The impact of IFQs on the productivity of the US Gulf of Mexico Red Snapper Fishery

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Motivation

Rights-based management (IFQs) enjoy a number of advantages over command and control regulation.

But have these anticipated benefits been realized in practice?

Our focus is to examine productivity changes following the adoption of IFQs in a multispecies fishery setting.

Objectives

This study has two objectives:

a) **Examine changes in total factor productivity (TFP) in the commercial red snapper fleet after the onset of the IFQ program using a Malmquist index derived from an output oriented SDF; and**

b) **Identify the main sources of productivity growth (if any).**

Table 1. Recent Empirical Studies Measuring Changes in Productivity in Fishing

First Author (Year of Pub.)	Fishery (Country/ies)	Method*	Multi-outputs	Control Variables‡	Quotas	Metrics†	Period of Analysis
Eggert (2013)	Mixed Species (Iceland, Norway, Sweden)	PI	No	S	No	TFP	1973-2003
Felthoven (2009)	Pollock (USA)	St	Yes	S, C, R	Yes	PC	1994–2003
Fox (2003)	Halibut (Canada)	PI	No	S	Yes	PC, PR	1988, 1991,1994
Fox (2006)	Mixed Species (Australia)	PI	No	S	Yes	PC, PR	1997-2000
Greeneville (2006)	Mixed Species (Norway)	St	No	--	No	TE, TFP	1997-2003
Hannesson (2007)	Mixed Species (Norway)	PI	No	S	No	TFP	1961–2004
Hannesson (2010)	Mixed Species (Norway)	PI	No	S	No	TC, TFP	186-1983
Hoff (2006)	Mixed Species (Denmark)	DEA	Yes	--	No	TE, SE, TC, TFP	1987–1999
Islam (2011)	Mixed Species (Malaysia)	PI	No	--	No	TFP	1990-2005
Jin (2002)	Groundfish (USA)	PI	Yes	S, R	No	TFP	1964-1993
Kim (2012)	Mixed Species (Korea)	DEA	Yes	S	No	TE, SE, TC, TFP	1995-2009
O'Donnell (2013)	Mixed Species (Australia)	St	Yes	C	No	TE, SE, TFP, EC	1974-2010
Oliveira (2009)	Mixed Species (Portugal)	DEA	Yes	S	Yes	TE, TC, TFP	1995-2004
Squires (1992)	Mixed Species (USA)	PI	Yes	S, R	Yes	TFP	1981-1989
Squires (2008)	Tuna (Korea)	DEA	Yes	S, C	No	TE, TC, TFP	1997-2000
Stephan (2013)	Multiple fisheries (Australia)	PI	Yes	S	Yes	TFP	1993-2012
Walden (2012)	Quahogs & Clams (USA)	DEA	Yes	S	Yes	TE, SE, TC, TFP	1980–2008
Walden (2013)	Groundfish (USA)	PI	Yes	-	Yes	TFP/EHI	1996-2010
Walden (2014)	Groundfish (USA)	PI	Yes	S	Yes	TFP/EHI	2007-2011

*: Stochastic (**St**), Data Envelopment Analysis (**DEA**); Productivity Index (**PI**)
‡: Stock (S); Climate (C); Regulations (R); Quotas (Q)
†: Technical Efficiency (**TE**); Scale Efficiency (**SE**); Technological Change (**TC**), Productivity Change (**PC**); Total Factor Productivity (**TFP**); Profit ratio (**PR**); Environmental Change (**EC**); EHI Economic health index (**EHI**)

Literature Review

- Most of the studies used productivity indexes (PIs)
  - easy to calculate and require less data
  - drawback is that by aggregating inputs and outputs, technological interdependencies cannot be assessed.
- DEA also has been a popular technique to measure TFP
  - Allows for Multi-inputs and -outputs
  - Fails to account for the stochastic nature of commercial fishing operations
- Only 2 studies use Stochastic method
  - Allows for Multi-inputs and -outputs
  - Allows for the inclusion of stochastic 'noise'
  - Its parametric nature generates valuable information

Case study: Red snapper fishery

- In 2012, Gulf of Mexico fishermen landed 3.6 mp of red snapper worth $14.2 m.
- Shared by commercial and recreational sectors
- Main gears: vertical lines (electric reels) and bottom longlines.
- Multispecies fishery - part of the reef-fish complex.
- IFQs since 2007 before that command and control management

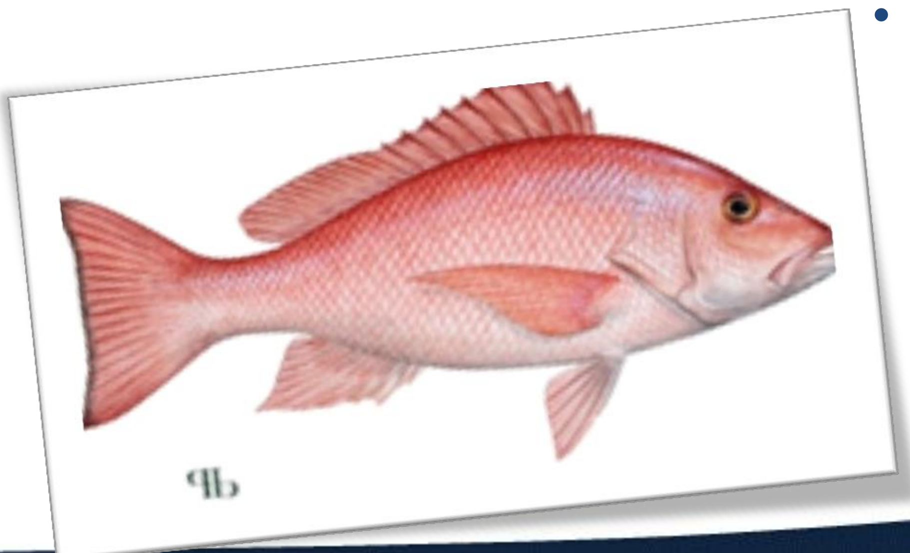
Command and Control Era

Management Regulations

- Limited access
- Annual quotas
- Trip limits (class 1 and 2 permits)
- Spring and fall quotas
- 10 day fishing seasons

Outcomes

- Derby fishing
- Overcapacity
- Over-exploitation
- Quota overages
- High discard rates
- Unsafe fishing conditions



Individual Fishing Quota (IFQ) Era

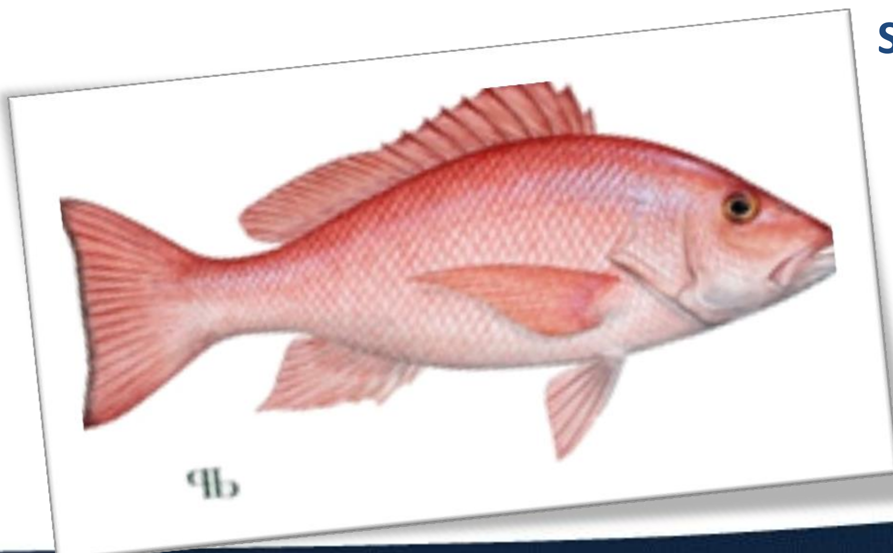
Management Objectives

- Reduce overcapacity
- Mitigate race to fish conditions

Outcomes

- Fleet size contracted
- Fewer but longer trips
- Year round fishery
- Higher ex-vessel and quota prices
- Resource condition improved
- No quota overages but discarding still high in Western Gulf

  Safer fishing conditions



Framework

Malmquist index using output oriented SDF

ODF measures the max amount by which an output vector can be expanded and still be produced with a given input vector.

Changes in TFP for vessel *i* between two consecutive periods (*t* and *t+1*) after accounting for resource abundance is defined as:

$$MI_{oi}(T_t, S_t) = \frac{D_o^t\left(x_i^{t+1}, y_i^{t+1}, S_t\right)}{D_o^t\left(x_i^t, y_i^t, S_t\right)}$$

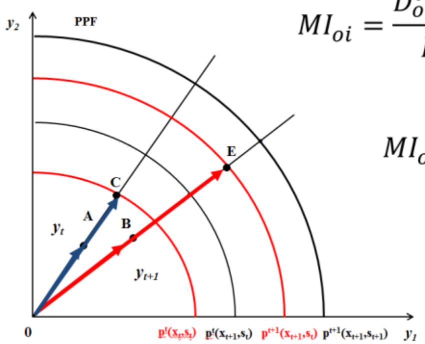
Decompose TFP growth into 3 components

$$MI_{oi}(T_t, S_t) = EC \cdot TC \cdot SC$$

EC- efficiency change (movement toward frontier)
TC- Technical change (frontier shift not due stock)
SC- Stock change (frontier shift due to stock)

Graphical depiction

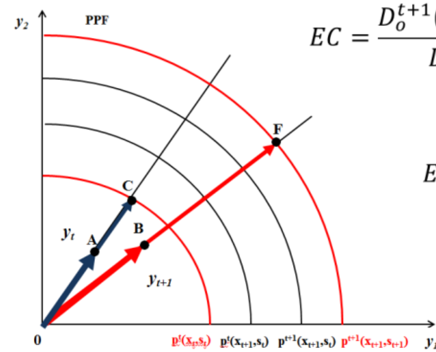
TFP



$$MI_{oi} = \frac{D_o^t\left(x_i^{t+1}, y_i^{t+1}, St\right)}{D_o^t\left(x_i^t, y_i^t, St\right)}$$

$$MI_{oi} = \frac{OB/OE}{OA/OC}$$

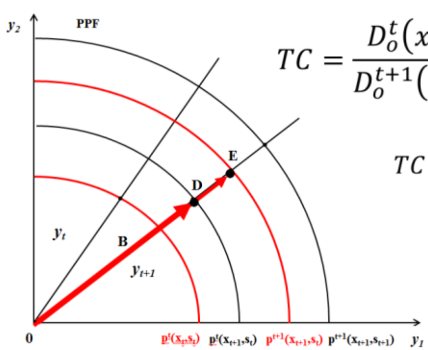
Efficiency change (EC)



$$EC = \frac{D_o^{t+1}\left(x_i^{t+1}, y_i^{t+1}, S_{t+1}\right)}{D_o^t\left(x_i^t, y_i^t, S_t\right)}$$

$$EC = \frac{OB/OF}{OA/OC}$$

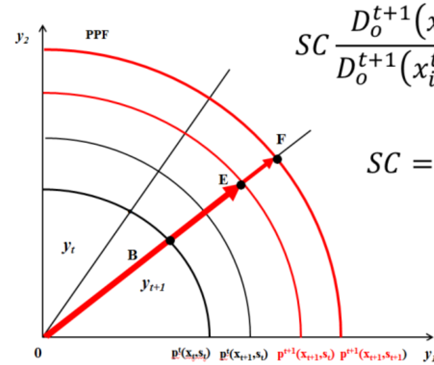
Technological change (TC)



$$TC = \frac{D_o^t\left(x_i^{t+1}, y_i^{t+1}, S_t\right)}{D_o^{t+1}\left(x_i^{t+1}, y_i^{t+1}, S_t\right)}$$

$$TC = \frac{OB/OD}{OB/OE} = \frac{OE}{OD}$$

Stock change (SC)

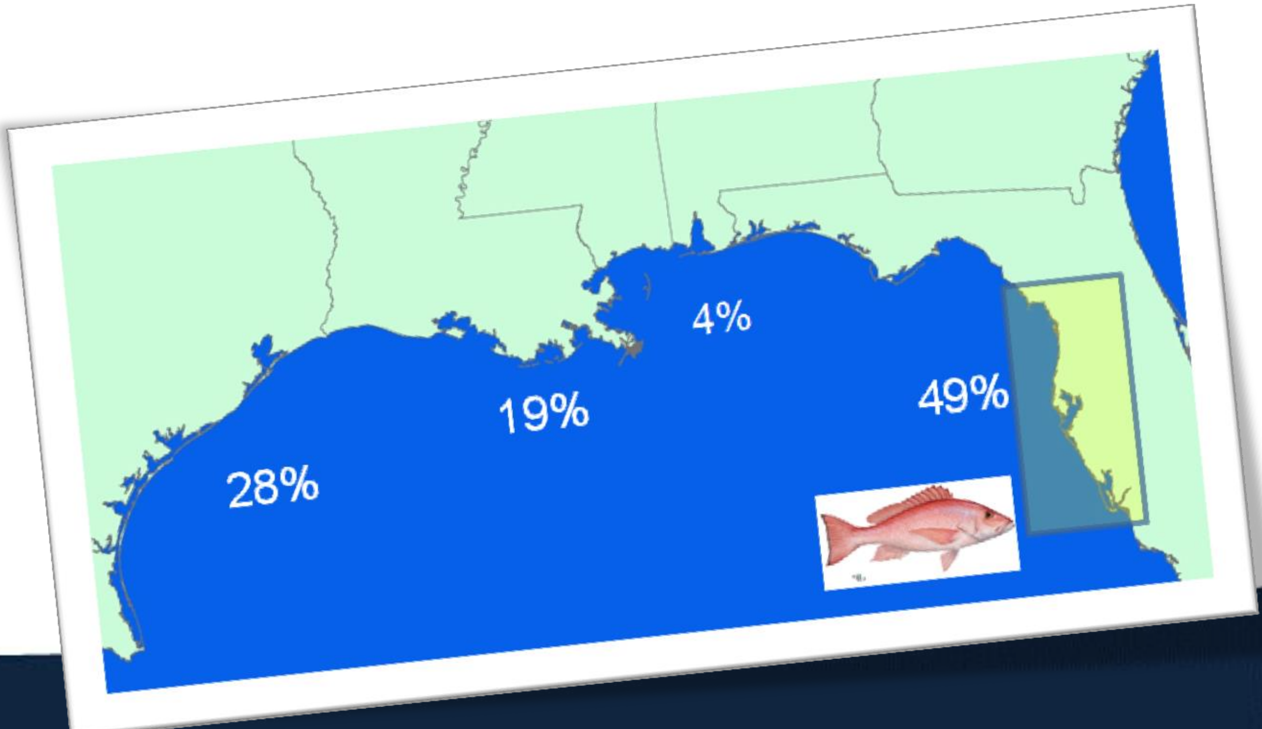


$$SC \frac{D_o^{t+1}\left(x_i^{t+1}, y_i^{t+1}, S_t\right)}{D_o^{t+1}\left(x_i^{t+1}, y_i^{t+1}, S_{t+1}\right)}$$

$$SC = \frac{OB/OE}{OB/OF} = \frac{OF}{OE}$$

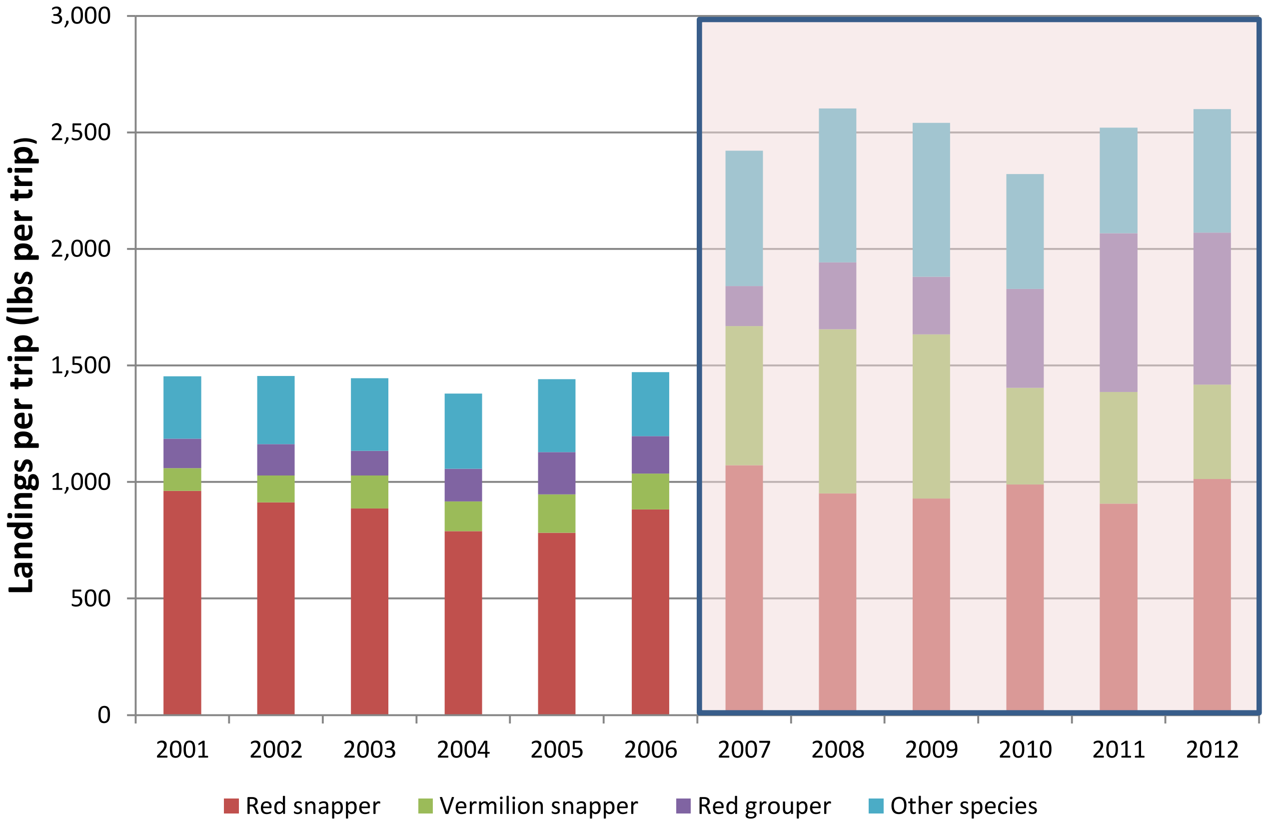
Data

- **Analysis period: 2001-2012** (command & control *vs.* IFQ)
- **Sources: NOAA's Logbook and PIMS programs**
- **Sample included 971 vertical line vessels (N=3,883 annual obs.).**

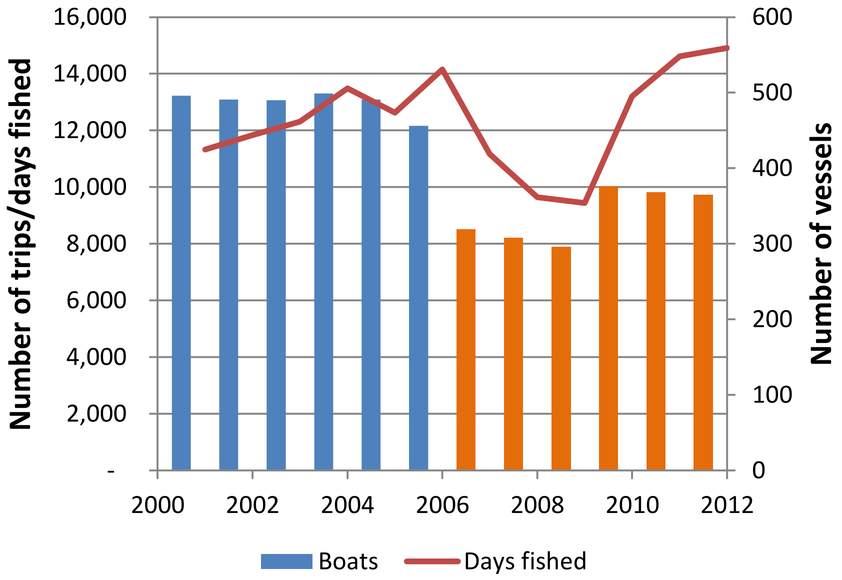


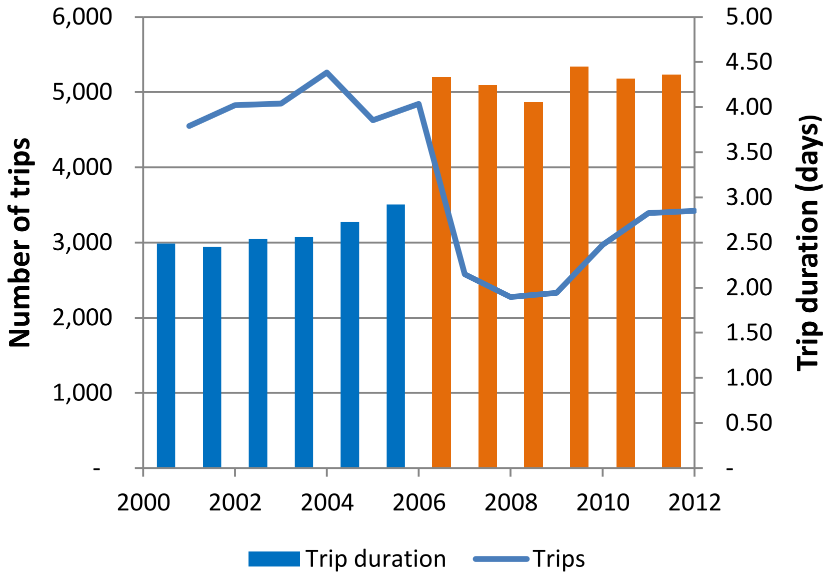
Landing Distribution

Catch composition

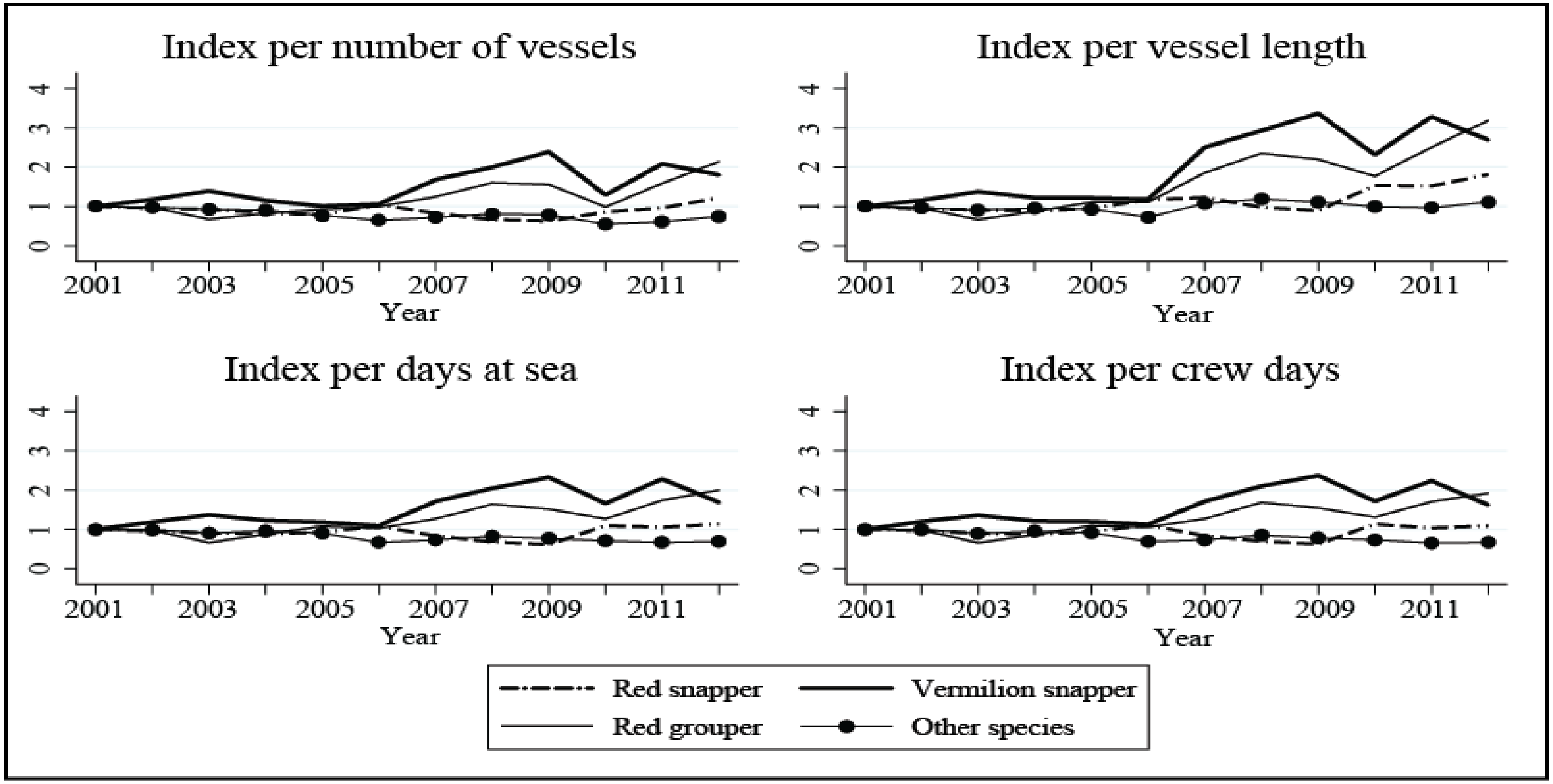


Changes in participation





Partial productivity



- The intuition offered by the **statistical** and **graphical** analyses ignores the influences of **stock levels** and **external factor** in the productivity of the fishery.
- Consequently, the goal of this study is to develop rigorous analysis of the impact of the **IFQ** program on the **TFP** of the fleet.
- To do so, we measure and decompose productivity changes based on a **Malmquist Index** (**MI**).
- To account for the **multi-output** and **random nature** of the red snapper fishery we estimate the MI using an output-oriented **stochastic distance frontier** (**OSDF**).

Model

- TL Output oriented SDF estimate with ML
- Outputs (4, y_i): red snapper, vermilion snapper, red grouper, and miscellaneous species
- Inputs (3, x_i): days away, crew size, and vessel length
- Other variables: Red snapper biomass, MEI index, class 2 license (200 lb. trip limit), season length, and area dummies

Stochastic Distance Function

$$-lny_{1i} = \beta_0 + \sum_{m=2}^{M} \beta_m ln\frac{y_{mi}}{y_{1i}} + \frac{1}{2}\sum_{m=2}^{M}\sum_{n=2}^{M} \beta_{mn} ln\frac{y_{mi}}{y_{1i}} ln\frac{y_{ni}}{y_{1i}} + \sum_{k=1}^{K} \beta_k lnx_{ki}$$

$$+ \frac{1}{2}\sum_{k=1}^{K}\sum_{l=1}^{K} \beta_{kl} lnx_{ki} lnx_{li} + \sum_{k=1}^{K}\sum_{m=2}^{M} \beta_{km} lnx_{ki} ln\frac{y_{mi}}{y_{1i}} + \sum_{m=1}^{M} \beta_{tm} t ln\frac{y_{mi}}{y_{1i}}$$

$$+ \sum_{k=1}^{K} \beta_{tk} t lnx_{ki} + \sum_{j}^{J} \theta_{hj} D_j + \sum_{h}^{H} \theta_h lnC_h + v_i + u_i$$

Distances (Jondrow et al 1982):

$$TE_i = D_{oi} = E(\exp(-u_i)|v_i - u_i) = -\frac{\sigma_u \cdot \sigma_v}{\sigma} \cdot \left[\frac{f((v_i - u_i) \cdot \lambda/\sigma)}{1 - F((v_i - u_i) \cdot \lambda/\sigma)} - \frac{(v_i - u_i) \cdot \lambda}{\sigma}\right]$$

Results

Reject that TI does not exist (frontier is better than regular production function)

Own and cross output and input terms, biomass (+), open season(+), and area dummies were statistically significant and had correct sign.

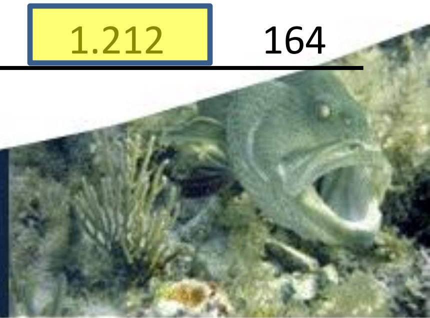
MEI variable not statistically significant

Partial distance elasticities and RTS

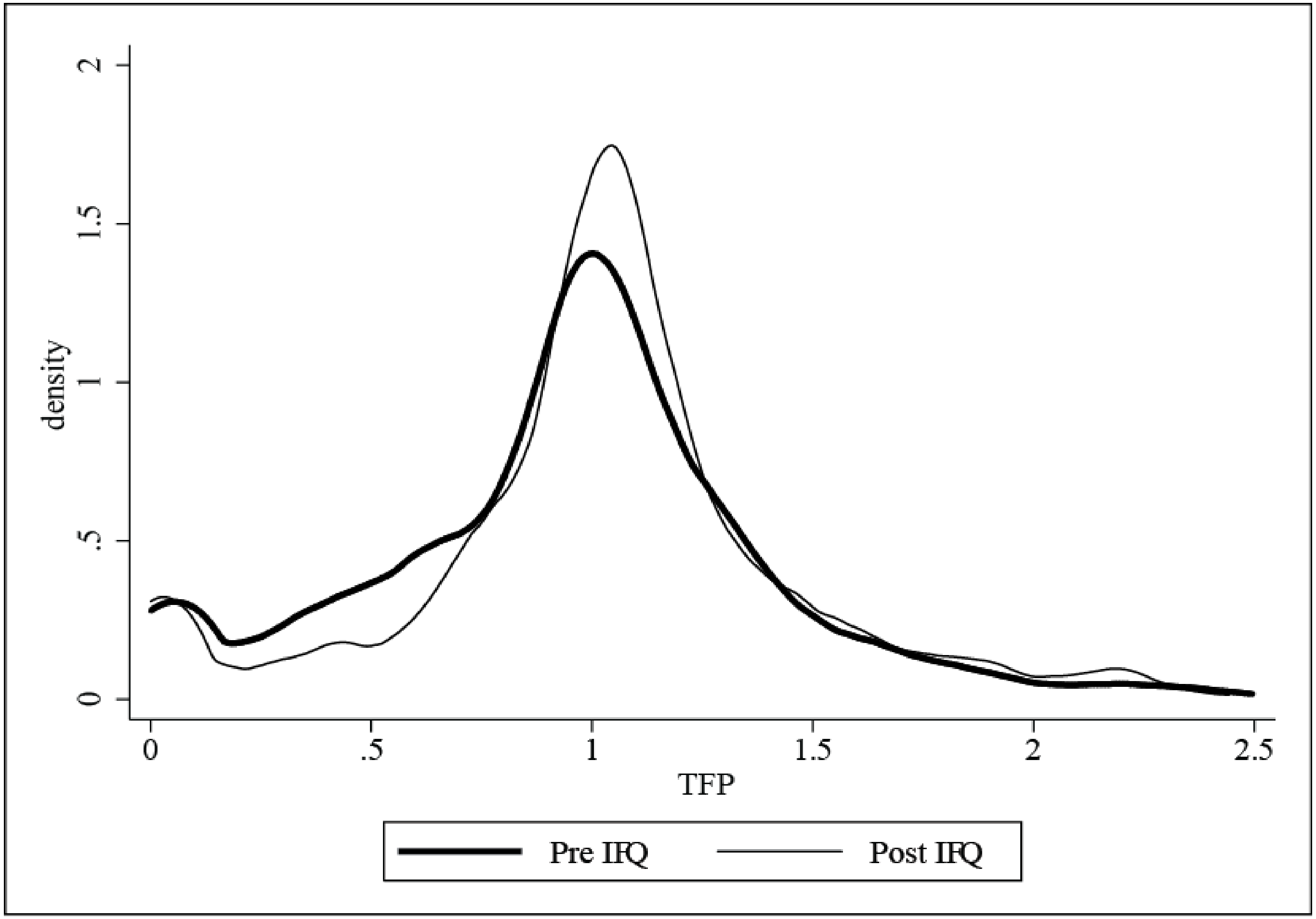
Elasticities	Whole Sample	Pre IFQ	Post IFQ
Red snapper	-0.42***	-0.43***	-0.39***
Vermilion snapper	-0.07***	-0.05***	-0.10***
Red grouper	-0.16***	-0.13***	-0.18***
Other species	-0.36***	-0.39***	-0.33***
Crew size	0.44***	0.43***	0.44***
Days away	1.05***	1.07***	1.03***
Vessel length	0.56**	0.72**	0.42**
RTS	2.05	2.22	1.89

Evolution of TFP (MI)

Period	Entire Fleet		Stay		Exit		New	
	Mean	n	Mean	n	Mean	n	Mean	n
2001-2002	0.954	290	0.994	157	0.908	133	--	--
2002-2003	0.894	299	0.945	177	0.824	122	--	--
2003-2004	0.971	308	0.949	197	1.010	111	--	--
2004-2005	0.850	303	0.881	214	0.781	89	--	--
2005-2006	0.990	287	1.032	236	0.818	51	--	--
2006-2007	0.839	247	0.839	247	--	--	--	--
2007-2008	**0.919**	**205**	**0.966**	**186**	**--**	**--**	**0.853**	**19**
2008-2009	**1.058**	**211**	**1.012**	**188**	**--**	**--**	**1.617**	**23**
2009-2010	**1.181**	**195**	**1.138**	**174**	**--**	**--**	**1.325**	**21**
2010-2011	**1.088**	**228**	**1.065**	**179**	**--**	**--**	**1.214**	**49**
2011-2012	**0.958**	**214**	**0.953**	**162**	**--**	**--**	**1.050**	**52**
Pre-IFQ*	0.930	1487	0.960	981	0.875	506	--	--
Post-IFQ*	1.041	1053	1.027	889	--	--	1.212	164



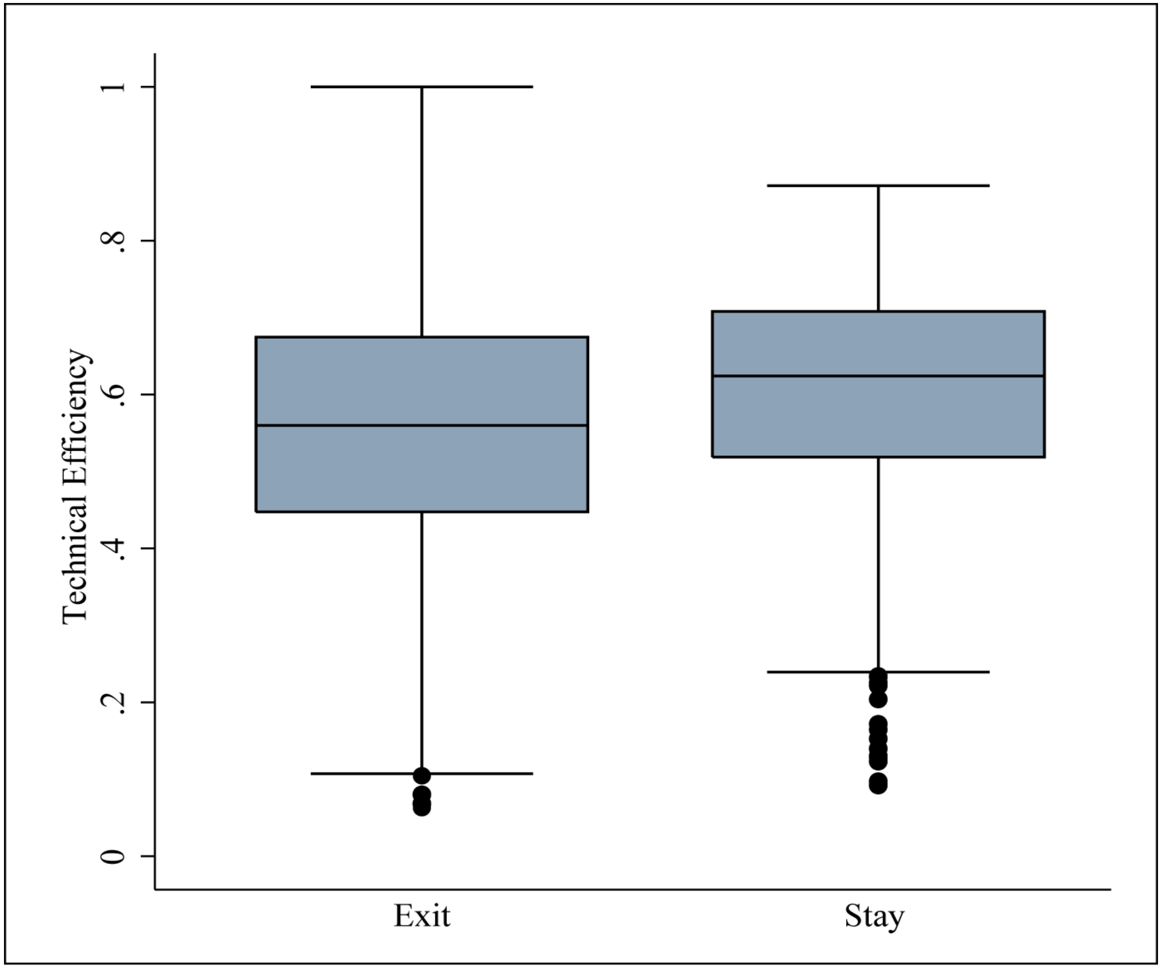
Kernel distribution of MI pre and post IFQ



MI and its components

Period	TFP	EC	TC	SC
2001-2002	0.954	0.964	0.992	1.001
2002-2003	0.894	0.899	0.997	1.000
2003-2004	0.971	0.980	0.991	1.000
2004-2005	0.850	0.863	0.983	0.998
2005-2006	0.990	0.990	0.996	0.999
2006-2007	0.839	0.887	0.946	1.003
2007-2008	**0.919**	**0.921**	**0.997**	**1.001**
2008-2009	**1.058**	**1.046**	**0.999**	**1.003**
2009-2010	**1.181**	**1.169**	**1.000**	**1.003**
2010-2011	**1.088**	**1.086**	**1.013**	**1.012**
2011-2012	**0.958**	**0.95**	**1.002**	**1.005**
Pre-IFQ*	0.916	0.931	0.984	1.000
Post-IFQ*	1.041	1.034	1.002	1.005

Distribution of TE scores during pre-IFQ era



Findings

- In general, the IFQ program has improved the productivity of the fleet in contrast to the outcomes observed during the command and control era.

- TFP increased after the onset of the IFQ program (sexennial average ~ 4%).

- Most of the observed productivity gains came from efficiency changes (83%) likely due to the departure of less productive vessels and the relaxation of management restrictions.

- Technological improvements (4%) and stock effects (16%) played a minor role.

Limitations

Various sources of potential biases, including

- lack of biomass estimates for the other species,
- loss of observations because MI relies of the geometric mean of two time periods and number of full-time vertical line vessels "fluctuated".

Future work

Build on these early results and start thinking about potential ways to tweak current policies to sustain and/or augment the fleet's productivity.

Buybacks are unlikely due to budget limitations, but there have been claims that fishermen have began targeting vermilion snapper to build a catch history in anticipation of a potential IFQ (flow of capital --> depressed productivity???)

Thank you