of operation.

THE QP MARKET

When the PGFT IFQ was implemented, the National Marine Fisheries Service (NMFS) provided a publicly available listing of IFQ permit holders and their QS and QP holdings (https://www.webapps.nwfsc.noaa.gov/ifq/) and a web-based system to implement transfers of QP between permit holders. This provided a relatively simple, efficient means to transfer QP and some information on who might have QP to sell, but it did not automatically create a functional, efficient QP market. That market is developing organically as quota holders, fishermen, and intermediaries develop trading relationships.

Since all QP transfers must be done through the online system operated by NMFS, I was able to analyse the full population of QP transfers. When making QP transfers through this system, the account holder making the transfer must indicate, along with the quantities of QP to be transferred, whether the transfer is a "self-trade" (meant to indicate a transfer within a company), a "cash sale," "barter," "cash and barter," or "other." Barter indicates swaps of QP of different quota stocks (e.g., 1,000 pounds of petrale sole QP for 200 pounds of canary rockfish QP).

The great majority of QP transfers made are identified as "self-trades" (table 1). This is not surprizing since QP must be transferred from QS accounts to vessel accounts to be used to balance catch, and some QS owners have multiple vessel accounts and move QP between them. If we consider only what appear to be arm's-length transfers (transferred not identified as self-trades), the most frequent transfer designation is "other." Optional descriptions that were provided with some of these transactions suggest that "other" includes transfers made within risk pools and cooperatives; contractual arrangements where payment is a share of revenue when fish is landed; and various miscellaneous reasons like gifts, corrections to prior transfers, bycatch QP to go along with a separate sale of target species QP, etc.

Cash sales include both single and multispecies transfers. Although the transferor is asked to provide a price per pound for each individual species in the multispecies trade, this is not required and is rarely filled out. The overall value of the sale must be indicated though a value of zero can be entered; and this provides a way to calculate price per pound for single-species

4. In 2015 some fishermen began to target yellowtail rockfish with midwater trawl gear, and at least one vessel encountered substantial bycatch of canary rockfish resulting in nearly complete use of all canary QP.

5. The groundfish trawl fishery consists of shallower shelf areas up to about 150 fathoms and deeper slope areas. The two are divided by rockfish conservation areas (RCAs) that close roughly the 100–150 fathom isobaths the length of the US Pacific Coast. RCAs are designed to provide protection to the overfished rockfish species.

Table 1. Transfer Count by Type, Year, and Single vs. Multispecies Transfers (with multispecies transfers counted as one transfer)

	2011		2012		2013		2014	
Transfer Type	Single	Multi	Single	Multi	Single	Multi	Single	Multi
Cash sale	281	96	340	67	384	63	411	62
Barter	221	64	275	48	262	35	191	37
Cash and barter	22	11	37	11	48	12	31	9
Other	395	196	606	260	663	400	596	360
Self-trade	410	394	512	308	641	327	528	326
Total	2,090		2,464		2,835		2,551	

transfers. An overall value other than zero is, in fact, provided on most transfers designated as cash sales. Although single-species transactions outnumber multispecies transactions, most multispecies cash transactions include many species (over 10, on average). Multispecies transactions provide a means to transfer balanced portfolios more easily and with more certainty than trying to build or sell a portfolio through individual transactions. As such they may serve to reduce transactions costs, but they also make price discovery difficult and may lead to inefficient pricing, as was found in the British Columbia groundfish IFQ (Holland 2013). The number of single species cash sales increased each year during the first four years of the program, from 281 in 2011 to 411 in 2014, while the number of multispecies cash sales declined (table 1). However, for many quota stocks, there are still only a handful of single-species cash sales each year (table A2 in the web appendix).

A substantial proportion of transfers is labelled as barter. The choice between barter and cash sales appears to be somewhat dependent on whether the parties have some existing social or business relationships. If we consider only "market" transfers (those identified as either barter, cash, or cash and barter), there is a clear preference for using barter over cash sales as the mechanism of trade when the parties both own vessels that sell fish to the same processor (figure 1). In

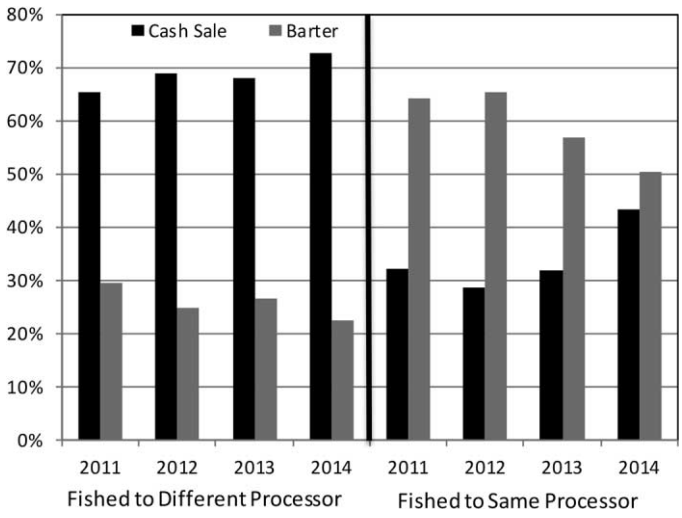

Figure 1. Percent of Annual Cash and/or Barter Transfers that were Cash Sales vs. Barter Depending on whether the Parties Involved Landed Fish to the Same Processor or Not

contrast, cash sales are preferred for parties that don't sell fish to the same processor. For these, 67% of market transfers are cash sales and 28% are barter, while for parties that do sell fish to the same processor, only 28% are cash sales and 64% are barters.

QP PRICES

Although cash sales comprised of only a single species make up only a fraction of QP transfers, they are the only means by which QP prices can be estimated given the amount of market activity to date. In principle, species-specific implicit prices for QP might be estimated from multispecies QP cash sales using a hedonic framework, and implicit relative values for barter data might be revealed by a modified hedonic model (Holland 2013). However, there has not been a sufficient number of multispecies cash sales to estimate a hedonic model with reliable prices. Hedonic models estimated with combined single-species and multispecies cash sale data yield prices nearly identical to the averages from single-species trades when the appropriate weighted least squares estimation model is used,[6] and price estimates are not statistically significant (and many appear unrealistic) for species that did not have single-species cash sales.

For cash sales that only included a single species, I calculate annual prices (table 2). To maintain confidentiality, prices are shown only when they represent transfers from at least three unique buyer-seller combinations. Thus for some of the more rarely traded species, it is not possible to present prices. The number of IFQ stocks with reportable prices increased from 12 in 2011 to 19 in 2013, but fell to 15 in 2014. The number with at least 10 priced cash transfers increased from just 5 stocks in 2011 to 13 in 2014. Thus there are signs that activity in the cash market for QP and the availability and reliability of price information is increasing. However, the market is still quite thin for most species.

Since NMFS has not published prices from QP sales and would likely not be able to do so for most species until well into the year (due to the small number of trades and confidentiality issues), the only publicly available means of price discovery for QP prices to date is auction closing prices from Jefferson Trading (http://jeffersonstatetradingco.com). Jefferson Trading has been running timed auctions for QP since the IFQ program's inception and has been posting closing prices. The entire history of auction closing prices can be downloaded from their website. Average prices from Jefferson Trading differ, in some cases substantially, from the average of NMFS prices (table A3 web appendix). The discrepancies presumably reflect transfers reported to NMFS that were not arranged through Jefferson Trading. Differences may also reflect some transfers facilitated by Jefferson Trading for which prices were not reported or were misreported to NMFS. For the more frequently traded IFQ stocks, Jefferson Trading average prices are mostly within 20% of NMFS average prices, suggesting that they provide a reasonable means of price discovery for the wider cash sale market.

It is not clear how many trades would be required to produce meaningful price estimates that are representative of value. Price dispersion provides one measure of price reliability and market efficiency. Newell, Sanchirico, and Kerr (2005) suggest that the price dispersion of 25–35% observed in the New Zealand quota lease[7] market is "reasonable" when compared to price disper-

6. Holland (2013) undertook a Monte Carlo analysis that demonstrated that bias in price estimates from a hedonic price model from multispecies QP sales could be mostly eliminated with a weighted least squares estimator using weights equal to one over the sum of the squared quantities in the trade.

7. Leasing quota is essentially the same as selling QP.

Table 2. Simple Average Annual Prices for Single-species Cash Sales Reported to the National Marine Fisheries Service and Average Pounds Transferred by Quota Stock

	Price Per Pound (Dollars)				Average Pounds
Quota Stock	2011	2012	2013	2014	Transferred
Arrowtooth flounder			0.01	0.01	49,059
Bocaccio rockfish S. of 40°10′ N.			0.22		1,449
Canary rockfish		1.83	3.43	2.30	300
Chilipepper rockfish S. of 40°10′ N.		0.03	0.02		23,163
Cowcod S. of 40°10′ N.					13
Darkblotched rockfish	0.36	0.44	0.74	1.17	1,947
Dover sole	0.05		0.00		118,385
English sole					–
Lingcod		0.05			11,221
Lingcod N. of 40°10′ N.					16,123
Lingcod S. of 40°10′ N.					–
Longspine thornyheads N. of 34°27′ N.	0.05	0.06	0.05	0.08	15,004
Minor shelf rockfish N. of 40°10′ N.					3,246
Minor slope rockfish N. of 40°10′ N.		0.04	0.03	0.02	10,231
Minor shelf rockfish S. of 40°10′ N.			0.04		5,476
Minor slope rockfish S. of 40°10′ N.	0.07	0.03			8,286
Other flatfish					63,881
Pacific cod	0.05	0.03			25,791
Pacific halibut (IBQ) N. of 40°10′ N.	1.42	1.11	1.73	1.05	1,007
Pacific ocean perch N. of 40°10′ N.			0.89	1.14	1,073
Pacific whiting	0.02	0.04	0.04	0.04	179,150
Petrale sole	0.34	0.40	0.27	0.29	10,448
Sablefish N. of 36° N.	1.09	0.96	0.86	1.05	10,303
Sablefish S. of 36° N.	0.84	1.00	0.26	0.16	6,922
Shortspine thornyheads N. of 34°27′ N.		0.06	0.05	0.06	11,090
Shortspine thornyheads S. of 34°27′ N.	0.15				788
Splitnose rockfish S. of 40°10′ N.					16,500
Starry flounder					–
Widow rockfish	0.46	0.43	0.70	0.26	6,933
Yelloweye rockfish		21.15	32.64	26.96	10
Yellowtail rockfish N. of 40°10′ N.		0.01	0.03	0.02	28,301

sion in commonplace commodities. Price dispersion for QP sales in the PGT IFQ is somewhat higher. For several species, price dispersion declined over the 2011–2014 period, but this is not the case for all species. If we consider stocks that had at least two buyers and two sellers in a given year, price dispersion averaged across stocks fell from 61% in 2011 to 44% in 2012. It fell again slightly to 42% in 2013 but increased to 45% in 2014. There is a weak, but statistically significant, relationship between the number of transfers for a stock in a year and price dispersion (see table A4 in web appendix). This fitted linear relationship predicts that price dispersion would fall from 53% with 5 trades to 33% with 50 trades and 12% with 100 trades.

A decline in price dispersion may be an indicator that the market is becoming more efficient (the law of one price prevailing); however, high price dispersion may also be the result of changes in prices over the year. Presumably prices are a function of derived demand (associated with the net value of the catch enabled by the QP), but also a function of supply relative to demand. For a target species like sablefish, petrale sole, or whiting, for which QP is mostly utilized, we might

expect prices to reflect average or marginal profits associated with catches. However, prices may decline toward the end of the year if it looks like there will be more QP left unutilized than can be carried over (each vessel account can carry over as much as 10% of its QP by species). QP prices might also change, however, if ex-vessel prices unexpectedly changed during the year. This could result in either increased or decreased QP prices, but either way it would contribute to higher price dispersion which cannot really be ascribed to inefficient pricing by the market except to the extent that the market was not able to anticipate the catch relative to total QP. For most species, there are not enough transfers to calculate more than annual prices, but for a few of the more frequently trade species I can calculate at least semi-annual prices (see table A5 in web appendix). For the Northern sablefish stock, QP prices were lower in the second half of the year than the first, and most of the cash sales also occurred then. The same is true for petrale sole in 2013 and 2014, but there was no difference in prices between the first and second half of 2012 for petrale sole, and prices were higher in the second half of 2011.

One thing that is seemingly in conflict with efficient market pricing is that QP prices comprise a significant proportion of ex-vessel prices for some species for which there is substantial unused QP available at year end (see tables A6 and A7 in web appendix). In fact, for canary rockfish, darkblotched rockfish, Pacific Ocean perch, widow rockfish, and yelloweye rockfish, QP prices are well above ex-vessel prices despite that fact that only a fraction of total QP was used in any year. These species are the overfished rockfish "bycatch" species that fishermen had been concerned might constrain catch of target species. The ratio of QP prices to ex-vessel prices is most extreme for yelloweye rockfish for which average QP prices have been 35 to 58 times the ex-vessel price, despite the fact that catches totalled only 6% of total QP. Canary rockfish QP sold for over 6 times ex-vessel price in 2013 when catch totalled only 26% of total QP. For Pacific halibut, which has a zero ex-vessel value (since it cannot be retained), average QP prices ranged from $1.11 to $1.73 over the 2011–2014 period, though catches did not exceed 43% of the total QP available.

If there is substantial excess supply of QP, we might expect QP prices to fall, particularly after surpluses persist for a few years. In the case of yelloweye rockfish, the high prices may really reflect transactions costs. Individual transfers are very small (averaging only 8 pounds), and total transfer values are not large, so the high cost per pound may reflect distribution of the transactions costs over a small number of pounds. This explanation is less likely for canary rockfish for which transfers averaged over 245 pounds and even less so for darkblotched rockfish, Pacific halibut, Pacific Ocean perch, and widow rockfish, for which average transfers exceeded 1,000 pounds. Whether or not these high prices can be attributed to transactions costs, they suggest inefficiency in the QP market since some individuals are paying substantial amounts for QP while others are simply leaving QP unused.

DISCUSSION

The role of an efficient QP market is at least three-fold. First, it serves to allocate QP to its highest value use (or at least to those who value it most). Second, it influences behavior. For example, prices for QP should encourage efficient use and discipline inefficient use of QP. In a multispecies fishery, QP prices, through the out-of-pocket cost or opportunity cost of QP, should induce fishermen to avoid constraining fish stocks for which QP prices should rise. A third important role of QP markets is to provide information to fishing businesses, fishery managers, and other stakeholders to support business planning and policy decisions (Newell, Papps, and Sanchirico

2007). The prices generated by QP markets also provide information to QP market participants on how to set prices in subsequent transactions.

The extent to which the distribution that occurs through the QP market maximizes value, provides the correct behavioral incentives, and provides useful, interpretable information, depends on whether the market is operating efficiently. A well-functioning market makes it possible for transacting parties to find each other, determine mutually acceptable quantities of the commodity to trade, negotiate compensation, and carry out the transaction with confidence. An efficient market also implies that the process of carrying out these transactions is easy and inexpensive; e.g., with minimal transactions costs.[8] Furthermore, we would expect prices in an efficient market to reflect the marginal value of the commodity and that prices would be fairly homogeneous, at least at a given point in time.[9]

An effective, efficient QP market is not automatically created when an IFQ system is implemented, even if an efficient mechanism for implementing transfers is. IFQ markets, particularly in multispecies fisheries with many jointly caught species, pose a number of challenges. Therefore, it is perhaps not surprising that an efficient market does not quickly emerge. The value of QP is a function of the value that can be produced with it (derived demand) rather than a direct consumption or resale value (Squires et al. 1998). Furthermore, that value is generally uncertain until the fish is actually landed and sold, and there may also be substantial heterogeneity in the value of QP to different fishermen. In multispecies fisheries the value of QP for one species is likely to be partly a function of holdings of QP of other species since a portfolio of QP is needed to balance catch from mixed tows of species, and control over species composition is imperfect. Even if a fisherman has a good idea of his overall QP needs, it may be difficult to determine what he should pay for QP of a given species and how much he should buy, unless he can simultaneously purchase the desired quantities of the other species in the portfolio at acceptable prices. When there are relatively few buyer and sellers, limited information on who has QP to sell, and substantial heterogeneity in derived values, it is not surprising that transactions costs remain high. This, in turn, drives fishermen to alternative trade mechanisms, such as barter and risk pools, that reduce risk but also inhibit the development of an efficient spot market for QP.

There are a number of indicators that suggest the QP market for PGT IFQ did not operate efficiently during its first four years of operation. Price dispersion is relatively high. The market is thin, particularly for species that are not primary targets. High prices for QP of some species with substantial unused QP in aggregate indicate high transactions costs or a failure to match up those with unused QP to those who could use it. Anecdotal evidence suggests this is occurring as a result of "hoarding" driven by the combination of uncertainty about individual QP needs and a lack of confidence that one could acquire QP on the market at a foreseeable, reasonable price should it be needed unexpectedly.

As my analysis shows, the forms of compensation used in inter-firm QP transactions are quite diverse, and transfers are not dominated by cash sales with individual prices for each species. Rather barter and contractual arrangements, including risk pools, are common. Given that

8. Dahlman (1979) described transactions costs as "search and information costs, bargaining and decision costs, and policing and enforcement costs."

9. Assuming prices reflect willingness to pay and thus the implicit value of the QP, a lack of price homogeneity for a commodity that is identical suggests that overall benefits would have been increased if more QP had gone to the individual who paid a higher price and less to the one who paid less. Alternatively, if prices do not reflect willingness to pay they are not sending the right signals to sellers who thus may be offering to little or too much for sale.

QP of a given species is a straightforward, non-differentiable commodity, we might expect to see a higher prevalence of cash sales, and the lack thereof may suggest an inefficient market. However, these transaction methods may be largely a product of uncertainty about the value and availability of QP and the associated risk. Value depends on whether the QP will actually be needed to balance catch, the cost of harvesting the fish, and the price received for it. A contractual arrangement (e.g., for a percentage of the value of the landed fish) shares the risk between the buyer and seller, and, if the seller is the buyer of the fish, she may be in a better position to bear some of that risk. Barter enables individuals to trade less-valued QP for more-valued QP without having to put cash up front, which may be difficult and risky financially for an individual fisherman. Multispecies cash sales or barter, though potentially less efficient in pricing particular species, may enable fishermen to acquire a balanced portfolio of QP and reduce market transaction risk—the undesired movement of prices as one is trading to form a portfolio (Ishikida et al. 2001). The formation of risk pools indicates a lack of confidence that QP needs for incidental catch can be met through the QP market. There are indications that market efficiency is increasing slowly, but the market may take many years to mature and may never become fully efficient.

Economists tend to trust that competitive markets are the most efficient means of distributing scarce resources (e.g., QP), but this may not be the case when these markets are inherently thin and must distribute multiple goods with jointly determined, highly uncertain demand and values. The centralized decision making of a large firm (whether an owner of multiple vessels or a processor that owns or buys and distributes QP to the vessels that deliver fish to it) that can harness disparate information and/or mitigate risk associated with uncertainty may actually be able to do a better job of maximizing value in some cases. It is notable that in mature multispecies IFQ systems in New Zealand, Iceland, and British Columbia, much of the QS has been acquired by large firms, often processors or vertically integrated firms with processing and harvesting capacity. Part of the reason for this is undoubtedly to increase their ability to build stable markets for their products by gaining control of what fish is landed when, but these firms are also able to move QP around to the vessels that sell fish to them to ensure QP is used efficiently and as fully as possible.

In the PGT IFQ, low QS aggregation limits that are deliberately intended to preserve the historical, small-firm structure of fleet ownership, may constrain the ability of larger firms (or processors) to acquire a large enough share of QS to support multiple vessels. Given these constraints, cooperatives and risk pools may play a similar role to firms in facilitating redistribution of QP to promote more efficient, fuller utilization. In the New England groundfish fishery, a catch share system was implemented with annual catch entitlements (ACE) allocated to cooperatives called "sectors" rather than individual vessels. Sectors distribute ACE to individual vessels, but sector managers can broker trades (redistributions) among vessels within sectors as well as trades with other sectors. In the British Columbia groundfish IFQ, vessels not affiliated with processors tend to address imbalance of catch and quota through barter at trade ratios that suggest nominal values not reflective of the scarcity of QP for constraining species – essentially an informal risk pool (Holland 2013). As noted earlier, in the PGT IFQ, some vessels have joined risk pools that pool quota for bycatch species (Holland and Jannot 2012).

There may be things that regulators can do to facilitate development of an efficient QP market and to nurture, or at least not undermine, other mechanisms for distributing QP in the fishery. First, regulators can make as much price information as possible available in a timely, easily

accessible manner. Confidentiality rules may limit this to some degree, and not providing confidentiality might be counterproductive if it undermines full and honest price reporting. However, it should be possible to provide and regularly update prices once a threshold of three unique parties is reached. Aggregation limits that, at face value, appear to be designed to make the market more competitive may actually constrain useful distribution mechanisms (e.g., risk pools and cooperatives), though they may also be necessary to avoid abuses of market power.

Most multispecies IFQ fisheries include a number of catch-balancing mechanisms that provide flexibility and thereby reduce the uncertainty and risk fishermen face if their catches turn out to be different than expected (Sanchirico et al. 2006; Squires et al. 1998). The provisions that allow carry-forward of 10% of QP in the PGT IFQ are an example of this, though they are less flexible than some other IFQ systems (e.g., vessels in British Columbia can carry forward or back up to 30% of QP). Iceland allows conversion of QP from one species to another to cover QP deficits, and this is also allowed for some species in the Gulf of Mexico grouper and tilefish IFQ (Holland et al. 2015). New Zealand allows individuals to land catch for which they don't hold QP and pay a "deemed value" in lieu of balancing in with QP. The deemed value can be refunded through the end of the year if the individual acquires QP to balance that catch. Deemed values effectively provide fishermen with a known maximum price for QP and also provide some guidance for the market (i.e., an upper bound for price). The PGT fishery is highly complex and has relatively rigid catch balancing rules that make an efficient market doubly important, but may also undermine its development. While it may not be desirable or legal under US law to implement some approaches used in other countries,[10] it may be possible to increase flexibility. For example, regulators could operate a limited deemed value scheme, perhaps designed primarily to give individuals time to acquire QP on the market without being forced to stop fishing.[11] Fishermen might also simply be given more time to balance QP deficits before being forced to stop fishing. Multi-year TACs and QP allocations could also facilitate catch balancing and reduce the risk of fishermen experiencing QP deficits by allowing catch balancing over a longer periods and thus more trips and tows.

The challenges of creating effective IFQ markets, and the likelihood that these markets will remain inefficient, should not necessarily be seen as a critique of IFQs or a call to consider other management approaches. But it is important for fishery managers to pay closer attention to how these markets are structured and what impedes their efficient operation. Some of these impediments may be reduced or removed by better system design.

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10. The New Zealand deemed value system, the Icelandic quota conversion system, and the BC groundfish 30% carryback, all can enable aggregate catch to exceed the TAC in a given year, which appears to be contrary to provisions of the US Magnuson-Stevens Act.

11. This might be accomplished by setting very high deemed values that would incentivize fishermen to look for QP on the market and then seek a refund of QP, thereby limiting the net use of deemed value to balance catch and the pool of QP required to support the system.

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