Supply chains and markets for red snapper

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by

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Executive summary

Since the introduction of catch shares in 2007 the market not only for red snapper, but all snapper species in the U.S. has changed dramatically. The catch share program immediately led to the harvesting season being extended from about two months to become a yearlong fishery. This led to red snapper partly being shifted to other supply chains and a significant increase in demand as both price and quantity has increased. It also reduced supply chain cost as price volatility was strongly reduced.

Currently, whole gutted snapper is sold at a retail price of about $10/pound (or $22/kg) at coastal fish mongers and higher further removed from the landing locations. This is the value that is spread in the supply chain from the fisher via transportation and logistics firms to the final seller for an unprocessed fish. Virtually all domestic red snapper is sold as fresh, with a price increase to between $25 and $35/pound when filleted. The price increase is primarily due to the weight loss, but there is also some contribution to GDP due to the labor and capital involved in the processing.

Red snapper is not a market in itself, as there are significant imports of fresh and frozen snapper (not segmented by species) and domestic landings of other snapper species. The competition in the snapper market was investigated by estimating an inverse demand system with five species: red snapper, vermillion snapper, other domestic snappers, imported fresh snapper and imported frozen snapper, as well as conducting a market integration analysis for the same data series. An important feature of the market is that total quantity as well as the red snapper quantity has increase significantly since 2007, as have real prices (and therefore the market value). This suggest a strong increase in demand.

The demand system indicates that demand for all snapper species are inflexible, indicating elastic demand. There is no shift in the demand between the different snapper species with the introduction of the catch shares, and the increased demand appears to be fully explained by increased scale in the market. However, while the demand flexibilities for snapper imports do not change, the price flexibility for red snapper increases significantly after 2007 making the demand less price sensitive. Assuming everything else constant, this change in the price elasticity for red snapper reduced the price reduction that otherwise would be expected with the increased quantities by between $1.36 and $1.64/pound.

The market integration analysis indicates that all species compete in the same market. However, vermillion and other domestic snappers are imperfect substitutes as the Law of One Price (LOP) is rejected, while this hypothesis cannot be rejected for the relationship between red snapper and the other two imported categories. Hence, the prices indicate that imports of snapper are dominated by red snapper. None of the prices are exogenous. Still, the importance of the red snapper can be seen by the fact that not only do all the prices have similar trends, but the volatility of the other prices is reduced to a similar degree as for red snapper after the introduction of the catch shares.

Given that only imported snappers, fresh and frozen, are fully integrated with red snapper, the hypothesis that the catch share program led to an increase in the price of red snapper was

tested relatively to the two import prices. In both cases, the hypothesis that the catch share program had no effects on the price relationship can be rejected, and in both cases the regressions indicate that the dockside price for red snapper increased by about 12% relatively to the import price or $0.35/pound. This comes on top of a 40% premium for domestic red snapper before the IFQ program, giving the domestic red snapper a premium of about $1.54/pond on average.

This welfare effect of the increased flexibility as well as the price premium over imports are indications that domestic red snapper has significant value to U.S. consumers beyond imported snappers generated down-streams in the supply chain. This fits with the larger literature that show that a number of attributes influence a product's value even in a well-integrated market. Such attributes include physical attributes such as fresh and credence attributes like fished in the U.S. While it is outside of the scope of this project to investigate the specific attributes, it clearly indicates that domestic red snapper has value beyond the quota value, the remuneration to labor on the vessels as well as in the supply chain and the return on capital for the same firms.

1. Introduction

Red snapper is the most important finfish species in the Gulf of Mexico, being the most valuable in terms of landing value and also one of the most sought after species for recreational fishers. When assessing the benefits of the commercial fisheries, common practice has been to assume that consumer benefits are relatively minor and virtually no consideration has been given to post-harvest benefits, largely because of the low US tariffs on imported seafood and a high import share makes an assumption of perfect substitutability reasonable, and partly because efficient labor and capital markets do not lock fishers and into snapper fishing. As a consequence, Agar and Carter (2014) use the quota value, and only quota value, as an estimate of the total economic benefits due to commercial snapper fishing. While this is obviously an underestimate, lack of data makes it very hard to document additional values.[1]

This report will try to shed light on some values in the supply chain based on commercial red snapper. Potential values in the fishery before the landings price will not be addressed. However, it is worthwhile to note that there exist a significant literature showing that there are a number of benefits associated with being a fisher or being on the water beyond monetary compensation (Pollnac et al., 2015; Seara et al., 2017). Hence, it is clear that also in this part of the supply chain there is value generated. The increase in the length of the harvest season (Agar et al., 2014) and the increased efficiency of the fleet (Solís et al., 2014) are clear indications that such effects are present. Moreover, as the fisheries are important in many coastal communities, there are also most likely values associated with the provision of services to the fleet and the fishers (Anderson et al., 2015).

As it is for all practical purposes is impossible to obtain data on retail prices and end user prices and the costs associated with input factors at various stages in the supply chain, the main focus will be on characterizing the market to obtain indicators that signifies values. Personal observation and interviews with industry representatives indicate that during the last year gutted red snapper retails for about $10/pound (or $22/kg) at coastal fish mongers and higher prices further removed -from the landing spots. This indicates basically a doubling of the value of the fish from the dock to the retailer. The price further increases to between $25 and $35/pound when filleted. Moreover, seafood is one of the food categories where the largest share takes place at a restaurant. NOAA (2018) reports that 68% of expenditures on seafood takes place away from home. It is very hard to estimate the contribution of the seafood to the value of a restaurant meal, but it is clear that the seafood is important. While one part of the price increase as one move down stream in the supply chain is the weight loss due to trimmings and cut-offs, value is also created.

The assumption that there is limited post-harvest value associated with domestic red snapper is also questionable. It is true that there are global markets for most seafood species (Anderson et al., 2018), and it will be shown in this report that this type of price determination process characterizes also the U.S. snapper market in that imported and domestic snappers are close substitutes. However, there is a large literature for foods in general showing that even in integrated markets, specific product attributes have value (Onozaka and McFadden, 2011). Such attributes include quality characteristics such as

[1] It is of interest to note though that Agar and Carter (2014) take a very conservative approach for commercial fishing, they implicitly are assuming that there are no costs for the input factors and no alternatives when assigning values to recreational fishing.

freshness and credence attributes such as origin. A typical consequence of IFQs is better handling and therefore improved quality (Homans and Wilen, 2005). Agar et al (2014) indicate that red snapper prices indeed did increase as season was extended following the introduction of IFQs, and vessels where also more efficiently used with longer trips. Moreover, there is a large literature that establish that origin U.S. have value for seafood (Garlock et al., 2020). Hence, both these factors provide avenues where there is increased value associated with domestic U.S. red snapper compared to imports.

This report will first use the basic data sets to characterize the U.S. snapper market. This will be followed by a market integration analysis, a demand analysis and a test for whether the introduction of the IFQs increased the margin between domestic and imported red snapper.

2. Snappers: U.S. Supply

Red snapper is a dominant species in the Gulf of Mexico reef fish complex and its stocks support substantial commercial and recreational fisheries in the Gulf of Mexico. Historically, the Gulf red snapper fishery was overfished and the commercial fishery sector suffered from overcapacity, short seasons and a race to fish. In 2007, an individual fishing quota (IFQ) program was implemented and thus far has been successful in reducing capacity and extending the season to a year-round fishery (GMFMC 2013; Agar et al. 2014). Immediately following implementation of the IFQ program there was a decline in total landings, but by 2009 landings had already began to increase and have steadily increased since then, indicating a recovering stock. In 2017, 3.039 mt of red snapper was commercially harvested, nearly double the commercial harvest in 2007. Still, high demand and high market value has motivated research on red snapper aquaculture which is still in the experimental phase. A major constraint to production has been challenges associated with feeding of early larval stages.

Essentially all red snapper commercially landed in the US is from the Gulf of Mexico. Landings of red snapper peaked around 6.0 mt in the mid-1960s before steadily declining until the early 1990s. During this time, about half of the red snapper catch was landed in Florida, but Louisiana and Texas quickly became important landing sites for Gulf red snapper in the 1990s as landings in Florida declined (Figure 2.1). In the late 1990s, the share of red snapper landed in Louisiana began to decline and the share in Florida began to rebound and these trends continued following implementation of the IFQ program in 2007. By 2017, 38 percent of Gulf red snapper was landed in Florida, 33% in Texas and 23% in Louisiana.

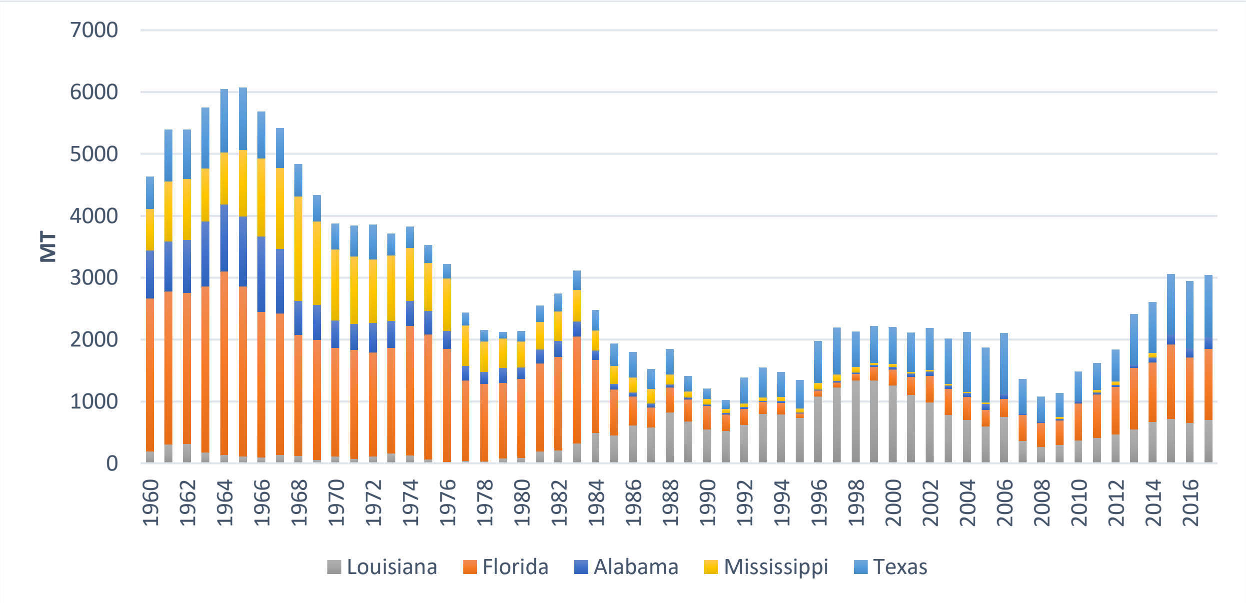

Figure 2.1. Commercial red snapper landings by Gulf state

However, at least from a market perspective the snapper complex also consists of two other important components; other domestic snappers and imports. Total U.S. supply is shown in Figure 2.2. The by far most important source is imports with fresh imports as the main category with 54.5% of the quantity in 2016. Frozen imports add another 25.5% to the supply so that imports made up 80% of the quantity in 2016. With 11.5% of the supply red snapper is the most important U.S. species. Hence, other snappers made up 8.5% of total supply in

2016. Because of their limited quantities only one of these species will be considered explicitly in this analysis, vermilion snapper, while the reminder snappers will be aggregated into an other category. In 2016, vermilion snapper made up 3.3% of the total supply.

Figure 2.2 tells a similar story to the quantity development for red snapper from 1992. The most important characteristic is a strong increase in available quantity, as this has increased from about 10 million tons to over 25 million tons. With the dominating role of the imports, most of the increase is due to increased imports. It is also worthwhile to note that frozen imports was not very important in the early 1990s, and did not really pick up until the turn of the century.

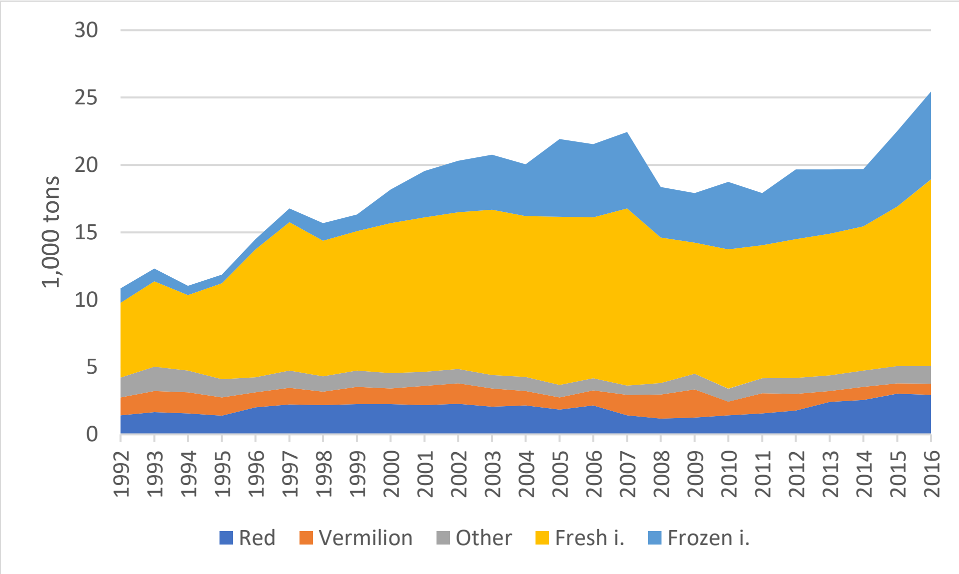

Figure 2.2. U.S. supply of snappers

Specific red snapper import data are not available, but rather aggregated with other species in the genus Lutjanus. However, as will be shown in the market integration analysis, most imports in chapter 3, most imports appear to be red snapper. Mexico is the largest exporter of snapper to the US, making up 25% of U.S. import volume, and is followed by Brazil (21%), Nicaragua (13%) and Panama (13%) (Figure 2.3). Interestingly, more than 90% of snapper imports from Mexico, Nicaragua and Panama are fresh, whereas only 15% of imports from Brazil are fresh. Frozen also dominates the imports from Indonesia and is important from Suriname suggesting that the increase in frozen imports after the turn of the century is largely due to snappers being imported from countries further away.

In Figure 2.4, real import values are shown in 2016 $. The U.S. supply is somewhat more important here. The red snapper share is 15.7% and the import share is down to 76.1%. This suggest that U.S. snapper fetch a higher price than imported snapper. This is confirmed in Figure 2.5 where real unit prices are shown. Domestic red snapper is clearly the highest priced snapper, and fetched $2.64 more than imported fresh snapper in 2016. It is also notable how the other domestic snappers had a similar price level to red snapper in the 1990s, but declined down to the level of imported fresh snapper in the 2000s. In fact, their inflation adjusted prices are basically the same as they were in 1990. Finally, the prices have increased significantly in the last half of the sample, indicating why real values have increased more then the quantity supplied.

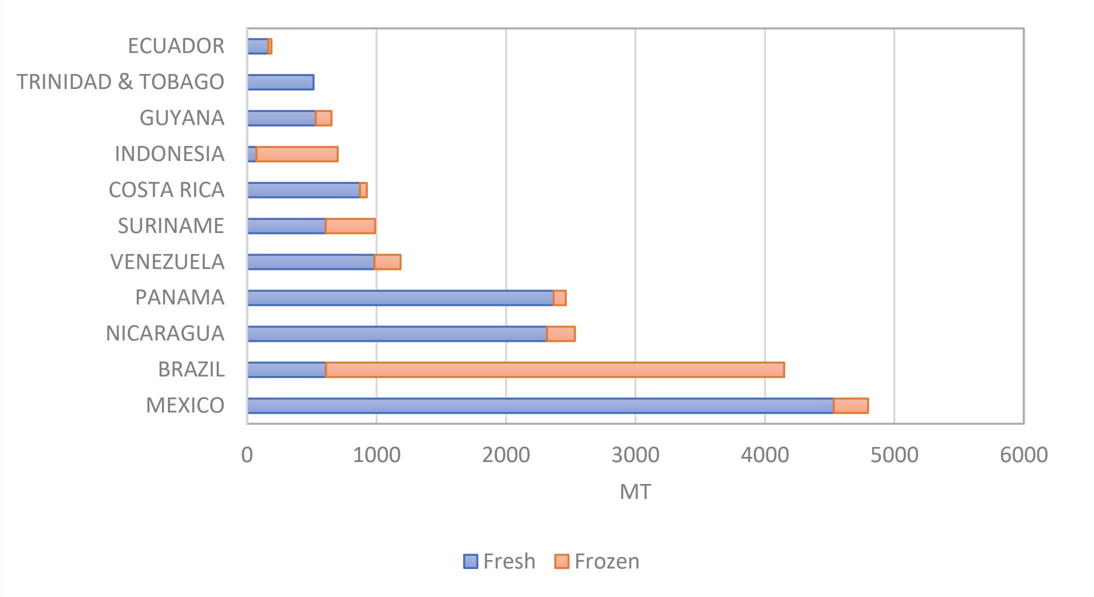

Figure 2.3 U.S. imports of snapper by country of origin in 2018

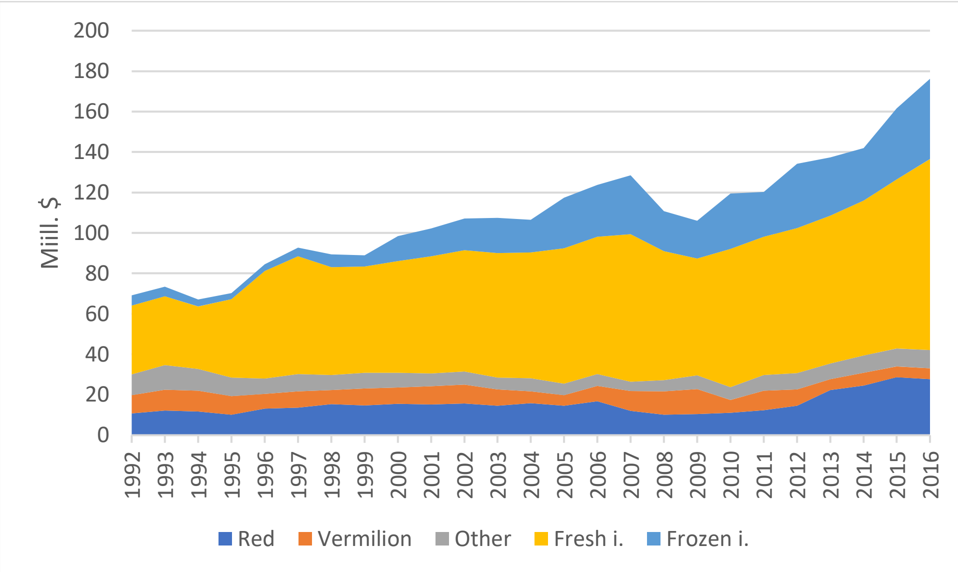

Figure 2.4 U.S. supply of snappers, real value (2016=1)

The observation that total quantity and price is increasing simultaneously is important, as this indicates the demand is increasing, i.e. the demand schedule is shifting to the right. This can be due both to economic factors such as increased expenditure on snappers or exogenous shifts such as stronger preferences (Brækkan et al., 2018). This will be further investigated in the demand analysis chapter.

While the annual data gives important insights, the most important impact of IFQ programs tend to be observed in data with higher frequency. As the race to fish is stopped, the harvest season tends to be extended (Birkenbach et al., 2017). Figure 2.7 show monthly landings and prices for red snapper. The impacts of the catch shares are obvious in that within year volatility in landed quantities is significantly reduced. Moreover, before the catch shares were introduced, there were several months every year with very low or zero landings. Since the main interest in this work is long run trends, to avoid the statistical challenges zero observations cause and the interpretational challenges of very thin quantities, the data used will be aggregated to a quarterly frequency.

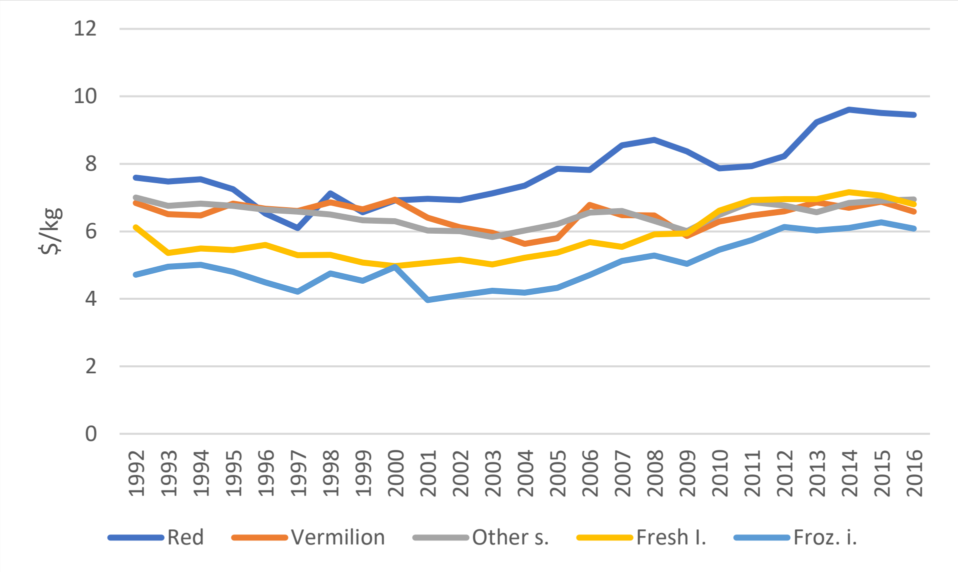

Figure 2.5 Real snapper prices (2016=1)

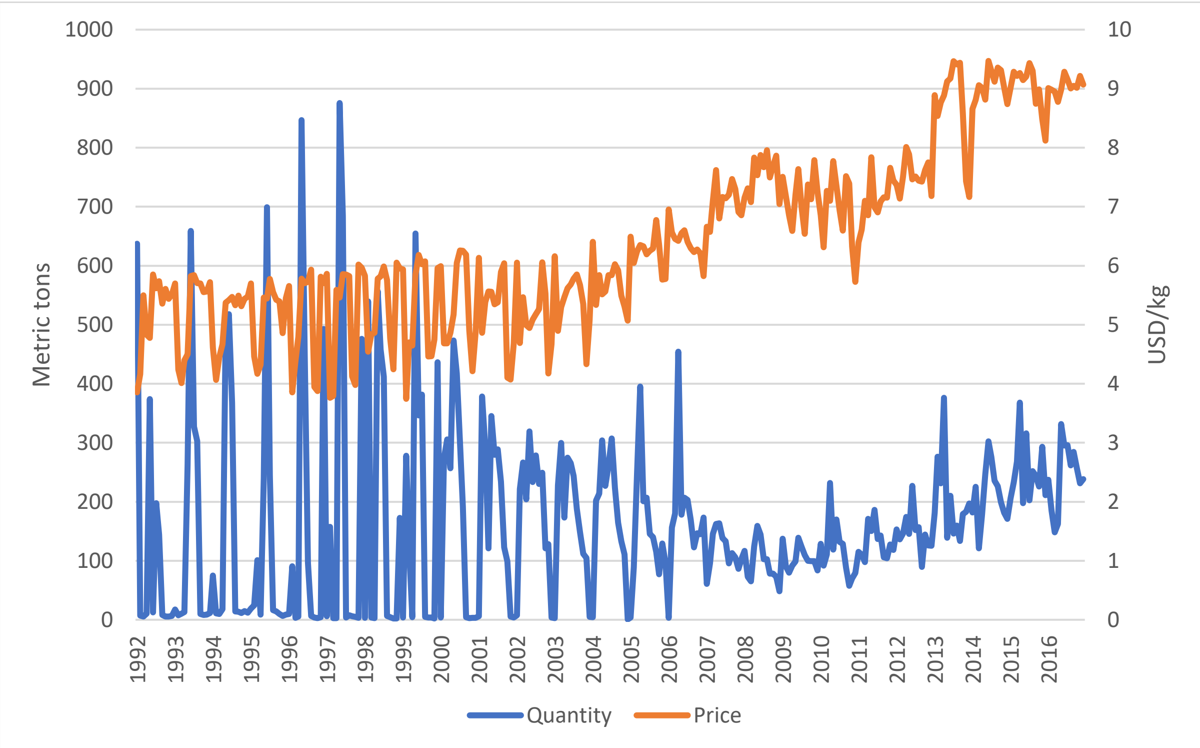

Figure 2.7 U.S. landings and prices for red snapper

The actual quantities and prices that is used in the empirical analysis is then shown in Figures 2.8 and 2.9. The trends are very similar to what was shown with the annual data, although prices are increasing more strongly since they are not adjusted for inflation. It is also of interest to note that the seasonality in landings before 2007 appears to be strongest for red snapper, indicating that this is where the race to fish was strongest. It is also of interest to note that the seasonality for vermilion and other snappers also appears to be reduced after 2007 despite the fact that the IFQ program does not encompass these species. This is most likely a reflection of how fishing effort was redistributed following the regulatory change.

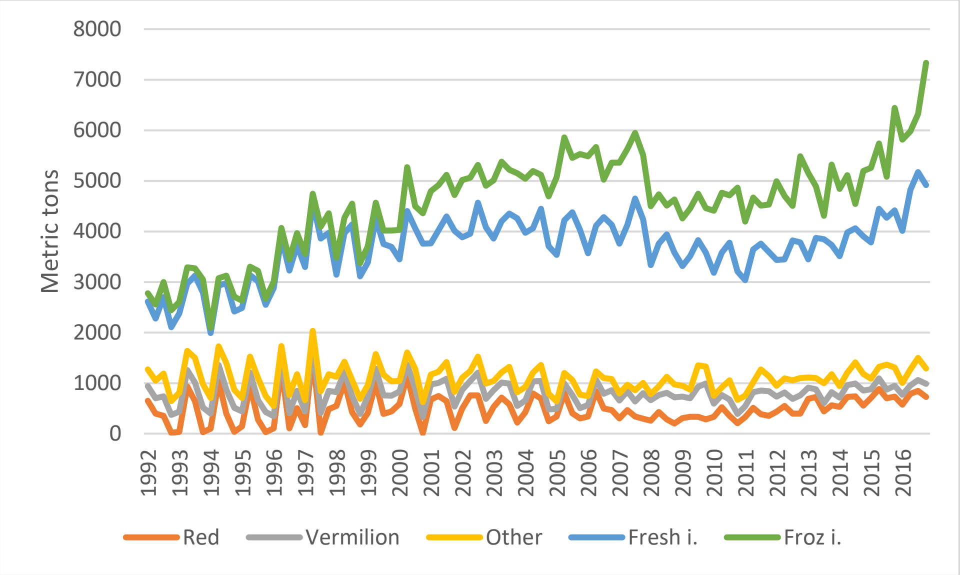

Figure 2.8 Snapper quantities in the U.S.

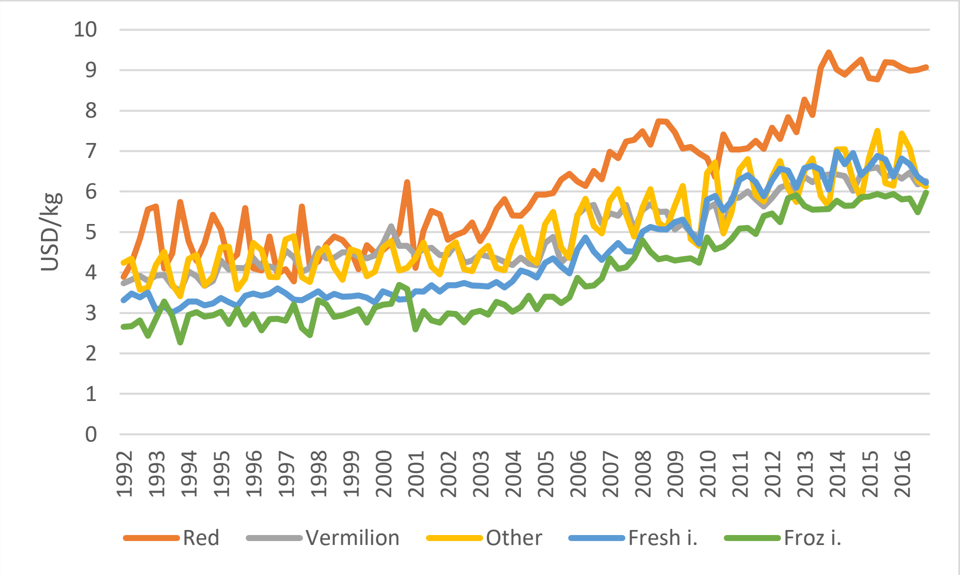

Figure 2.9 Snapper prices in the U.S.

3. Market integration

3.1 Method

The basic relationship in the empirical analysis of market integration follows the standard approach in the literature, and is given as:

$$\ln p^1 = \alpha + \beta \ln p^2 + e_t \qquad (3.1)$$

where p_t^i is the price observed in market level *i* at time *t* and the parameter α captures the margin. While this is the standard specification when only price data are available, the constant term can be made a function of different cost variables if such data are available (Asche, Gordon and Hannesson, 2004). The error term e_t is assumed to be white noise. If $\beta = 0$, there is no relationship between the two price series; if $\beta = 1$, then the price transmission is complete. If $\beta \neq 0$ and $\beta \neq 1$, there is a relationship between prices that varies with the price level.

Since the late 1980s it has become evident that traditional econometric tools cannot be used when prices series are nonstationary, since normal inference theory breaks down (Engle & Granger, 1987). Cointegration analysis is then the appropriate tool to infer causal long-run relationships between nonstationary time series. We use here the Johansen test (Johansen, 1988; Johansen and Juselius, 1991) since it allows for hypothesis testing on the parameters in the cointegration vector and exogeneity tests. The Johansen test is based on a vector autoregressive error correction model (VECM). With a vector $\boldsymbol{P_t}$ containing the *N* prices to be tested for cointegration, the system can be written as

$$\Delta P_t = \sum_{i=1}^{k-1} \Gamma_i \Delta P_{t-i} + \Pi P_{t-k} + e_t \qquad (3.2)$$

The matrix Π contains the parameters in the long-run relationships (the cointegration vectors). When Π has less than full rank, $0<r<N$, there exist *r* cointegration vectors or *r* stationary linear combinations of $\boldsymbol{P_t}$, and *N-r* stochastic trends. In this case one can factorize $\Pi = \alpha\beta'$, where both α and β are ($N\times r$) matrices. The elements of the leading diagonal of the factor loading matrix α represents the equivalent of the speed of adjustment parameters in a single equation setting (but which are influenced by the off-diagonal elements when there is more than one cointegration vector), and β contains the cointegration vectors (the error correcting mechanism in the system). In our context, when investigating prices at two levels in the supply chain, we expect there to be one cointegration vector.

Two different asymptotically equivalent tests are available to determine the rank of Π, the max and the trace tests. Tests with respect to the structural relationship between the prices (markets) are tests of restrictions on the parameters in the cointegration vectors, *β*. To illustrate, consider the case of a market with two product. Assume that the two price series are nonstationary but cointegrated, and that one lag is sufficient to capture the dynamics. The price relationships (suppressing the error terms) can be represented as

$$\begin{bmatrix} \Delta p_t^1 \\ \Delta p_t^2 \end{bmatrix} = \begin{bmatrix} a_1 \\ a_2 \end{bmatrix} \begin{bmatrix} b_1 & b_2 \end{bmatrix} \begin{bmatrix} p_{t-1}^1 \\ p_{t-1}^2 \end{bmatrix} \qquad (3.3)$$

If $b_1 = -b_2$, the prices are proportional and the price transmission is complete. Usually, b_1 is normalized, so we need to examine whether $b_2 = -1$. The parameters a_i measure the impact of deviations from the long-run relationship or weak exogeneity. However, given our relatively short dataset, we did not conduct the weak exogeneity tests in this study because of their weak power with few observations.

3.2 Empirical results

The first set of tests to be reported are the bivariate test in Table 3.1. With one exception, all price pairs are found to be cointegrated with one cointegration vector, while the hypothesis that there is not more than one cointegration vector is always rejected. The exception is the relationship between fresh imports and vermilion snapper where also the null hypothesis of no cointegration vectors cannot be rejected. Hence, the cointegration tests provide relatively strong evidence that all the prices share the same stochastic trend, with a small question mark for fresh and vermilion snapper that will be resolved in the multivariate tests.

The LOP is not rejected between red and fresh imported, fresh imported and frozen imported and vermillion and other snapper. In addition, with a *p*-value of 0.033, the evidence against the null hypothesis is relatively weak for the relationship between fresh imported and red snapper as this is not rejected at a 1% level.

There is little evidence of price leadership in the system as the null of weak exogeneity fails to be rejected only for fresh imports in relation to red snapper and for frozen in relation to vermilion snapper. For relationship between red and fresh imports, the *p*-value is 0.051, and there is some evidence against the null as it would be rejected at a 10% level, and it is very close to be rejected at a 5% level.

Table 3.1. Bivarate cointegration tests, *p*-values in parenthesis

	Max		Trace		LOP	Weak	Exogeneity
Red/	39.03*	(<0.001)	36.83*	(<0.001)	2.659	31.973*	(0.000)
Fresh	2.20	(0.751)	2.20	(0.737)	(0.103)	3.789	(0.051)
Red/	45.69*	(<0.001)	43.84*	(<0.001)	4.522*	30.459*	(0.000)
Frozen	1.78	(0.802)	1.78	(0.802)	(0.033)	12.185*	(0.001)
Red/	35.38*	(<0.001)	34.00*	(<0.001)	13.496*	26.101*	(0.000)
Vermlion	1.39	(0.879)	1.39	(0.879)	(<0.001)	8.225*	(0.004)
Red/	120.05*	(<0.001)	119.23*	(<0.001)	51.886*	41.804*	(0.000)
Other	0.82	(0.958)	0.82	(0.958)	(<0.001)	88.443*	(0.000)
Fresh/	41.47*	(<0.001)	38.65*	(<0.001)	0.306	5.691*	(0.017)
Frozen	2.81	(0.623)	2.81	(0.623)	(0.580)	26.111*	(0.000)
Fresh/	13.70	(0.318)	11.75	(0.208)			
Vermilion	1.95	(0.784)	1.95	(0.784)			
Fresh/	145.50*	(<0.001)	142.60*	(<0.001)	118.760*	18.408*	(0.000)
Other	2.90	(0.607)	2.90	(0.607)	(<0.001)	130.56*	(0.000)
Frozen/	23.83*	(0.014)	22.00*	(0.004)	16.407*	4.703*	(0.031)
Vermilion	1.83	(0.805)	1.83	(0.805)	(<0.001)	6.538*	(0.011)
Frozen/	137.97*	(<0.001)	136.06*	(<0.001)	108.550*	0.375	(0.540)

Other	1.91	(0.791)	1.91	(0.791)	(<0.001)	105.26*	(0.000)
Vermlion/	82.69*	(<0.001)	80.69*	(<0.001)	0.011	6.934*	(0.008)
Other	1.99	(0.776)	1.99	(0.776)	(0.914)	64.463*	(0.000)

* indicates statistically significant at a 5% level

In table 3.2, the results for the multivariate cointegration tests containing all five prices are reported. The null hypothesis of a given number of cointegration vectors is rejected up to a rank of 3, while it cannot be rejected for a rank of 4. Hence, these tests indicate four cointegration vectors and accordingly that all prices follow the same stochastic trend. All the weak exogeneity tests are rejected, indicating no evidence of price leadership. Finally, a test of the LOP has a $\chi^2(4)$ distributed test statistic of 30.693, and as the *p*-value < 0.001, this hypothesis it clearly rejected.

Table 3.2. Multivariate cointegration tests, all prices, *p*-values in parenthesis

Rank	Variable	Trace		Max		Weak	Exogeneity
Rank=0	Fresh	189.81*	(<0.001)	68.93*	(<0.001)	17.831*	(0.001)
Rank=1	Frozen	120.88*	(<0.001)	59.89*	(<0.001)	43.348*	(<0.001)
Rank=2	Red	60.99*	(<0.001)	35.23*	(<0.001)	41.174*	(<0.001)
Rank=3	Vermilion	25.77*	(<0.001)	23.47*	(0.002)	31.717*	(<0.001)
Rank=4	Other	2.3	(0.719)	2.3	(0.719)	42.032*	(<0.001)

* indicates statistically significant at a 5% level

In table 3.3, the results for the multivariate cointegration tests for a system containing the two import prices and the price of red snapper are reported. The null hypothesis of a given number of cointegration vectors is rejected up to a rank of 1, while it cannot be rejected for a rank of 2. Hence, these tests indicate two cointegration vectors and in accordance with all the previous tests that all prices follow the same stochastic trend. All the weak exogeneity tests are rejected also here, indicating no evidence of price leadership. A test of the LOP has a $\chi^2(2)$ distributed test statistic of 4.105, and as the *p*-value of 0.135, this hypothesis cannot be rejected.

Table 3.3. Multivariate cointegration tests, red snapper and imports, *p*-values in parenthesis

Rank	Variable	Trace		Max		Weak	Exogeneity
Rank=0	Fresh	99.11*	(0.000)	55.88*	(0.000)	10.614*	(0.005)
Rank=1	Frozen	43.23*	(0.000)	41.30*	(0.000)	38.922*	(0.000)
Rank=2	Red	1.93	(0.787)	1.93	(0.787)	41.001*	(0.000)

* indicates statistically significant at a 5% level

In sum, these market integration tests indicate that there is one integrated market for snappers with a common price determination process. The fact that none of the prices are found to be leading indicates that any shock in any part that influence one price will influence all prices, and this is true for positive as well as negative shocks. Finally, the LOP tests indicates that the markets for the two imported product forms and domestic red snapper is fully integrated, while other snappers are not perfect substitutes for red snapper. This also implies that although imports constitute two generic snapper categories, these categories primarily consist of red snapper due to constant relative price with domestic red snapper. The imports will therefore be regarded as imports of red snapper.

4. Demand analysis

4.1 Method

The most common functional form for a demand system is the almost ideal demand system (AIDS) of (Deaton and Muellbauer, 1980). This model is formulated in terms of the budget shares, and has the advantage of being expressed in levels and being linear when using a price index that satisfies the parameter consistency. However, in markets where the quantities produced may be considered exogenous, such as seafood from fisheries, an inverse almost ideal demand system (IAIDS) is normally applied. In this system, the budget share is the determined by the quantity, and scale of consumption (Brown, Lee, and Seale, 1995; Eales and Unnevehr, 1994; Holt, 2002). More specifically, the share equations to be estimated are given as:

$$S_i = \alpha_i + \sum_j \gamma_{ij} \ln q_j + \beta_i \ln Q \qquad (4.1)$$

where S_i is the expenditure share of the *i*th commodity, q_j is the demanded quantity, and $\ln Q$ is the Divisia volume index defined by:

$$\ln Q_t = \sum_i w_{kt} \ln q_{jt} \qquad (4.2)$$

To be consistent with economic theory, the following restrictions must hold;

Adding up: $\sum_i \alpha_i = 1, \sum_i \gamma_{ij} = 0, \sum_i \beta_i = 0$

Homogeneity: $\sum_j \gamma_{ij} = 0$

Symmetry: $\gamma_{ij} = \gamma_{ji}$

As the demand system is singular, one equation has to be dropped from the estimation. The parameters of the equation can be retrieved using the adding-up condition, and the system will be invariant to which equation is deleted.

Important outputs can be computed from the inverse demand system are flexibilities, that empirically show how prices varies with changes in own quantities, quantities of other goods and expenditure (scale of consumption).

The scale flexibility is given as:

$$f_i = -1 + \frac{\beta_i}{s_i} \qquad (4.3)$$

Scale elasticities are less then -1 (e.g. -2) for necessities and greater than -1 (e.g. -0.5) for luxuries.

The Marshallian price flexibilities are given as:

$$f_{ij} = -\delta_{ij} + \frac{\gamma_{ij}}{s_i} + \frac{\beta_i}{s_i} S_j \qquad (4.4)$$

where $\delta_{ij} = 1$ for $i = j$ (f_{ii} is the own-price flexibility) and $\delta_{ij} = 0$ otherwise (f_{ij} as uncompensated cross-price flexibility). The own-price flexibility will be equal to the inverse of the elasticity if there are no substitutes, while in general the Antonelli and Hessian matrices are general inverses of each other (Deaton and Muelbauer, 1980). If the cross-price elasticity is negative, the two goods are substitutes and if it is positive they are complements. Please note that the homogeneity condition on elasticity form is $\sum_j f_{ij} - f_i = 0$. Hence, the sum of the price elasticities will be negative as the scale flexibility is negative.

Estimating the demand system only for snapper species requires the assumption that the demand for snappers is weakly separable form other food products. This implies that substitution between snapper and other food is fully captured by the expenditure term.

4.2 Empirical results

The estimated parameters for the inverse AIDS system for the five snapper species are reported in table 4.1. All the equations have good explanatory power, with R^2 at 87% or higher. A Wald test that there was not a structural change in 2007 is clearly rejected with a *p*-value <0.001, indicating that the introduction of the catch shares led to a shift in demand structure. However, it is interesting to note that this is primarily a rotation of the demand schedules. For several species including red snapper there is not a statistically significant change in the constant term in either quarter. It is here of interest to note that the system was also estimated with a linear trend, but the null hypothesis that this should not be present could not be rejected. Hence, the demand growth that is associated with increasing prices and quantities is caused by the economic variables (Brækkan et al., 2018). More specifically, it is caused by increased expenditure on snappers.

For each parameter, the parameter value is first reported for the period before 2007, and then the dummy after 2007, so that the parameter value for e.g. computing the elasticties after 2007 are the sum of these two parameters. As one can see, a majority of the economic parameters are statistically significant. For the seasonal dummies there are fewer significant parameters, but there are still several and enough to reject the hypothesis of no seasonality with a *p*-value <0.001.

It is worthwhile to relate these results to Keithly and Tabarestani (2018). They model the impact of the grouper/tilefish IFQ program in an IAIDS system to test for the impact on price. The do find, as is also found here, that the constant term does not change. However, it is worthwhile to emphasize that this is a test of whether the demand equation shift, not whether the price change. Hence, their conclusion that this implies that the price did not change following the introduction of the catch shares is not supported by these tests.

Table 4.1. Estimated IAIDS model parameters

	Share equations			
	Fresh snapper	Frozen snapper	Red snapper	Vermilion snapper
Variables	Coef. (St. Error)	Coef. (St. Error)	Coef. (St. Error)	Coef. (St. Error)
Fresh snapper imp.- before 2007	0.221***	-0.057**	-0.036**	-0.052**
	(0.006)	(0.003)	(0.003)	(0.003)
after 2007	0.191***	-0.084**	-0.046**	-0.033**
	(0.020)	(0.012)	(0.012)	(0.007)
Frozen snapper imp. - before 2007	-0.057***	0.077**	-0.010**	-0.009**
	(0.003)	-0.003	(0.002)	(0.002)

after 2007	-0.084***	0.140**	-0.025**	-0.022**
	(0.012)	(0.011)	(0.007)	(0.005)
Red snapper - before 2007	-0.036***	-0.010**	0.060**	-0.008**
	(0.003)	(0.002)	(0.004)	(0.001)
after 2007	-0.046***	-0.025**	0.091**	-0.015**
	(0.012)	(0.007)	(0.014)	(0.004)
Vermilion snapper - before 2007	-0.052***	-0.009**	-0.008**	0.073**
	(0.003)	(0.002)	(0.001)	(0.003)
after 2007	-0.033***	-0.022**	-0.015**	0.068**
	(0.007)	(0.005)	(0.004)	(0.004)
Other snapper - before 2007	-0.076***	-0.001	-0.007**	-0.004
	(0.002)	(0.001)	(0.001)	(0.003)
after 2007	-0.027***	-0.008	-0.005	0.002
	(0.006)	(0.005)	(0.005)	(0.003)
Scale - before 2007	-0.034**	0.066**	-0.005	-0.012
	(0.015)	(0.009)	(0.015)	(0.008)
after 2007	-0.090**	0.02	0.026	0.042**
	(0.035)	(0.024)	(0.039)	(0.014)
First quarter - before 2007	-0.020**	0.020**	-0.016	-0.001
	(0.008)	(0.005)	(0.010)	(0.003)
after 2007	0.043***	-0.009	-0.016	-0.016**
	(0.016)	(0.010)	(0.017)	(0.006)
Second quarter - before 2007	-0.063***	-0.002	0.057**	-0.007
	(0.010)	(0.006)	(0.012)	(0.003)
after 2007	-0.018	0.023**	0.007	-0.004
	(0.013)	(0.008)	(0.015)	(0.005)
Third quarter - before 2007	0.000	-0.008	0.010	-0.005
	(0.008)	(0.005)	(0.010)	(0.003)
after 2007	-0.014	0.015	0.002	0.005
	(0.013)	(0.009)	(0.014)	(0.004)
Fourth quarter - after 2007	0.046**	-0.015	-0.021	-0.012
	(0.022)	(0.014)	(0.014)	(0.008)
Constant	0.544***	0.143**	0.148**	0.088
	(0.007)	(0.004)	-0.008	(0.002)
R^2	0.932	0.970	0.877	0.968
Stationarity of residuals	-3.753***	-0.3003***	-4.054***	-4.674***

* indicates significant at 10% level, ** at a 5% level and *** at a 1% level.

The scale flexibilities within the snappers group before 2007 vary significantly. It is smaller than -1 for fresh imports, vermilion and other snappers, and also significantly different from -1. The null that it is equal to -1 cannot be rejected for frozen imports, while it is much larger at -0.038 for red snapper indicating that this is a luxury product. After 2007, the null that they are equal to -1 cannot be rejected for any for the species but vermilion snapper, indicating that and increase in expenditure is spread evenly between these species. The magnitude of the scale elasticity for vermilion snapper is much smaller at -0.38

All the own price elasticities are larger than -1 and statistically different from -1, and the elasticity is not statistically different from 0 for vermilion snapper after 2007. The difference is also large enough for the corresponding elasticities to be smaller than -1 indicating elastic demand. This is not surprising given the high degree of market integration found in chapter 3. Most cross-quantity flexibilities are statistically significant and negative indicating substitutes.

The increase in the elasticity for red snapper is important, as it means that the price effect of the increased landings has changed significantly. Moreover, it is not surprising, as Homans and Wilen (2005) show how one are able to serve more price elastic (less price flexible) markets when the harvesting season is extended. Lee and Thunberg (2013) simulates welfare gains from an IFQ system, but their approach is not useful here since it is based on quantity changes. However, the change in the elasticities allows a crude estimate of the welfare gains in providing red snapper year round rather in a race to fish setting, everything else equal, as the movement along the demand schedule is a measure of the changed welfare (Lee and Thunberg, 2013). From 2007 to 2016 the red snapper landings increased by 1.5 thousand tons from 1.4 to 2.9 or by 107.1%.

Table 4.3 Snappers Marshallian price flexibilities

	Fresh imp.	Frozen imp.	Red snapper	Vermilion s.	Other snapper	Scale
Before 2007						
Fresh imp.	-0.704(0.021)***	-0.123(0.010)***	-0.093(0.010)***	-0.114(0.010)***	-0.160(0.010)***	-1.195(0.037)***
Frozen imp.	-0.416(0.070)***	-0.277(0.040)***	-0.030(0.022)	-0.050(0.026)*	-0.006(0.022)	-0.776(0.128)***
Red snapper	0.286(0.079)***	0.057(0.020)***	-0.472(0.025)***	0.039(0.016)**	0.052(0.016)***	-0.038(0.138)
Vermilion s.	-0.644(0.045)***	-0.099(0.025)***	-0.117(0.014)***	-0.307(0.043)***	-0.059(0.031)*	-1.226(0.082)***
Other snapper	-0.970(0.035)***	-0.067(0.019)***	-0.118(0.011)***	-0.072(0.030)**	-0.128(0.036)***	-1.355(0.064)***
After 2007						
Fresh imp.	-0.724(0.055)***	-0.191(0.022)***	-0.137(0.033)***	-0.068(0.015)***	-0.057(0.014)***	-1.177(0.060)***
Frozen imp.	-0.350(0.096)***	-0.298(0.047)***	-0.095(0.053)*	-0.112(0.028)***	-0.028(0.027)	-0.883(0.117)***
Red snapper	-0.363(0.210)*	-0.128(0.086)	-0.119(0.163)	-0.103(0.060)*	-0.035(0.051)	-0.749(0.268)***
Vermilion s.	-0.101(0.163)	-0.239(0.072)***	-0.147(0.102)	0.099(0.078)	0.086(0.060)	-0.303(0.226)
Other snapper	-0.508(0.168)***	-0.141(0.074)*	-0.120(0.103)	0.052(0.064)	-0.340(0.130)***	-1.057(0.268)***

* indicates significant at 10% level, ** at a 5% level and *** at a 1% level.

The price in 2007 was $3.89/pound ($8.57/kg) and the value of the fishery was $12 mill. With a price flexibility of -0.472 this would reduce the price by 50.6% or to $4.24. With a price flexibility of -0.119 this would reduce the price by 12.7% or to $1.92/pound ($7.36/kg). The price difference implies a welfare loss of S1.41/pound ($3.11/kg), and with landings of 2.9 thousand tonnes of $9.05 mill in total. If one uses the price in 2016 ($4.32/pound), the welfare loss increases to $1.63/pound ($3.60/kg).

5. Price increase due to catch shares?

To investigate whether the price of U.S. red snapper changed due to the introduction of the IFQ program, the market integration tests suggest two obvious candidates for control variable, the two import prices. Since the LOP is found to hold these prices have the closest alignment to the U.S. snapper price, and are better candidates than the two other types of domestic snappers where there is not full market integration.

The tests will be conducted with a simple OLS regression where we test if the margin has changed. In general, this can be written as

$$\ln p^1 = \alpha + \alpha_D D + \beta \ln p^2 + e_t \qquad (5.1)$$

The variable D is a dummy variable taking the vale 0 before the exogenous shock and the value 1 after. In our case, this is 2007 when the IFQ program was introduced. The parameter of interest here is α_D. If this is statistically significant, there has been a change in the margin, and the new margin is $\alpha+\alpha_D$.

When the LOP holds, we can impose the restriction $\beta=1$, and the equation simplifies to

$$\ln p^1 - \ln p^2 = \alpha + \alpha_D D + e_t$$

The results of such a regression for respectively imported fresh and imported frozen red snapper is reported in Table 5.1. All parameters are statistically significant at a 1% level. As can be expected when the left-hand side variable is a price difference, the R^2 is relatively low. The estimated parameters indicate that the premium for domestic red snapper relatively to the imports before 2007 was respectively 40.6% and 57%. In 2007 they increased by respectively 11.6% and 13.5%, that is a relatively similar magnitude. The average real import price of fresh imported snapper since 2007 was $3.00/pound ($6.62/kg). This price suggests that the premium before catch shares was $1.20/pound ($2.65?kg) and this increased by $0.35/pound with the catch shares.

Table 5.1. Premium for U.S. red snapper relatively to imports

	Fresh imports	Frozen imports
α	0.406	0.570
	(0.001)***	(0.011)***
α_D	0.116	0.135
	(0.014)***	(0.018)***
R^2	0.169	0.153

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