Dynamic Target Choice Model in Multi-fisheries

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This study

- Estimates harvester's in-season decision of which fishery to target under ITQ management with limiting bycatch.
- Key Idea:
  - Choice of target within a season must make a dynamic plan for using quota, in addition to current factors.
  - Develop reduced-form variable that captures in-season dynamics of quota use.
- Key Result
  - Including the dynamic quota use variable in the RUM improves the fit of the model.
  - Policy counterfactual with the parameter estimates shows the reduction in bycatch with maintained main target.

Theory on ITQ management

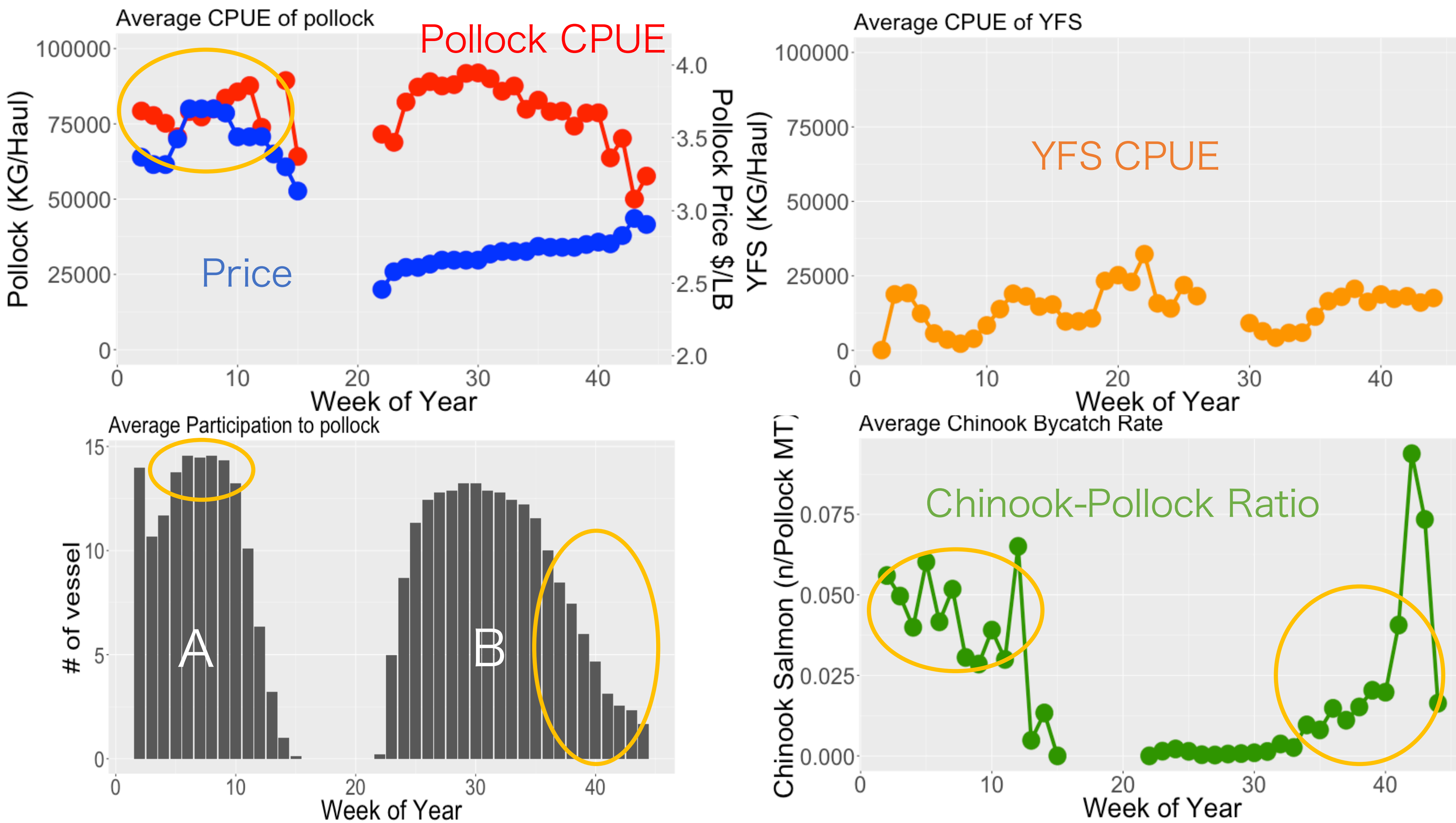
- Single Species Framework
  - ITQ corrects common property problem under bycatch and no production externalities. (Boyce 1992, 1996)
    - Harvesters take into account shadow costs of quota.
- Multi-fishery participation
  - The opportunity cost of fishing is affected by availability of other fisheries.
  - The effect of management in one fishery may affect the timing of participation in another
    - Individual quota allows delay of participation

Empirical Approach: Harvester Behavior under ITQ

	Single target species	Multi-fishery
Myopic	An advantage of Individual quota is to flexibly allocate the harvest over a season.	The choice problem must consider biological/economic condition of other fisheries available for harvesters.
Dynamic	The choice problem (entry decision) must consider quota allocation over a season.	<u>This Study</u> • Harvester choice: Multiple target fisheries • Consider the dynamic quota use within a season.

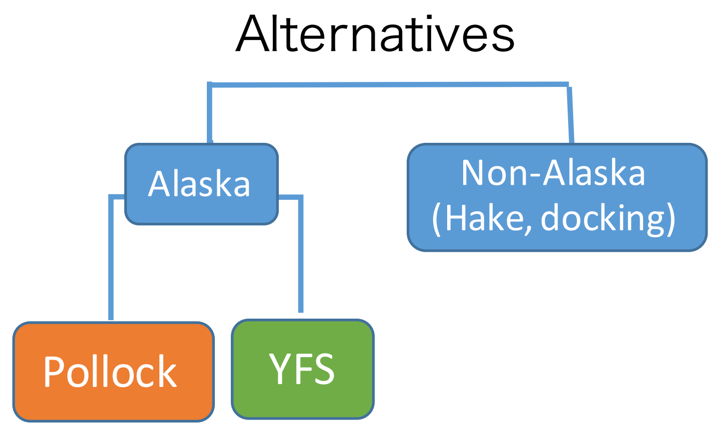
Application to a fishing fleet

- Offshore fleet (Catcher-Processor)
  - Listed in American Fisheries Act
  - Weekly data
- Main targets
  - Pollock: ITQ management
    - 2 seasons : A (Jan-Jun) & B (Jun-Oct), High value from roe in A season
  - Yellowfin Sole (YFS): TAC
    - No more than "traditional catch" level.
  - Pacific Hake: IQ management, in West coast
    - No Individual data for this, but just numbers of vessels in this fishery.
- Prohibited Species Catch (bycatch)
  - Salmon (<u>Chinook</u> & Chum)


Average CPUE of pollock
Pollock CPUE
Price
Pollock (KG/Haul)
Pollock Price $/LB
100000
75000
50000
25000
0
4.0
3.5
3.0
2.5
2.0
0
10
20
30
40
Week of Year
Average CPUE of YFS
YFS CPUE
YFS (KG/Haul)
100000
75000
50000
25000
0
0
10
20
30
40
Week of Year
Average Participation to pollock
# of vessel
15
10
5
0
A
B
0
10
20
30
40
Week of Year
Average Chinook Bycatch Rate
Chinook-Pollock Ratio
Chinook Salmon (n/Pollock MT)
0.075
0.050
0.025
0.000
0
10
20
30
40
Week of Year

Empirical Model

- Random Utility Model
- Weekly choice of fishery
- Model incorporates
  - Choice of other fisheries
  - Dynamic quota use



Covariates: Switching cost, # of vessel in hake

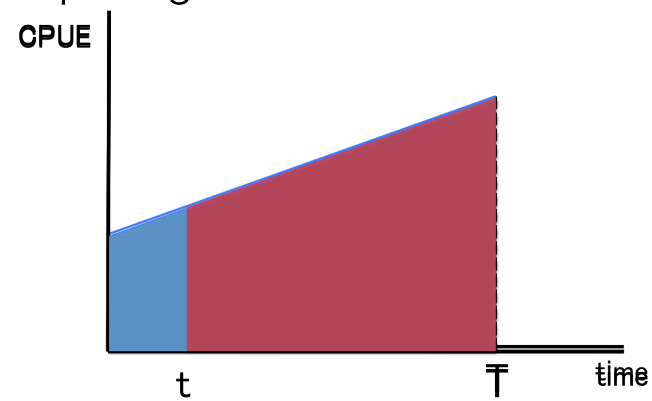
Fixed Effects

$$U_{ijyw} = \beta_j(X_{iyw})E\left(\frac{Rev}{Haul}\right)_{ijyw} + \gamma(Y_{iyw})E(Bycatch_{ijyw}) + \phi' Z_{ijyw} + \xi_i + \varepsilon_{ijyw}$$

State Variable: <u>Quota Speed,</u> Policy (A91), cumulative catch

Capturing Dynamic Quota Use

- Reduced form variable: Quota Speed
    - Capture the pace of actual quota use relative to “potential” use
    - Compare the quota left relative to the time left
    - Remaining time is weighted by the expected Revenue PUE
        - If the expected RPUE is high, “more time” to use quota given number of weeks remaining in the season.
    - The value lies between -1 and +1.
        - If it is negative, the usage is too fast.



$$qspeed_{it} = \frac{\%QuotaLeft_{it} - \%WeightTimeLeft_{it}}{\%QuotaLeft_{it} + \%WeightTimeLeft_{it}}$$

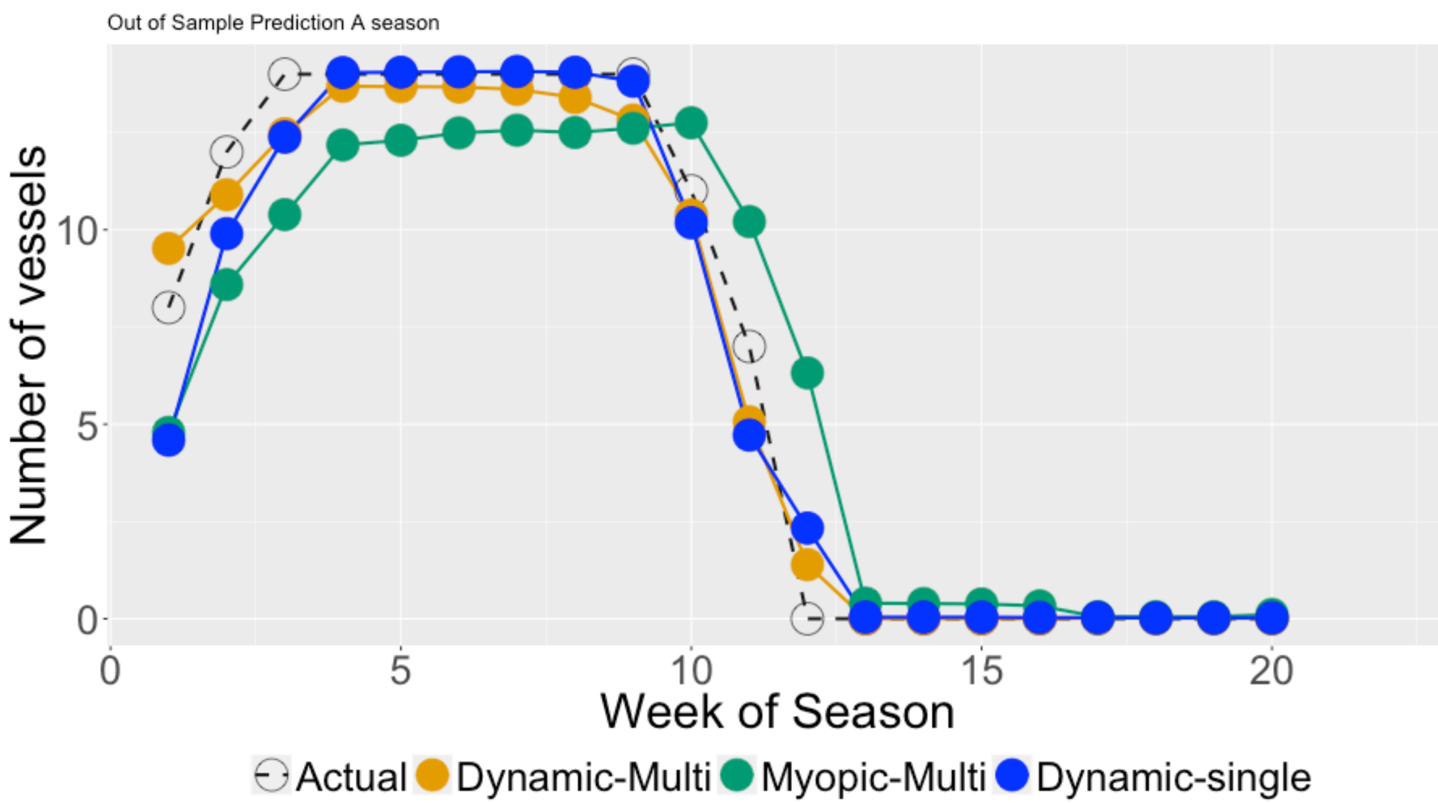
Estimation Result

	Dependent variable: Target					
	A Season			B Season		
	Myopic	Single target	Dyn + Multi	Myopic	Single target	Dyn + Multi
	(1)	(2)	(3)	(4)	(5)	(6)
Expected Revenue	0.006^{***}	0.012^{***}	0.025^{***}	-0.012^{***}	-0.006^{*}	-0.006
	(0.001)	(0.003)	(0.002)	(0.003)	(0.003)	(0.003)
Expected Bycatch Rate	16.445^{***}	7.115	26.660^{*}	-69.664^{***}	-51.420^{**}	-88.232^{***}
	(4.821)	(7.649)	(10.575)	(9.246)	(19.817)	(23.176)
Exp. Rev. x QSpeed		0.041^{***}	0.028^{***}		0.038^{***}	0.023^{***}
		(0.004)	(0.003)		(0.003)	(0.002)
Exp. Byc. Rate x QSpeed		45.498^{**}	59.712^{**}		96.776^{***}	33.467
		(16.619)	(22.107)		(27.121)	(30.037)
Akaike Inf. Crit.	1636.36	607.6	958.73	1484.43	858.74	980.98
Observations	2,551	2,551	2,551	2,668	2,668	2,668
Log Likelihood	-795.181	-279.800	-453.367	-719.214	-405.369	-464.489

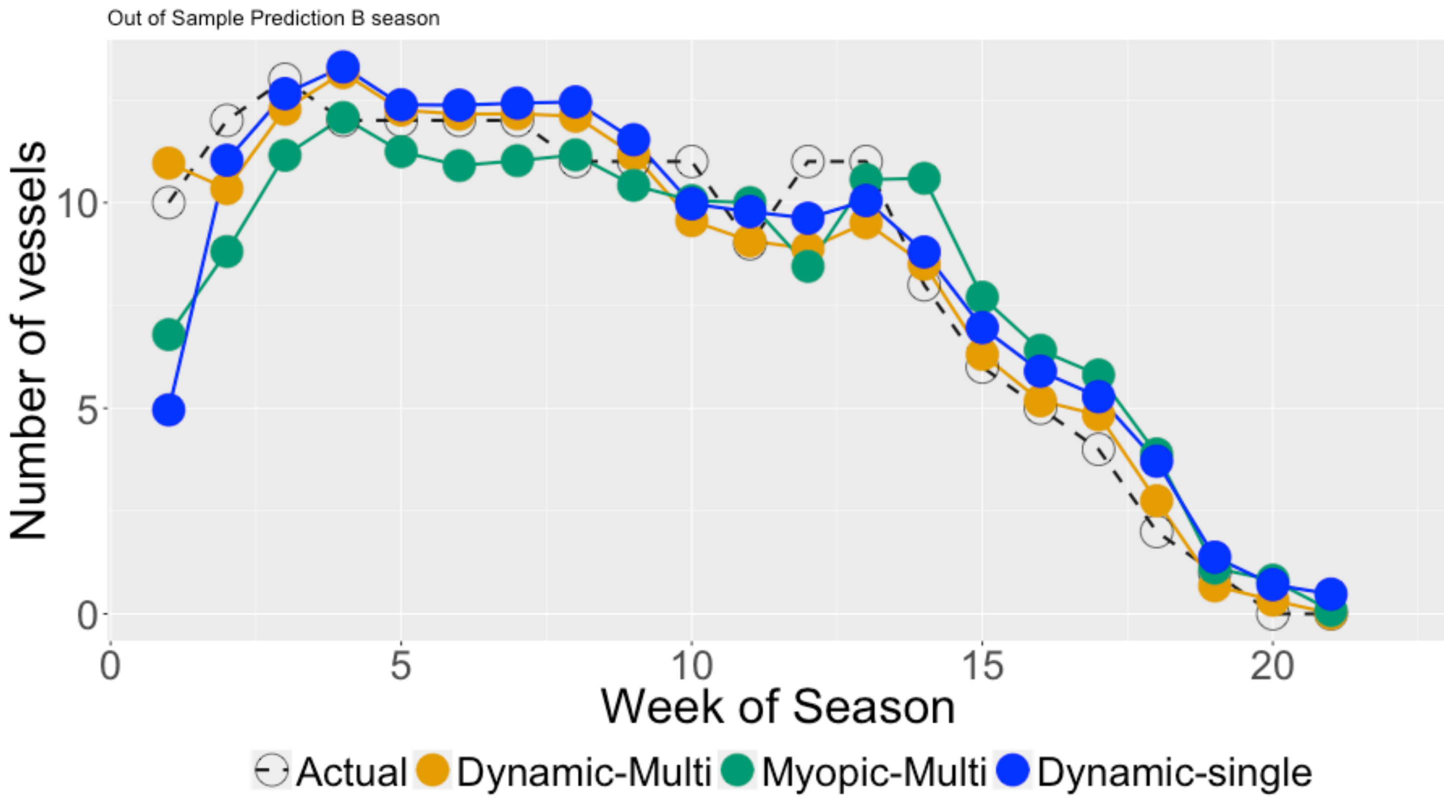
Note: Only Key Variables are shown

$^{*}p<0.05$ $^{**}p<0.01$ $^{***}p<0.001$

Pollock Participation Prediction (A season)



Pollock Participation Prediction (B season)

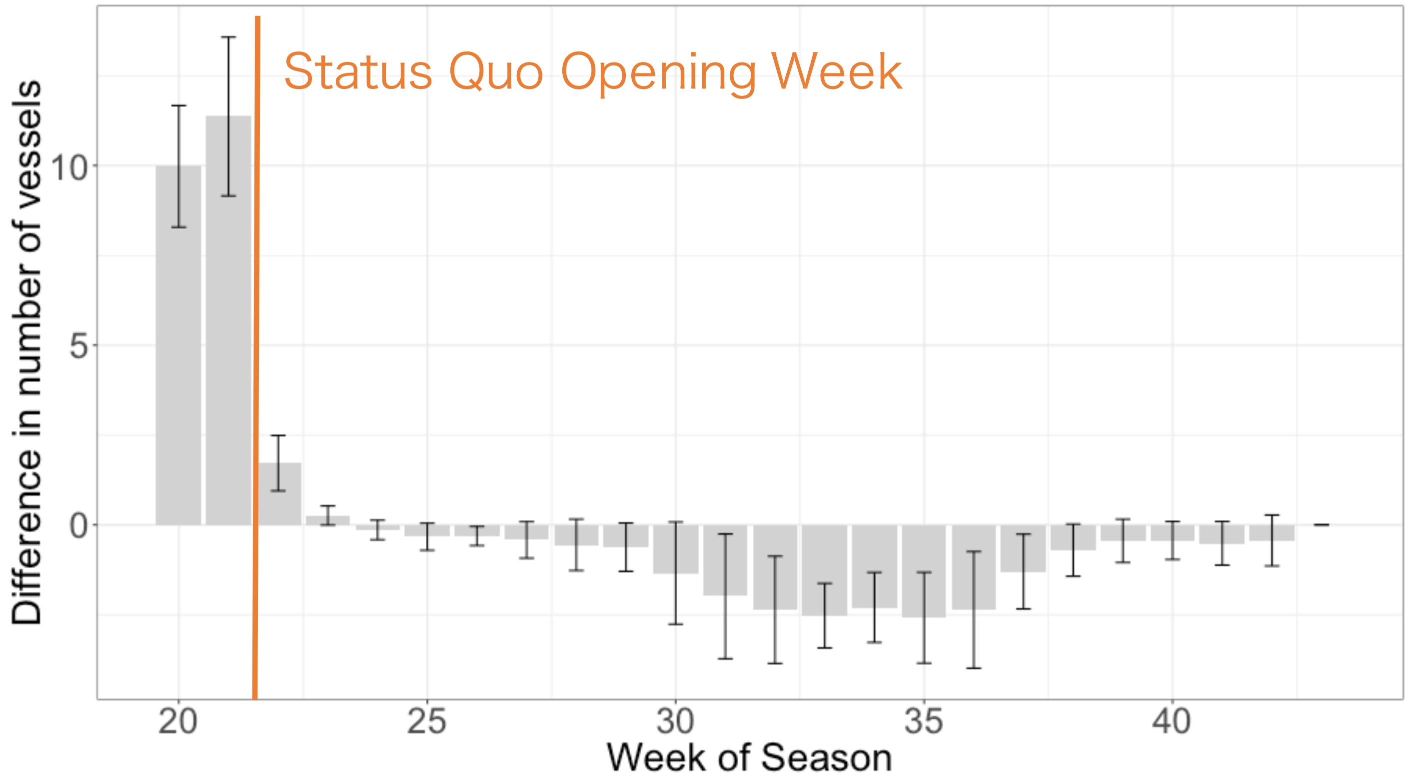


Use in Policy Evaluation

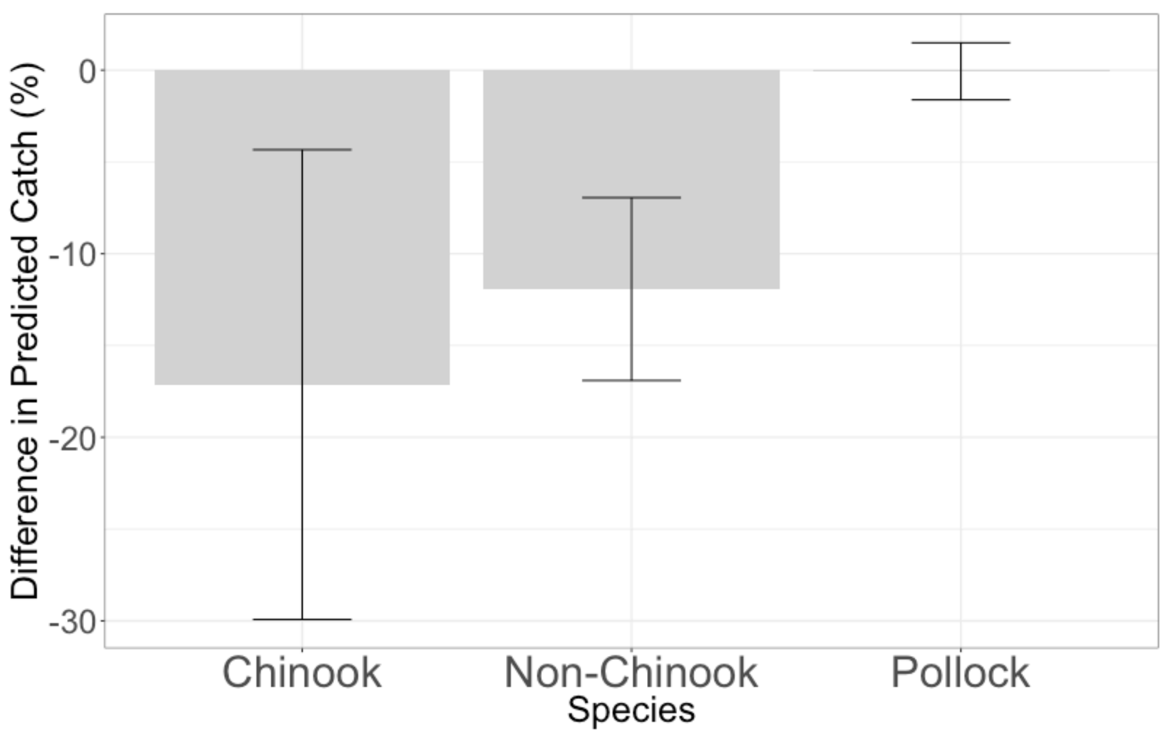
- Setting
  - Proposed Policy: Open B season 2 weeks earlier than status quo.
  - Predict the participation decision by using parameter estimates.
  - Calculate the pollock catch and salmon bycatch based on the predicted participations.
  - Predict based on the data of each year (2005-2013) and take averages.

Counterfactual

Changes in pollock participation as result of earlier B season opening



Counterfactual
Total Changes in catch and bycatch
as result of earlier B season opening



Summary

- Harvester behavior depends on their alternative opportunities
  - Especially under ITQs, dynamic planning is possible.
  - Variable Quota Speed is one way of estimation without solving full dynamic programming.
    - Significantly improves fit over static, single-species models
- Biological/Economic Variables in other fisheries
  - Without them, the estimates may be biased due to omitted opportunity costs.

Appendix

Multi-fisheries problem

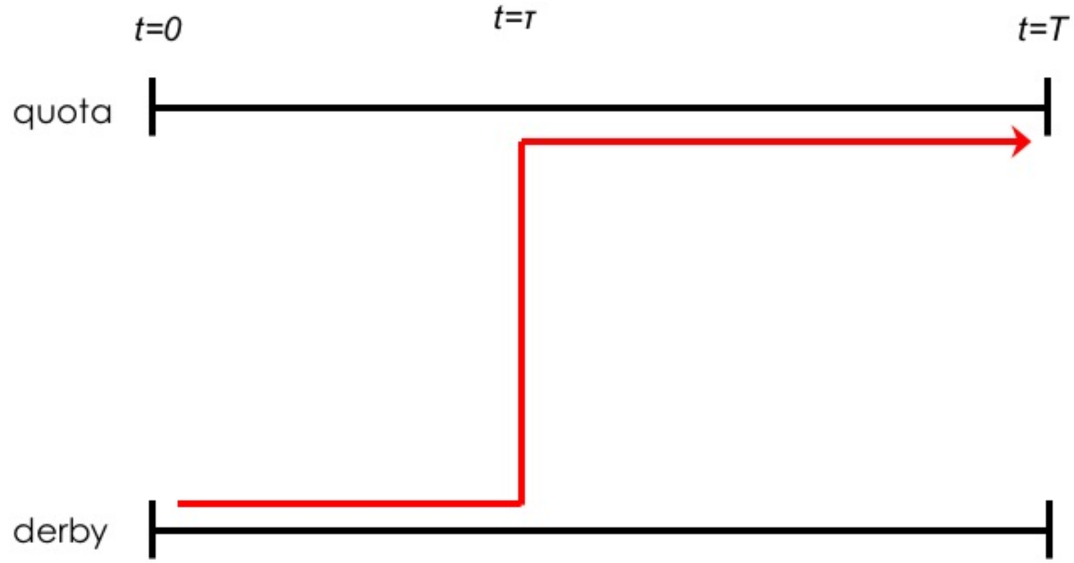
- Most of harvesters participate more than one species during a fishing season.
  - Seasonality
  - Portfolio: decrease the risk
    - Bycatch problem:
- Single fishery management may not be ideal
  - Management on a fishery cause effort spillover into another fishery.
  - Management effect given multiple alternative fisheries is under-researched
- In ITQ fisheries, the allocation is a dynamic problem.
  - Target choice problem is a dynamic problem.

This study

- Model the process of dynamic fisheries choice.
  - Construct the seasonal model of fishery choice
  - Estimate a simple empirical model with dynamic variable
- Apply the model to a fleet in Alaskan Pollock fishery
  - Simulate the policy change with the model estimates, and evaluate the outcome

Theoretical framework

- The harvesters problem (Single agent)
  - Given quota, maximize the seasonal profit from two fisheries : ITQ and TAC management fisheries (1 and 2)
  - Considers time-variant price and bycatch rate
  - Avoid bycatch for (possible) three reasons
    - Constrained by individual bycatch quota (e.g. PSC limit)
    - Social penalty
      - Contemporaneous bycatch (e.g. list of weekly dirty 20 vessels)
      - Cumulative bycatch (e.g. seasonal dirty 20 vessels)
  - Start in fishery 2 (TAC), and move to fishery 1 (ITQ)
    - Assume that the price of fishery 1 rises over time.


t=0
t=τ
t=T
quota
derby

Theoretical Model of dynamic fisheries choice

- Individual problem

$$max \int_0^{\tau} (p^{f2} - c) e_{it}^{f2} dt + \int_{\tau}^{T} \{ [(p_t^{f1} - c) - \delta q_t^b] e_{it}^{f1} - \kappa z_{it} \} dt$$

- Subject to

$$\int_{\tau}^{T} e_{it}^{f1} dt \leq Q_i \ , \quad \int_{\tau}^{T} q_t^b e_{it}^{f1} dt \leq Q_i^b$$ (main and bycatch quota)

$$\dot{z} = q_t^b e_{it}^{f1}$$, (changes in cumulative bycatch)

$$0 \leq e_{it}^{f1} \leq \bar{A} \ , \ 0 \leq e_{it}^{f2} \leq \bar{A}$$ (Capacity constraint)

Theoretical Model of dynamic fisheries choice

- Set up Lagrangian and solve for e_{it}^{f1}, e_{it}^{f2}, and τ.

$$\mathcal{L} = \int_0^{\tau} (p^{f2} - c) e_{it}^{f2} dt +$$

Fishery 2

$$\int_{\tau}^{T} \{[(p_t^{f1} - c) - \delta q_t^b] e_{it}^{f1} - \kappa z_{it} + \mu_t q_t^b e_{it}^{f1}\} dt$$

Fishery 1

$$-\mu_T \int_{\tau}^{T} q_t^b e_{it}^{f1} dt + \int_{\tau}^{T} \dot{\mu}\, z_{it} dt$$

Flow const.

$$+\lambda_1 \left(Q_i - \int_{\tau}^{T} e_{it}^{f1} dt \right) + \lambda_2 \left(Q_i^b - \int_{\tau}^{T} q_t^b e_{it}^{f1} dt \right) +$$

Quota const.

$$\int_0^T \lambda_{3t} (\bar{A} - e_{it}^{f1}) dt + \int_0^T \lambda_{4t} (\bar{A} - e_{it}^{f2})\, dt + \int_0^T \lambda_{5t} e_{it}^{f1} dt + \int_0^T \lambda_{6t} e_{it}^{f2} dt.$$

Capcity const.

Theoretical Model of dynamic fisheries choice

- Solution for effort in fishery 2

$$\left(p^{f2} - c\right) = \lambda_{4t} - \lambda_{6t}$$

  - λ_{4t}: LM on capacity constraint (< A), λ_{6t}: LM on non-negative constraint.
  - => either λ_{4t} or λ_{6t} is positive.
- The LHS is positive => $e_{it}^{f2} = \bar{A}$

Theoretical Model of dynamic fisheries choice

- Solution for effort in fishery 1

$$\left(p_t^{f1} - c\right) - \lambda_1 - [\delta + \kappa(T-t)]q_t^b - \lambda_2 q_t^b = \lambda_{3t} - \lambda_{5t}$$

  - λ_1: shadow cost of main quota, λ_2: shadow cost of bycatch quota
  - λ_{3t}: LM on capacity constraint (< A), λ_{5t}: LM on non-negative constraint.
  - => either λ_{3t} *or* λ_{5t} is positive.
- If the LHS is positive , $e_{it}^{f1} = A^{-}$
- If the LHS is negative, $e_{it}^{f1} = 0$

Theoretical Model of dynamic fisheries choice

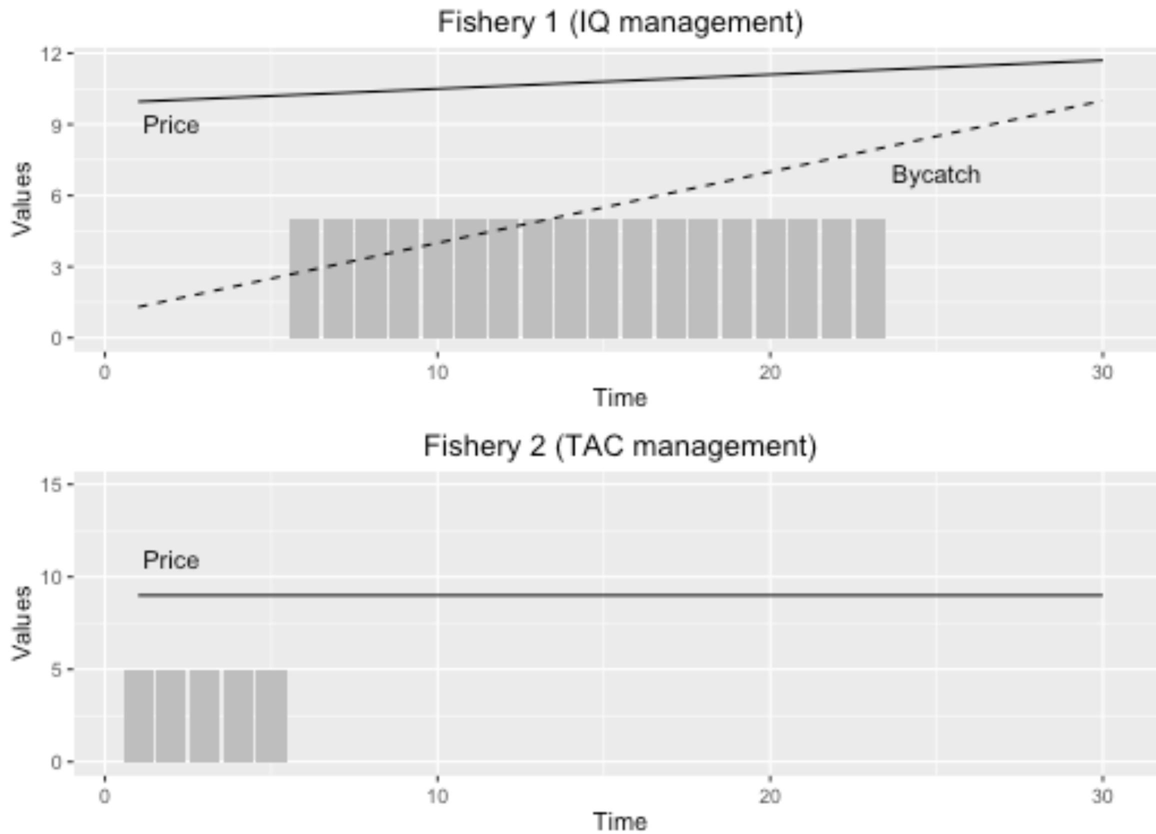
- Solution for τ.

$$\left(p^{f2} - c\right) = \left(p_{\tau}^{f1} - c\right) - \lambda_1 - [\delta + \kappa(T - \tau)]q_{\tau}^{b} - \lambda_2 q_{\tau}^{b}$$

- Impose linear forms on price 1 and bycatch rate, and solve for τ.

$$\tau = \frac{-\left[\beta^{P} - (\delta + \kappa T - \lambda_2)\beta^{b} + \kappa\alpha^{b}\right]}{2\kappa\beta^{b}} + \frac{\sqrt{\left[\beta^{P} - (\delta + \kappa T - \lambda_2)\beta^{b} + \kappa\alpha^{b}\right]^{2} - 4\kappa\beta^{b}[\alpha^{P} - (\delta + \kappa T - \lambda_2)\alpha^{b} - p_2]}}{2\kappa\beta^{b}}$$

Theoretical Prediction



Empirical Model: Random Utility

- Utility: Pollock

$$
\begin{aligned}
&U_{iyw}^{P} \\
&= \alpha^{P} + \beta_1 ExpRev_{iyw} + \beta_2 ExpChinPollRatio_{iyw} \\
&+ \beta_3 SpeedQuotaPoll_{iyw} + \beta_4 SpeedQuotaChin_{iyw} + \beta_5 SwitchCost_{itw} \\
&+ \beta_6 A91_{iyw} + \beta_7 A91_{iyw} \times SpeedQuotaChin_{iyw} \\
&+ \beta_8 A91_{iyw} \times ExpChinPollRatio_{iyw} + \sum_{w} \beta_w^{P} DW_w + \sum_{i} \beta_i^{P} DV_i + \varepsilon_{iyw}^{P}
\end{aligned}
$$

- *ExpRev*: Expected Revenue
- *ExpChinPollRatio*: Expected Chinook-Pollock Ratio, the contemporaneous bycatch measure
- *SpeedQuota*: Speedo of quota usage (next slide)
- *Switch Cost*: Dummy variable (1 if the choice of the week and the week before is different)
- *A91*: Dummy for Amendmend 91 (1 if >=2011)
- *DW*: Dummy variable for week of season (fixed effects)
- *DV*: Dummy variable for individual vessel (fixed effects)

Empirical Model: Quota Speed

- How do we incorporate the dynamic cost of quota usage (λ_1 & λ_2)?
- In theory, the shadow cost is time-invariant (at the t=0)
- In reality, the realization of the catch makes harvesters re-calculate the shadow value in each period.
  - If the usage is too fast (relative to the pace initially planned), the shadow value of the remaining quota gets higher
- We generate a variable which take into account this speed of quota usage.

Weighted time left