Fleet Capacity Dynamics in the Gulf of Mexico red snapper IFQ Fishery: 12 Years After

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- Magnuson-Stevens Act (MSA) requires periodic evaluations of US catch shares (CS) programs
- The Gulf Council implemented 2 CS programs (2007:RS and 2010:GT) to address problems associated with overcapacity and derby-fishing conditions
- Both 5-years assessments found these programs did well combating issues associated with derby fishing (short seasons, market gluts, safety at sea) but found that progress towards reducing overcapacity lagged. For example, Solis et al. (2014) showed that 20% of the red snapper fleet could harvest the entire quota

- Here we examine the performance of IFQ programs under two arrangements:
  - The red snapper IFQ as a fishery in and of itself;
  - The Gulf reef fish IFQ fishery (red snapper combined with grouper-tilefish)
- Examine changes in TE, excess capacity and overcapacity in these 2 CS programs

- We deploy novel econometric developments that account for vessel-specific heterogeneity, which (should) produce meaningful measures of technical efficiency (TE) and overcapacity
- The academic literature has show that TE estimates can vary widely depending on whether transient (time-varying) inefficiency, persistent inefficiency, or both, are modeled explicitly
- Failing to understand the implications of these sources of inefficiencies could result in well-intended policies that have unintended consequences (Kumbhakar and Lien, 2018).

- Using a stochastic output distance frontier (ODF) we find that the overall fleet in both arrangements is reasonably technically efficient, but overcapacity exists, even 10 years post IFQ

- The stochastic ODF measures the maximum amount by which an output vector can be proportionally expanded holding an input vector fixed
- One of the most common empirical forms for the ODF is the translog (TL) functional form

- The TL represents a global second order approximation to the true ODF and is represented as:

$$\begin{aligned}\ln D_{oit} = \beta_0 &+ \sum_{m=1}^{M} (\beta_m + \rho_m t) \ln y_{mit} + \sum_{k=1}^{K} (\delta_k + \nu_k t) \ln x_{kit} \\ &+0.5 \sum_{p=1}^{M} \sum_{m=1}^{M} \beta_{mp} \ln y_{mit} \ln y_{pit} \\ &+0.5 \sum_{k=1}^{K} \sum_{l=1}^{K} \delta_{kl} \ln x_{kit} \ln x_{lit} \\ &+ \sum_{m=1}^{M} \sum_{k=1}^{K} \gamma_{mk} \ln y_{mit} \ln x_{kit} \end{aligned} \tag{1}$$

- We have our final, panel stochastic ODF:

$$
\begin{aligned}
-\ln y_{1it} = \beta_0 &+ \sum_{m=2}^{M} (\beta_m + \rho_m t) \ln \tilde{y}_{mit} + \sum_{k=1}^{K} (\delta_k + \nu_k t) \ln x_{kit} \\
&+ 0.5 \sum_{p=2}^{M} \sum_{m=2}^{M} \beta_{mp} \ln \tilde{y}_{mit} \ln \tilde{y}_{pit} \\
&+ 0.5 \sum_{k=1}^{K} \sum_{l=1}^{K} \delta_{kl} \ln x_{kit} \ln x_{lit} \\
&+ \sum_{m=2}^{M} \sum_{k=1}^{K} \gamma_{mk} \ln \tilde{y}_{mit} \ln x_{kit} \\
&+ \kappa \boldsymbol{z}_{it} + v_{it} + u_{it} + \alpha_i \qquad (2)
\end{aligned}
$$

- For the red snapper IFQ, we have four outputs (red snapper, other snappers, grouper-tilefish species, and a miscellaneous or residual group), one quasi-fixed input (vessel length) and two variable inputs (days fished and crew size)

- $\boldsymbol{z}_{it}$ includes quarter dummies ($Q4$ is the baseline), regional landing location (county-level) dummies, biomass estimates for red snapper, red grouper, gag and yellowedge grouper as well as IFQ implementation dummies for red snapper (2007-2018) and grouper tilefish (2010-2018)

- For the Gulf reef fish IFQ fishery model (i.e., red snapper with grouper-tilefish) we employ a similar model with the exception that instead of having four species groupings we only have three: red snapper and grouper-tilefish, other snappers, and a residual group

- The ODF as constructed here allows for both vessel specific heterogeneity as well as time constant vessel inefficiency
- This is achieved by writing $\alpha_i = c_i + \tau_i$, where c_i captures vessel heterogeneity and τ_i captures time invariant, or persistent, inefficiency

- Recognizing this distinction in unobservable heterogeneity is important as it is likely that there exist differences across vessels participating in the IFQ that do not vary over time (like innate skipper skill) as well as persistent habits that vessels may demonstrate that lead to lower catch rates than otherwise expected
- We assume that $\tau_i \geq 0$ to capture this

- We also note that given the length of time our analysis focuses on (17 years) learning is likely to occur
- This is captured in u_{it}; here if $u_{it} \leq u_{it+1}$ $\forall t$ then time-varying inefficiency is decaying over time, and one reason for this can be learning on behalf of the skipper
- τ_i has no time component so this acts to quantify unobservable skill in fishing, i.e. persistent inefficiency

- Assuming that x_{kit} and $\ln \tilde{y}_{mit}$ are uncorrelated with α_i, OLS produces consistent but inefficient estimates
- However, we cannot recover either u_{it} or τ_i
- A simple, multi-step procedure originally proposed in Kumbhakar, Lien and Hardaker (2014) is available, known as plug-in likelihood while an even simpler approach based on method of moments recently appeared (Kumbhakar and Lien, 2018) which is what we use here

- These multi-step approaches require distributional assumptions to disentangle u_{it} from v_{it} and τ_i from c_i
- We use normal-half normal distributional pairs

- Following NMFS guidelines **harvesting capacity** is defined as the "maximum amount of fish that the fishing fleets could have reasonably expected to catch or land during the year under the normal and realistic operating conditions of each vessel, **fully utilizing** the machinery and equipment in place, and given the technology, the availability and skill of skippers and crew, the abundance of the stocks of fish, some or all fishery regulations, and other relevant constraints" (Terry et al. 2008)

- Further, NMFS defines **excess capacity** as the difference between harvesting capacity and estimated catch or landings and overcapacity as the difference between harvesting capacity and a short-term target catch level such as an annual catch limit or proxy (Terry et al. 2008).

- This study adopts the definition of **fishing capacity** as the potential (maximum) output that a fishing fleet could harvest given the current stock of capital and other fixed inputs, the state of the technology and the available biomass (FAO 1998)

- With the notion of maximal output, estimation of capacity requires us to work with a stochastic production frontier (Parmeter and Kumbhakar, 2014).

- A standard approach to measuring capacity is, at the vessel level, determining maximum attainable output with the full utilization (unrestricted use) of variable inputs given the existing capital and other fixed factors of production
- Felthoven et al. (2009) look at days at sea in their estimation of capacity

- To that end, several alternative approaches have been proposed to estimate capacity, including:
  - Identifying the maximum observed variable input levels of all vessels with similar fixed input endowments (for instance comparing catch rates across vessels of the same length;
  - Identifying the theoretically maximum variable input usage levels;
  - Increasing the observed variable input levels by an *ad hoc* amount, such as an increase of 25 or 50%

- Our approach to estimate capacity is more focused and, we believe, consistent with Terry et al. (2008)
- We hold inputs fixed at observed levels and ask what each vessel could catch if they were to eliminate both persistent and time-varying inefficiency
- In some sense we are moving vessels in the output direction radially to assess capacity whereas other approaches move the vessels in the input direction to calculate capacity

- The data used in this study were obtained from the National Marine Fisheries Service (NMFS) Southeast Coastal Fisheries Logbook Program and the Permits Information Management Systems (PIMS) databases
- The logbook database contains detailed trip-level information on landings and fishing effort, and the PIMS database contains information on vessel characteristics

- For the red snapper IFQ fishery we only used reported landings from vertical line vessels, while for the combined analysis we used both vertical line and long line vessels
- To avoid potential biases due to heterogeneous fishing technologies, we modeled the vertical line and longline fleets separately

Table: Descriptive statistics for red snapper IFQ model.

		Mean	St. Dev.
Red Snapper (lbs.)	y_1	763.6	1,700.655
Other Snapper (lbs.)	y_2	317.8	808.485
Grouper/Tilefish (lbs.)	y_3	356.5	655.675
All Other Species (lbs.)	y_4	249.8	646.5
Vessel Length (ft.)	x_1	37.7	9.7
Days Away	x_2	3.4	2.7
Crew	x_3	2.7	1.2
Red Snapper Biomass (mt.)	z_1	68,957.8	17,255
Gag Biomass (mt.)	z_2	10,844	3,516.1
Red Grouper Biomass (mt.)	z_3	20,747	4,522.8
Yellowedge Grouper Biomass (mt.)	z_4	5,730.5	187.5

Table: Partial distance input/output elasticities and RTS pre and post IFQ: Assumes different technology pre- and post-IFQ for red snapper IFQ model.

	Whole Sample	Pre-IFQ	Post-IFQ
Output Elasticities			
Red Snapper	-0.275	-0.313	-0.250
Other Snapper	-0.187	-0.185	-0.189
Grouper/Tilefish	-0.315	-0.279	-0.339
Other Species	-0.222	-0.224	-0.221
Input Elasticities			
Vessel Length	1.066	1.228	0.957
Days Away	0.971	0.872	1.037
Crew	0.403	0.401	0.403
RTS	1.374	1.274	1.441

Figure: Density plot of time varying technical efficiency for GoM vessels, pre/post IFQ for red snapper IFQ model.

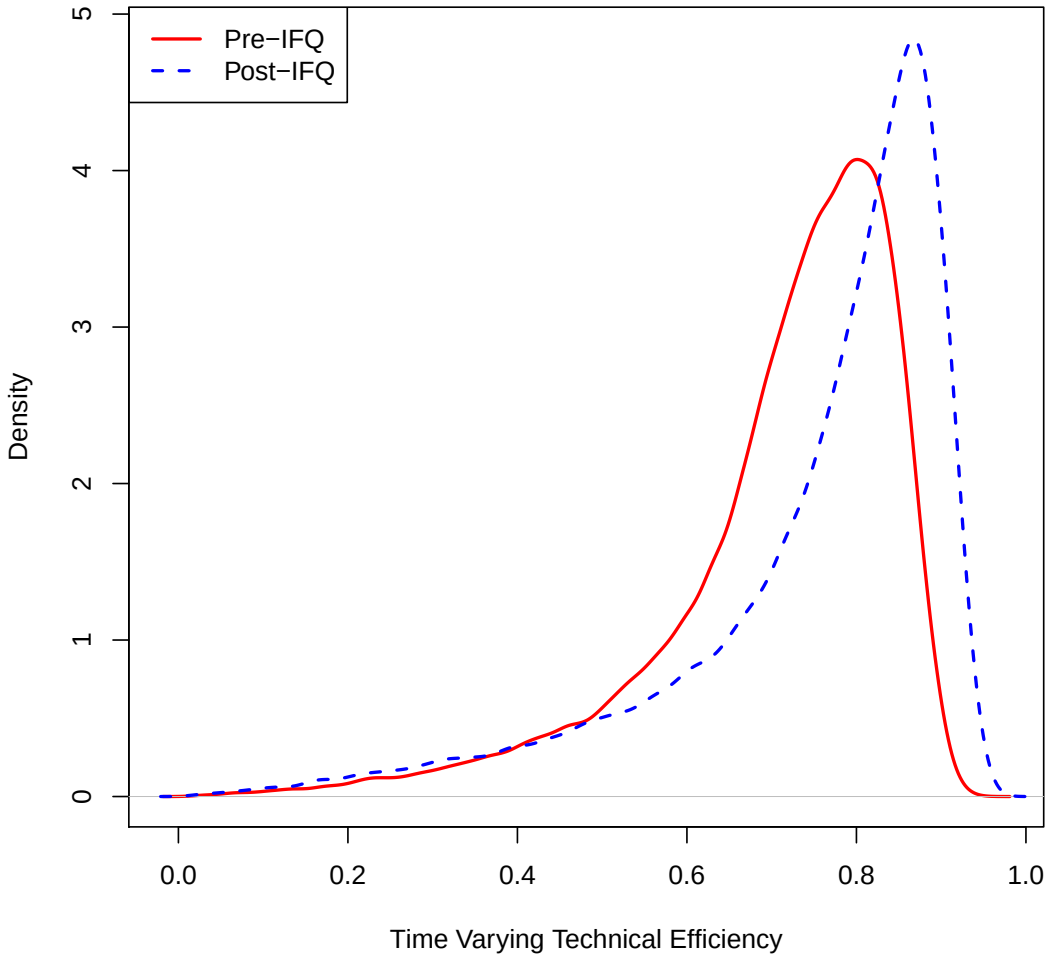

Table: Annual fleet capacity measures pre and post-IFQ

	Red Snapper		
	Actual Catch	C^{OTE}	C^{TVE}
$Entire$	$4,251$	$7,286$	$6,352$
$Pre-IFQ$	$3,871$	$5,849$	$5,849$
$Post-IFQ$	$4,410$	$7,885$	$6,562$
$2007-2011$	$2,485$	$4,515$	$3,722$
$2012-2018$	$5,785$	$10,292$	$8,590$

Table: Annual fleet size measures for red snapper.

Year	Quota	Efficient Vessels	Total Vessels	% Vessels	Quota Utilization
2002	$4,189,189$	111	430	0.258	1.051
2003	$4,189,189$	115	425	0.271	1.025
2004	$4,189,189$	116	439	0.264	0.991
2005	$4,189,189$	127	432	0.294	0.864
2006	$4,189,189$	109	394	0.277	1.021
2007	$2,297,297$	68	291	0.234	0.960
2008	$2,297,297$	77	279	0.276	0.974
2009	$2,297,297$	57	286	0.199	0.974
2010	$2,297,297$	44	334	0.132	0.958

Table: Annual fleet size measures for red snapper.

Year	Quota	Efficient Vessels	Total Vessels	% Vessels	Quota Utilization
2011	$3,190,991$	75	319	0.235	0.981
2012	$3,300,901$	45	316	0.142	0.979
2013	$3,712,613$	49	313	0.157	0.971
2014	$5,054,054$	62	346	0.179	0.992
2015	$5,054,054$	49	345	0.142	0.985
2016	$6,097,297$	63	352	0.179	0.993
2017	$6,312,613$	67	369	0.182	0.996
2018	$6,312,613$	68	376	0.181	0.996

- Now for the combined fisheries

Table: Descriptive statistics for Gulf reef fish IFQ fishery.

		Mean	St. Dev.
Red Snapper/Grouper/Tilefish (lbs.)	y_1	1,261.6	2,042.5
Other Snapper (lbs.)	y_2	221.1	683.4
All Other Species (lbs.)	y_3	301.3	753.8
Vessel Length (ft.)	x_1	37.7	9.6
Days Away	x_2	3.9	3.3
Crew	x_3	2.6	1.1
Red Snapper Biomass (mt)	z_1	66,582.3	16,443.2
Gag Biomass (mt.)	z_2	10,473.5	3,495.5
Red Grouper Biomass (mt.)	z_3	20,955.4	4,243.9
Yellowedge Grouper Biomass (mt.)	z_4	5,705.9	178.2

Table: Partial distance input/output elasticities and RTS pre and post IFQ for combined fishery: Assumes different technology pre- and post-IFQ as well as across line type.

	Whole Sample	Pre-IFQ	Post-IFQ
Output Elasticities			
RS/GT	-0.517	-0.511	-0.527
Other Snapper	-0.248	-0.267	-0.220
All Other Species	-0.234	-0.222	-0.252
Input Elasticities			
Vessel Length	0.974	0.913	1.066
Days Away	0.853	0.822	0.899
Crew	0.366	0.363	0.371
RTS	1.220	1.185	1.271

Table: Partial distance input/output elasticities and RTS pre and post IFQ for combined fishery: Assumes different technology pre- and post-IFQ as well as across line type.

	Whole Sample	2010-2014	2015-2018
Output Elasticities			
RS/GT	-0.517	-0.509	-0.546
Other Snapper	-0.248	-0.232	-0.209
All Other Species	-0.234	-0.259	-0.246
Input Elasticities			
Vessel Length	0.974	0.944	1.185
Days Away	0.853	0.944	0.856
Crew	0.366	0.368	0.374
RTS	1.220	1.312	1.230

Figure: Density plot of overall technical efficiency and its components for Gulf reef fish IFQ fleet.

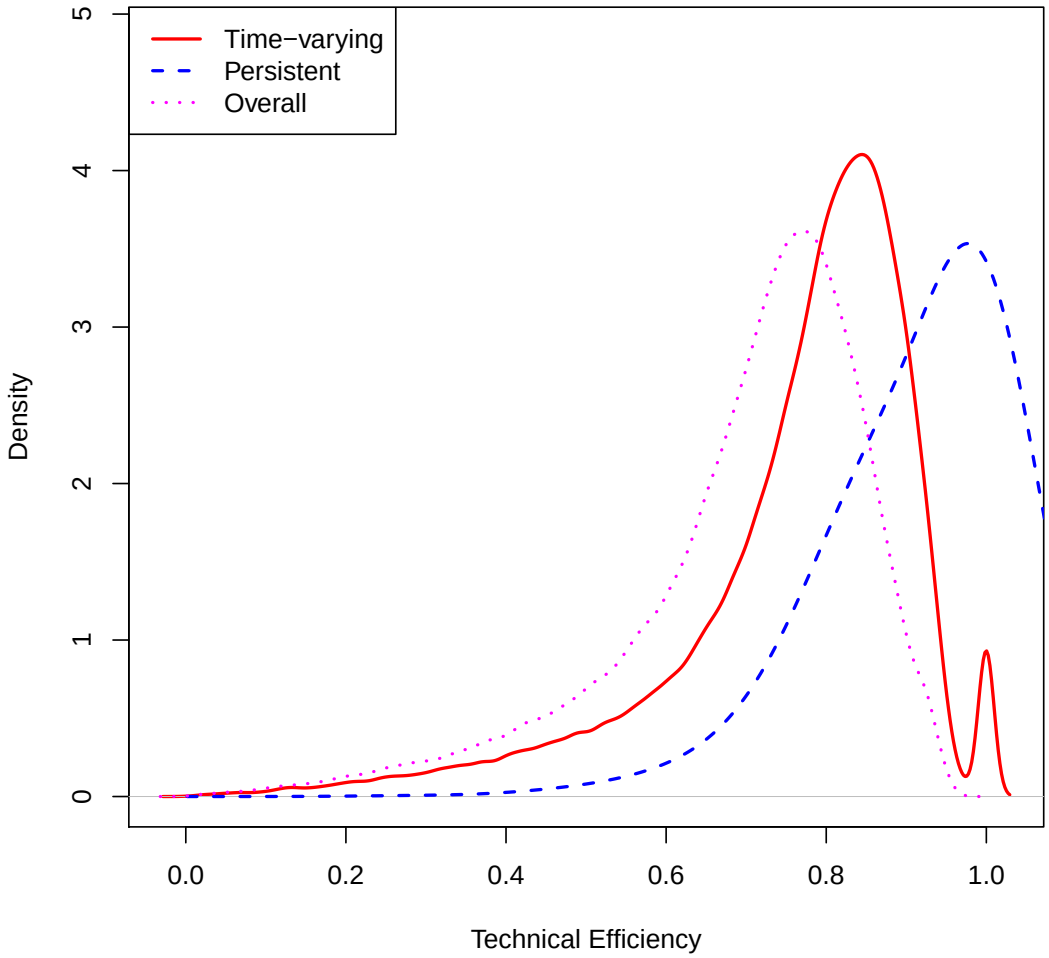

Figure: Density plot of time varying technical efficiency for Gulf reef fish IFQ fleet, pre/post IFQ by line type.

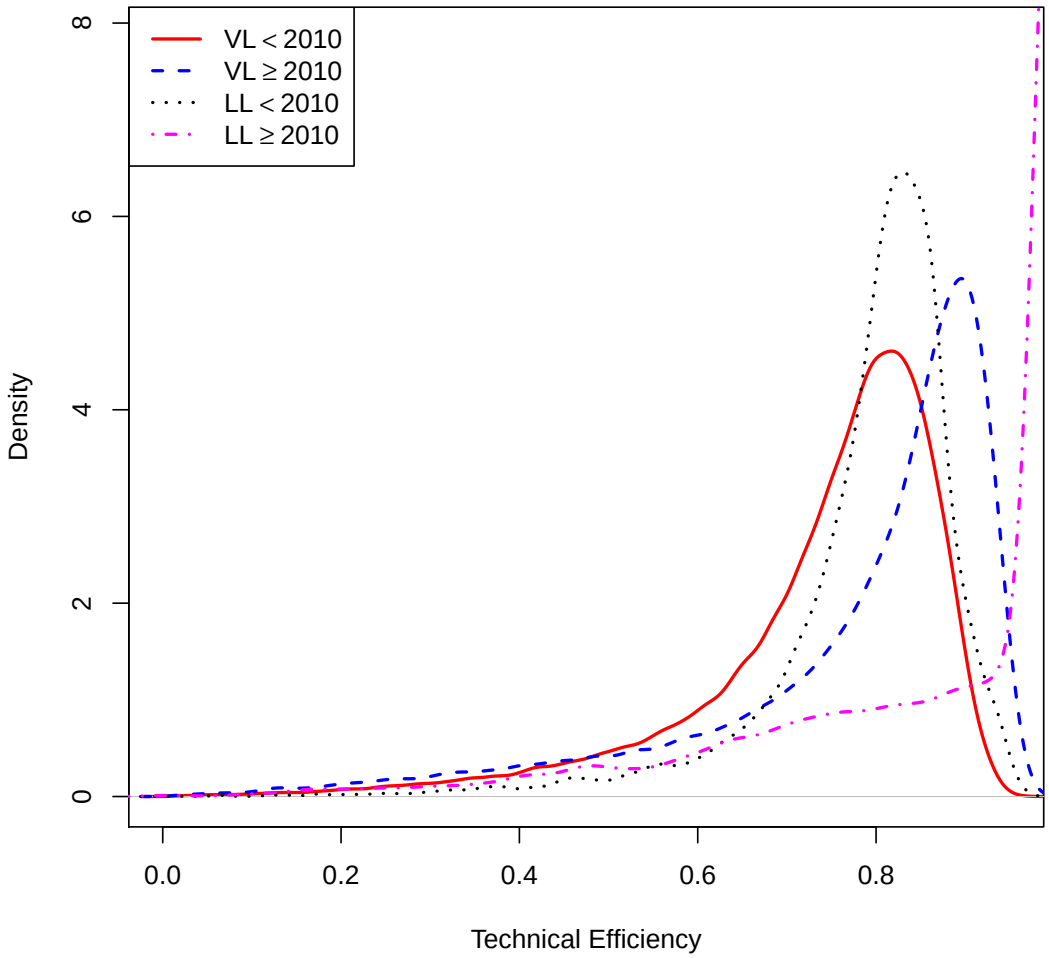

Table: Annual fleet capacity measures pre-IFQ for combined fisheries.

	Actual Catch	C^{OTE}	C^{TVE}
2002	$13,374$	$19,545$	$18,803$
2003	$12,525$	$18,469$	$17,724$
2004	$13,043$	$18,971$	$18,142$
2005	$12,030$	$17,676$	$16,916$
2006	$11,236$	$16,060$	$15,417$
2007	$8,692$	$12,285$	$11,783$
2008	$9,225$	$13,250$	$12,692$
2009	$7,544$	$11,190$	$10,868$

Table: Annual fleet capacity measures post-IFQ for combined fisheries.

	Actual Catch	C^{OTE}	C^{TVE}
2010	$6,446$	$11,277$	$9,578$
2011	$8,630$	$13,723$	$11,887$
2012	$9,900$	$16,173$	$13,988$
2013	$10,112$	$15,825$	$13,777$
2014	$10,916$	$17,715$	$15,385$
2015	$11,262$	$19,084$	$16,386$
2016	$11,021$	$17,458$	$15,065$
2017	$9,556$	$15,138$	$13,054$
2018	$8,701$	$13,877$	$11,955$

Table: Annual fleet capacity measures pre- and post-IFQ for combined fisheries.

	Actual Catch	C^{OTE}	C^{TVE}
$Entire$	$10,248$	$15,748$	$14,319$
$Pre-IFQ$	$10,959$	$15,931$	$15,293$
$Post-IFQ$	$10,541$	$17,073$	$14,740$
$2010-2015$	$9,201$	$14,943$	$12,923$
$2015-2018$	$10,135$	$16,389$	$14,115$

Table: Annual fleet size measures

Year	Quota	Efficient Vessels	Total Vessels	% Vessels	Quota Utilization
2010	$12,220,991$	482	482	1.000	0.613
2011	$10,830,901$	222	470	0.472	0.895
2012	$11,867,613$	223	461	0.484	0.935
2013	$13,510,054$	261	445	0.587	0.869
2014	$13,734,054$	224	479	0.468	0.949
2015	$15,437,270$	265	469	0.565	0.877
2016	$16,947,297$	390	464	0.841	0.774
2017	$17,162,613$	494	494	1.000	0.679
2018	$17,162,613$	486	486	1.000	0.616

- This study assessed the impact of the IFQ program on the TE and overcapacity of the red snapper IFQ and Gulf reef fish IFQ fisheries
- Drawing on recent econometric developments that account for vessel-specific heterogeneity, we find that time-varying TE improved after the adoption of IFQ

- In the red snapper fishery, time-varying TE rose by almost 6% (from 0.711 pre-IFQ to 0.751 post-IFQ) and in the Gulf reef fish fishery it increased by 5% (from 0.746 pre-IFQ to 0.787 post-IFQ)
- In contrast, overall TE declined post-IFQ in both fisheries; however, this result was affected by the inability of the model to capture persistent TE in the pre-IFQ periods

- We estimated that slightly less than 20% of the red snapper IFQ fleet could harvest the entire red snapper quota
- The estimation of overcapacity in the Gulf reef fish IFQ fishery was more challenging because the fleet did not catch the entire quota
- Nonetheless, we found that, on average, since 2010 about 72% of the existing fleet could have harvested the actual catch

- If we consider only those years when 75% or more of the quota was taken (2011-2016), then 57% of the fleet could have harvested the entire catch
- A smaller fleet is likely to be required since 2019 as the red grouper quota was reduced from 7.8 million pounds in 2018 to 3.0 million pounds in 2019
- In 2019 combined fleet is catching below their quota (70%) even after the quota was reduced from 7.8 million pounds