

# Catch more to catch less: Estimation of fishing timing choice as bycatch avoidance behavior in the Bering Sea Pollock fishery



Keita Abe

Department of Economics, University of Washington  
(Norwegian School of Economics from August)

[keita43a@uw.edu](mailto:keita43a@uw.edu)

# Harvester Behavior of Bycatch Avoidance

- How does a harvester avoid bycatch?
  - Harvesters exhibit bycatch avoidance behavior under bycatch restrictions.
  - Change fishing gears, locations, and timing. (Smith 2012, Abbott et al. 2015)
  - Under individual quota management, harvester can flexibly choose timing in a season.
- Timing choice is dynamic.
  - Harvester consider quota use allocation over the season.

# This study

- Estimates harvester's in-season decision
  - Which fishery to target under ITQ management with bycatch limit.
- Approach:
  - Discrete choice model with a theory-motivated specification
  - Develop proxy variable that captures in-season dynamics of quota use.
- Application
  - Catcher-Processor fleet of Alaskan Pollock fisheries (Chinook salmon as bycatch)
- Key Result
  - Dynamic Avoidance of bycatch is shown
  - Policy counterfactual with the parameter estimates shows the reduction in bycatch with maintained main target.

# Empirical application

## Alaskan Pollock Fleet

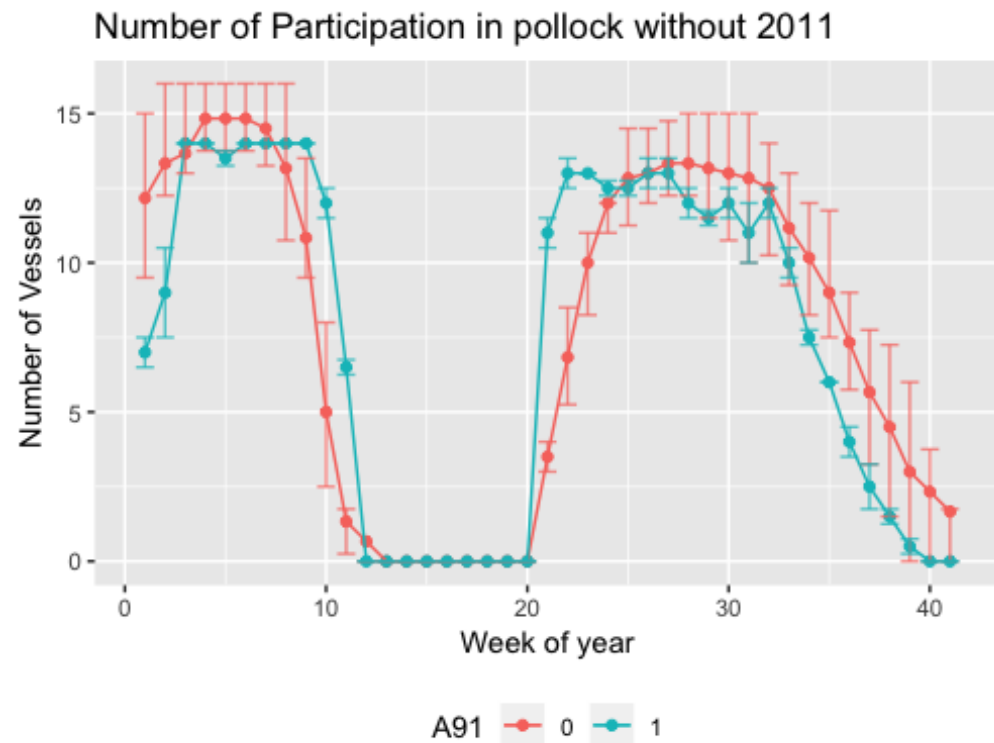
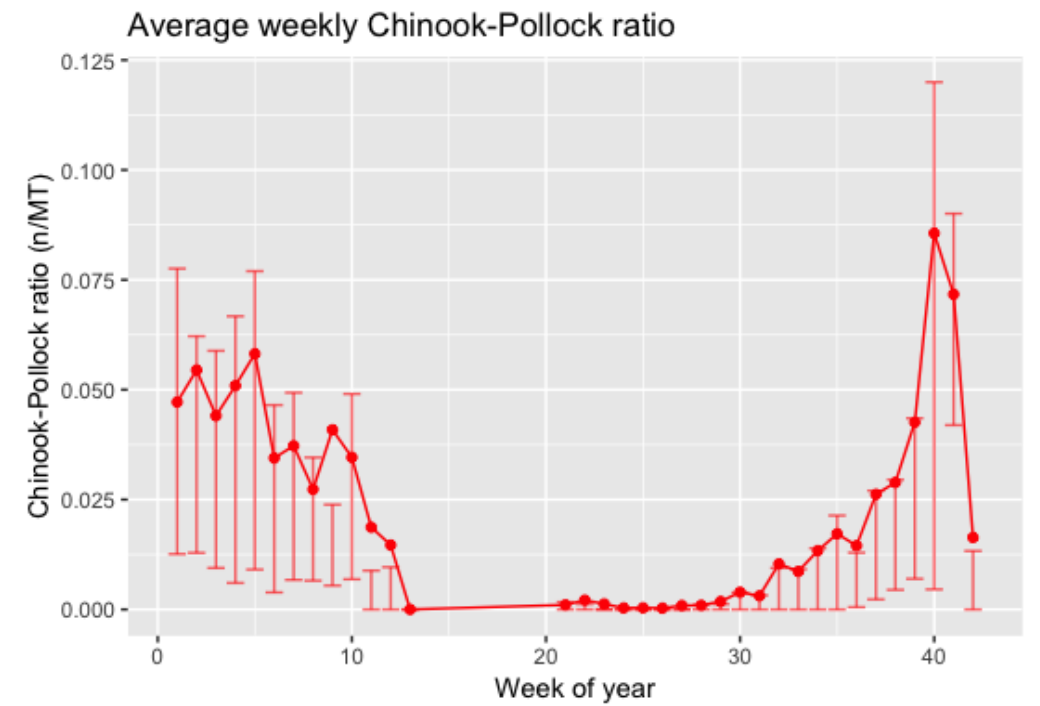
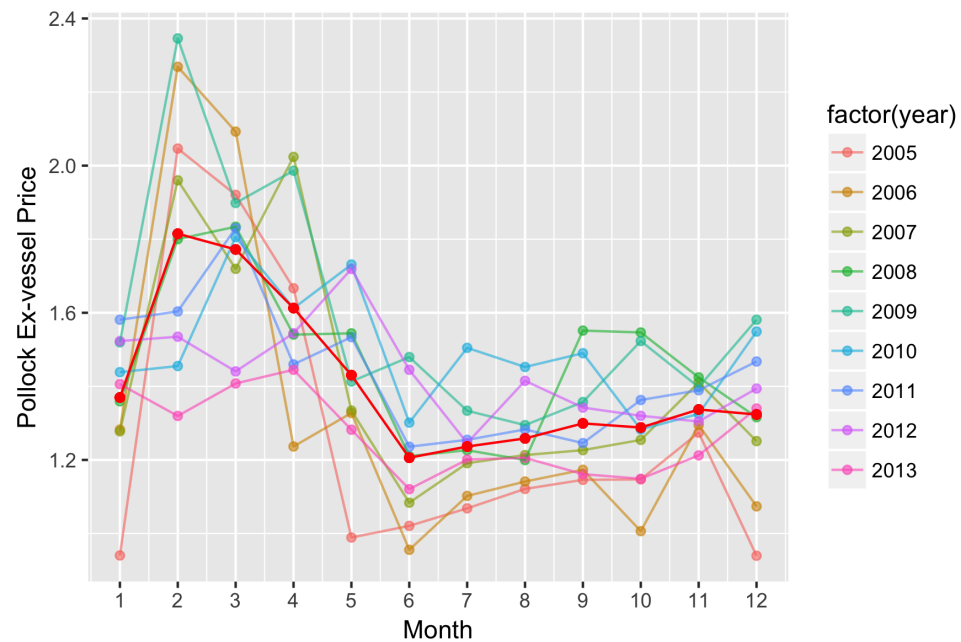
- Offshore fleet (Catcher-Processor)
  - Listed in American Fisheries Act
  - Weekly data, 2005-2013
- Main target
  - Pollock: ITQ management (Cooperative quota)
    - 2 seasons : A (Jan-Jun) & B (Jun-Oct), High value from roe in A season
- Other species
  - Yellowfin Sole (YFS)
    - No more than “traditional catch” level.
  - Pacific Hake: IQ management, in West coast
    - No Individual data available



# Prohibited Species Catch (Bycatch)

- Salmon species is designated as prohibited species catch (PSC).
  - Resource is fully allocated to commercial/subsistence users.
  - All salmon caught as bycatch cannot be retained or sold.
  - Chinook (King) salmon are caught in large numbers in some years
- Amendment 91 of Fisheries Management Plan
  - Management for Chinook salmon bycatch implemented in 2011
  - Limits on salmon bycatch
  - Incentive plan: vessels with bad performance are restricted to access fishing grounds





# Theoretical Framework

- Harvester's problem: To maximize seasonal profit.
  - Harvester's choice: sequence of participation and fisheries decisions. => Choice from two fisheries
    - Fishery 1 is under ITQ management. Fishery 2 is open access.
- Individual's seasonal objective function is

$$V = \int_0^T \{ [d_{it} (\overset{\text{Price of Fish 1}}{p_{1t}} \underset{\text{Catch rate of Fish 1}}{q_{1t}} - c - \gamma \overset{\text{Bycatch rate}}{b_t} q_{1t}) + (1 - d_{it}) (\overset{\text{Price of Fish 2}}{p_{2t}} \underset{\text{Catch rate of Fish 2}}{q_{2t}} - c) ] \} dt$$

- Maximize V subject to constraints

$$\int_0^T d_{it} q_{1t} dt \leq Q_{1i} \quad \text{Main-target quota}$$

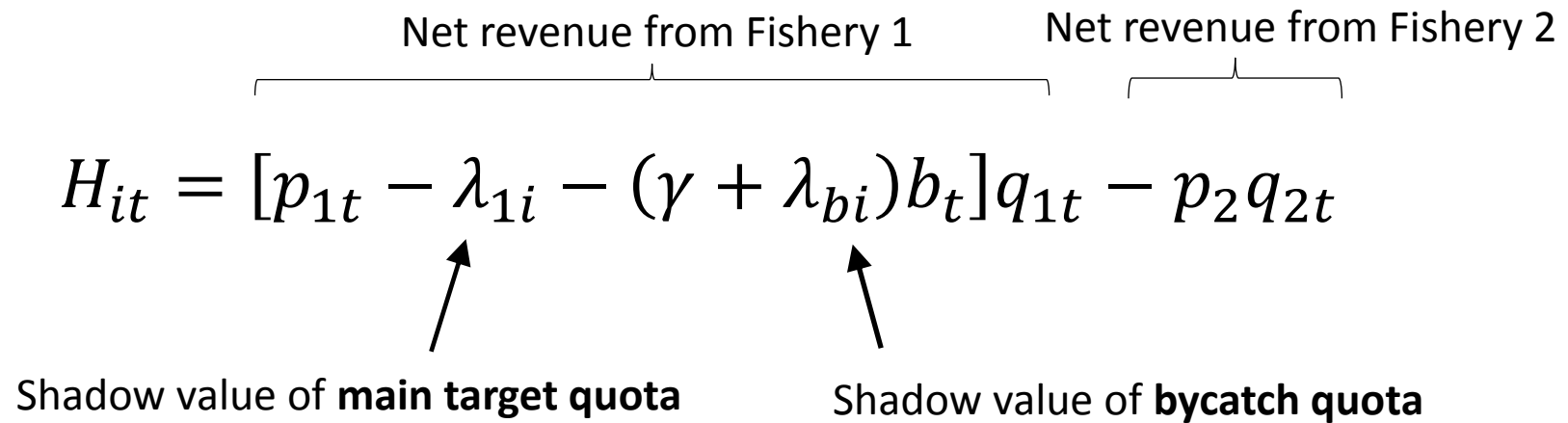
$$\int_0^T d_{it} b_t q_{1t} dt \leq Q_{bi} \quad \text{Bycatch quota}$$

$$0 \leq d_{it} \leq 1 \quad \text{Range of the choice variable}$$

# Harvester's seasonal problem: FOC

- Solution: Participation Index

$$H_{it} = \overbrace{[p_{1t} - \lambda_{1i} - (\gamma + \lambda_{bi})b_t]q_{1t}}^{\text{Net revenue from Fishery 1}} - \overbrace{p_2 q_{2t}}^{\text{Net revenue from Fishery 2}}$$

  
Shadow value of **main target quota**      Shadow value of **bycatch quota**

- Decision rule:  $d_{it} = I\{H_{it} \geq 0\}$



# Comparative Statics: Dynamic Avoidance

- Suppose the main target quota binds.  $\lambda_{1i} > 0$
- The total derivative of the decision in period  $t$  with respect to the bycatch rate in period  $r \neq t$  is

$$\begin{aligned} \frac{\partial d_{it}}{\partial H_{it}} \frac{dH_{it}}{db_r} &= \frac{\partial d_{it}}{\partial H_{it}} \left( \frac{\partial H_{it}}{\partial \lambda_1} \frac{\partial \lambda_1}{\partial b_r} \right) \\ &= \frac{\partial d_{it}}{\partial H_{it}} \left( q_{1r} \gamma \frac{\left( \frac{\partial d_{it}}{\partial H_{it}} \right) q_{1r}^2}{\int_0^T \left( \frac{\partial d_{is}}{\partial H_{it}} \right) q_{1s}^2 ds} \right) \\ &> 0 \end{aligned}$$

Effect of change is through the shadow value of main target quota

More likely to target Fishery 1 if future bycatch rate increases!

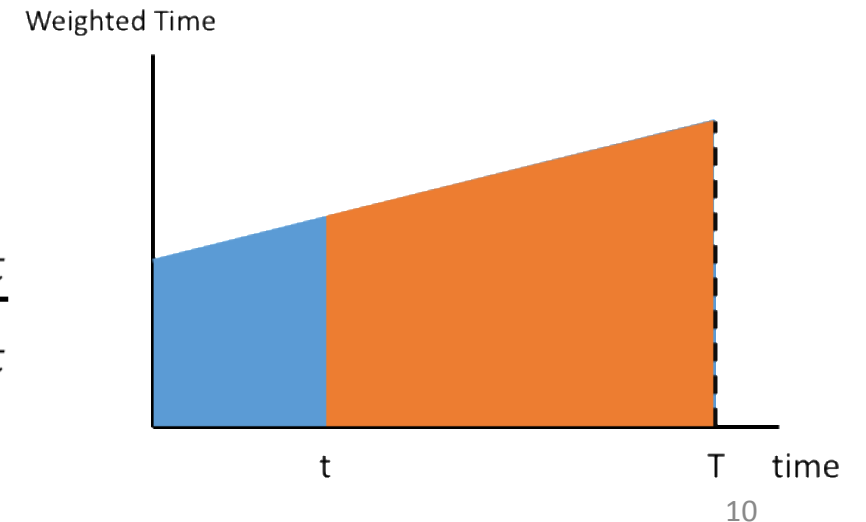
# Empirical Question

- Does the harvesters exhibits the dynamic behavior?
  - Dynamic Avoidance?
- => Does quota usage influences the choice of harvesters?

# Capturing Dynamic Quota Use

- Proxy variable: Quota Speed
  - Capture the pace of actual quota use relative to “potential” use
    - => Each period, harvesters recalculate shadow cost.
  - Compare the quota left relative to the time left
  - Remaining time is weighted by the expected CPUE and probability of participation
    - If the expected CPUE is high, “more time” to use quota given number of weeks remaining in the season.
    - High chance of participation -> “more time”
  - The value lies between -1 and +1.
    - If it is negative, the usage is too fast.

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



# Empirical Model

State Variable:

Quota Speed, Bycatch Quota Speed,

Policy (A91)

$$U_{iyw} = \beta^{poll}(QSpeed_{iyw})EREV_{iyw}^{poll} + \beta^{yfs}EREV_{iyw}^{yfs} \\ + \gamma (QSpeed_{iyw}, A91)ECPR_{iyw} + \phi'Z_{iyw} + \xi_i + \varepsilon_{iyw}$$

Fixed Effects

Covariates: Switching cost, # of vessel in  
hake

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

	Dependent variable:				
	Pollock Target Dummy				
	(1)	(2)	(3)	(4)	(5)
EREV (Poll)	0.023 (0.032)	0.137** (0.042)	0.148*** (0.043)	0.130** (0.045)	0.155*** (0.044)
EREV (YFS)	-0.808*** (0.232)	-0.621** (0.237)	-0.489* (0.239)	-0.523* (0.246)	-0.498* (0.241)
Expected Chin-Poll Ratio	186.550*** (21.806)	227.954*** (27.200)	243.141*** (28.046)	263.979*** (32.707)	
Switch Cost	-3.554*** (0.479)	-5.060*** (0.650)	-5.645*** (0.708)	-4.738*** (0.696)	-2.683*** (0.565)
EREV (Poll) x Q Speed		0.121* (0.059)	0.274*** (0.077)	0.210** (0.080)	0.208*** (0.028)
ECPR x Q Speed		58.039 (38.543)	-5.334 (46.882)	-1.085 (49.699)	
ECPR x A91	3.855 (5.871)	3.111 (6.235)	-3.064 (6.512)	-13.622 (7.071)	
ECPR x Price (Poll)					205.772*** (24.091)
EREV (Poll) x Q Speed x A91			-0.386* (0.184)	-0.975 (0.550)	-0.476** (0.155)
EREV (Poll) x BQ Speed x A91				0.537 (0.479)	0.323* (0.127)
ECPR x Q Speed x A91			76.976 (147.617)	374.089 (333.766)	
ECPR x BQ Speed x A91				-136.094 (231.361)	
AIC	459.03	373.23	349.9	330.57	320.01
LR test		89.806***	27.328***	23.324***	
Observations	1,356	1,356	1,356	1,356	1,356
R <sup>2</sup>	0.274	0.320	0.334	0.345	0.347
Log Likelihood	-224.517	-179.614	-165.950	-154.287	-153.004

Note: \* \*\* \*\*\* p<0.001

# A Season Result

Positive coefficient on expected bycatch rate?  
=> The timing of high price and high bycatch overlaps

Positive coefficient on Q speed!  
- If slow (=less shadow cost), target pollock.

	Elasticities
EREV (Pollock)	0.267
EREV (YFS)	-0.139
Switch Cost	-0.048
EREV x Q Speed	0.019
ECPR x Price	1.287
EREV x Q Speed x A91	0.000
EREV x BQ Speed x A91	0.083

	Dependent variable:				
	(1)	(2)	(3)	(4)	(5)
EREV (Poll)	-0.096 (0.101)	-0.134 (0.106)	-0.134 (0.106)	-0.146 (0.108)	
EREV (YFS)	0.533 (0.516)	0.494 (0.526)	0.535 (0.529)	0.521 (0.531)	
Expected Chin-Poll Ratio	-19.497 (26.293)	-54.890 (35.371)	-56.319 (35.178)	-68.702 (36.127)	-10.572 (23.594)
Switch Cost	-5.188** (0.611)	-5.103*** (0.645)	-5.112** (0.643)	-5.107*** (0.650)	-5.190*** (0.390)
Number of Hake Vessels	-0.100** (0.031)	-0.092** (0.032)	-0.097** (0.032)	-0.101** (0.033)	-0.087** (0.027)
EREV (Poll) x Q Speed		0.011 (0.079)	0.056 (0.103)	0.045 (0.102)	
ECPR x Q Speed		99.885 (57.794)	103.884 (89.455)	104.914 (81.991)	97.030* (41.402)
ECPR x A91	17.008 (26.460)	22.659 (33.156)	26.081 (33.810)	4.150 (46.529)	
EREV (Poll) x Q Speed x A91			-0.120 (0.148)	-0.118 (0.151)	
EREV (Poll) x BQ Speed x A91				-0.960 (1.520)	
ECPR x Q Speed x A91			2.285 (117.855)	26.014 (125.193)	
ECPR x BQ Speed x A91				699.942 (1,194.110)	
AIC	475.1	471.25	474.17	476.96	466.75
LR test		7.846*	1.085	1.203	
Observations	1,983	1,983	1,983	1,983	1,983
R <sup>2</sup>	0.299	0.302	0.302	0.303	0.345
Log Likelihood	-231.548	-227.625	-227.083	-226.481	-229.376

Note: \*p<0.05 \*\*p<0.01 \*\*\*p<0.001

## B Season Result

Not significant!

Not much variation in revenue?

Negative, but not significant

Positive

⇒ If slow (less shadow cost), willing to incur more bycatch to target pollock.

⇒ Not to catch later when the bycatch is very high.

	Elasticities
ECPR	-0.02
Switch Cost	-0.14
# of Hake vessels	-0.05
ECPR x Q Speed	0.02

# Result Summary

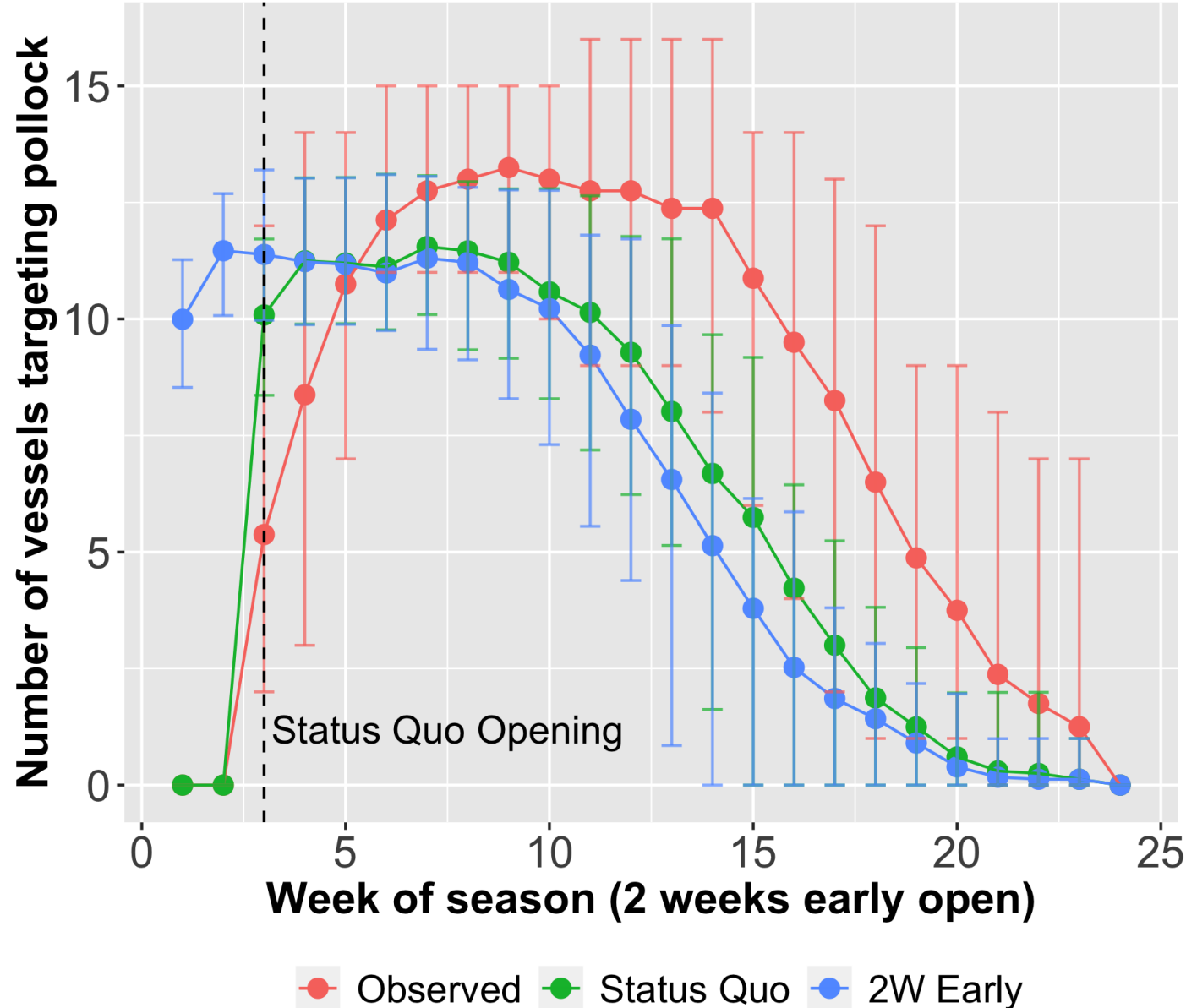
- A season
  - Driven by the revenue and target quota use
  - No Bycatch Avoidance?
    - Timing of bycatch and timing of high price overlap
    - Difficulty of identification with Weekly data
- B season
  - Not sensitive to change in revenue (CPUE or price)
    - Not much variation
  - Dynamic avoidance is the main reason
    - Catch as much pollock as they can before salmon comes.

# Use in Ex-ante Policy Evaluation

- Setting
  - Proposed Policy: Open B season 2 weeks earlier than status quo.
    - To avoid Chinook salmon bycatch in later season.
  - Predict the participation decision by using parameter estimates.
  - Predict catches based on the data of each year (2005-2013) and take averages.
- Questions
  - Is Pollock catch actually maintained?
  - Does Chinook salmon bycatch decrease?
  - What happens to Non-Chinook salmon bycatch?



## Weekly number of vessels targeting Pollock

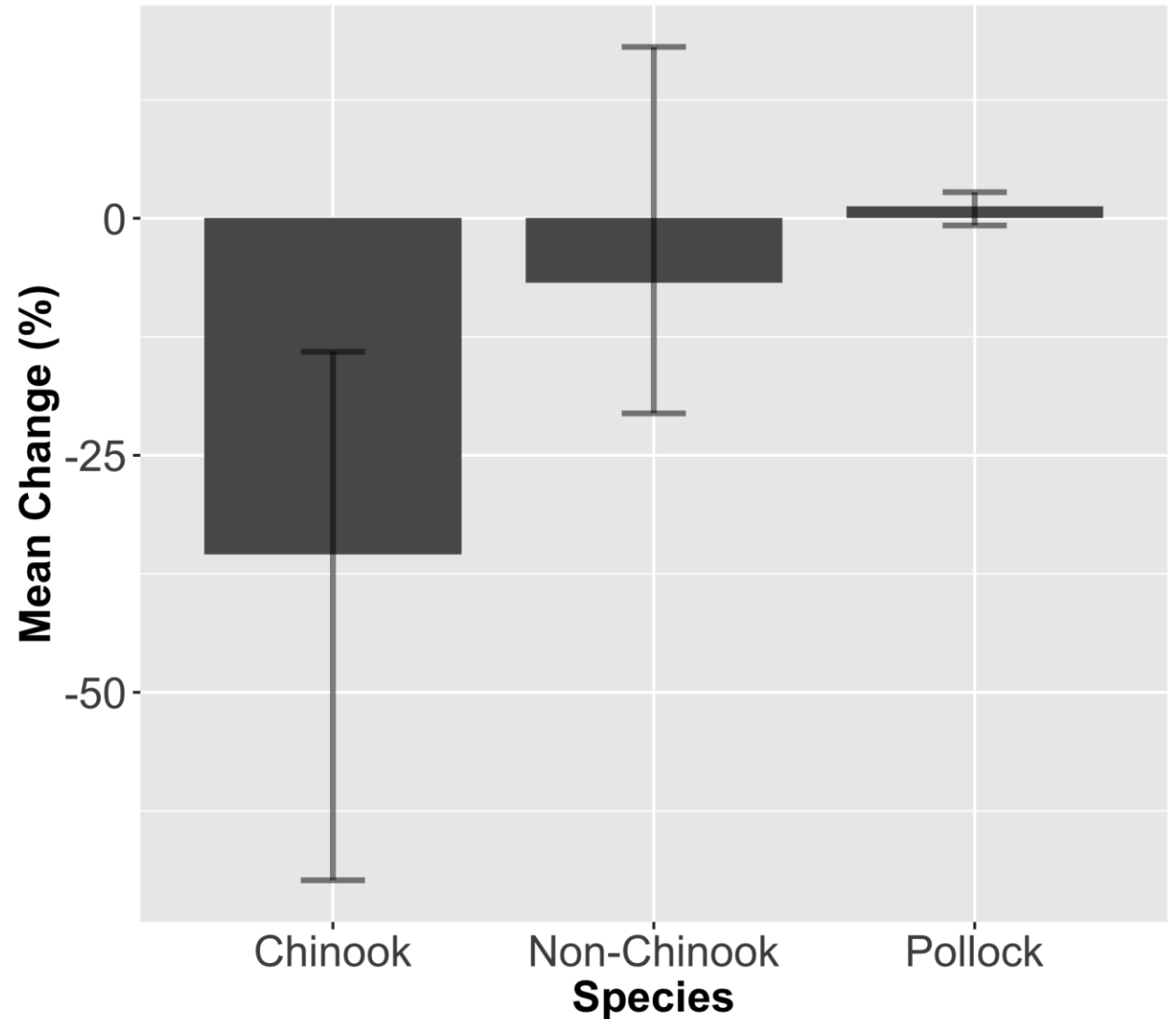


- Underpredicted?
  - Sum of probability v.s. Number of vessels
  - No Fixed Effects

## Change in annual catch and bycatch

Change in catches of each species by policy simulation

	Mean	Min	Max
Chinook (n)	-203.071	-507.851	-41.848
Non-Chinook (n)	-2050.332	-7795.592	273.602
Pollock (MT)	3903.272	-1735.942	9655.766



# Conclusion

- Choice of participation timing is a margin of dynamic avoidance
- Theory-motivated specification enables estimation of dynamic behavior
  - Variable Quota Speed is one way of estimation without solving full dynamic programming.
    - Significantly improves fit over static model
- Combinations with other margins?
  - Internal margin (e.g. number of tow in a week)
  - Location choices

Keita Abe

Department of Economics, University of Washington

keita43a@uw.edu



# Appendix: Chapter 2

# 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.

# Theoretical Model: Harvester's seasonal problem

- Set up
  - A harvester choose a fishery from two fisheries (Fishery 1 and 2) in each period
- The individual's seasonal objective function is

$$V = \int_0^T \{ [d_{it} (p_{1t} q_{1t} - c - \gamma b_t q_{1t}) + (1 - d_{it}) (p_{2t} q_{2t} - c)] \} dt$$

- Incentive of bycatch avoidance
  - Bycatch quota
  - Direct cost  $\gamma$ 
    - E.g. Restriction on other margins. Fear of regulatory changes if there is excessive bycatch

Price of Fish 1

Bycatch rate

Price of Fish 2

Catch rate of Fish 1

Catch rate of Fish 2

# Theoretical Model (Cont.)

- The individual problem is

$$\begin{array}{ll} \max_{\{d_{it}\}} V & \text{s.t.} \\ \int_0^T d_{it} q_{1t} dt \leq Q_{1i} & \text{Main-target quota} \\ \int_0^T d_{it} b_t q_{1t} dt \leq Q_{bi} & \text{Bycatch quota} \\ 0 \leq d_{it} \leq 1 & \text{Range of the choice variable} \end{array}$$

- Set up Lagrangian

$$L = V + \lambda_{1i} \left[ Q_{1i} - \int_0^T d_{it} q_{1t} dt \right] + \lambda_{bi} \left[ Q_{bi} - \int_0^T d_{it} b_t q_{1t} dt \right] + \eta_{1t} d_{it} + \eta_{2t} (1 - d_{it})$$

# Harvester's seasonal problem: FOC

- Get the expression below from the FOC

$$H_{it} = [p_{1t} - \lambda_{1i} - (\gamma + \lambda_{bi})b_t]q_{1t} - (p_2 - \lambda_{2i})q_{2t}$$

- Where  $H_{it} = \eta_{2it} - \eta_{1it}$
- we can write the decision variables as indicator functions.

$$d_{it} = I\{H_{it} \geq 0\}$$

# Comparative statics: Price 1

- Total Derivative w.r.t. price 1 in t

$$\frac{\partial d_{it}}{\partial H_{it}} \frac{dH_{it}}{dp_{1t}} = \frac{\partial d_{it}}{\partial H_{it}} \left( \frac{\partial H_{it}}{\partial p_{1t}} + \frac{\partial H_{it}}{\partial \lambda_{1i}} \frac{\partial \lambda_{1i}}{\partial p_{1t}} I\{\lambda_{1i} > 0\} + \frac{\partial H_{it}}{\partial \lambda_{bi}} \frac{\partial \lambda_{bi}}{\partial p_{1t}} I\{\lambda_{bi} > 0\} \right)$$

- Effect of change in price 1: Direct effect +  
(effect through shadow value of main-target quota and/or bycatch quota)

# Change in shadow cost w.r.t. price

$$\frac{\partial \lambda_{1i}}{\partial p_{1t}} = \frac{\left( \frac{\partial d_{it}}{\partial H_{it}} \right) q_{1t}^2}{\int_0^T \left( \frac{\partial d_{is}}{\partial H_{is}} \right) q_{1s}^2 ds}$$

## Interpretation?

If the change in the price causes the change in the behavior, the catch changes. If this increment is large relative to the whole change in total seasonal catch, it eats large portion of quota. Hence, the shadow value of the quota increase more.

# Proposition 1: Change in the price of Fishery One

- Suppose that the harvester maximize the ex-ante seasonal profit by choosing one from two fisheries in each period given the constraints:
- (1) Assuming that the main target species individual quota is binding ( $\lambda_{1i} > 0$ ), an increase in the price of Fishery One in a given period **raises the chance** to participate in Fishery One in the period as a direct effect, but decreases the chance as the shadow cost of the main target species individual quota rises.

# Proposition 1: Change in the price of Fishery One

- (2) Assuming that the bycatch individual quota is binding ( $\lambda_{bi} > 0$ ), an increase in the price of Fishery One in a given period raises the chance to participate in Fishery One in the period as a direct effect, but decreases the chance as the shadow cost of the bycatch individual quota rises.



# Corollary 1

- Assuming that the neither individual quota is binding, an increase in the price of Fishery One raises the chance to participate in Fishery One. (No dynamic effect).

# Comparative statics: Bycatch Rate

- Total derivative w.r.t. bycatch rate in t

$$\frac{\frac{\partial d_{it}}{\partial H_{it}} \frac{dH_{it}}{db_t}}{\frac{\partial H_{it}}{\partial b_t}} = \frac{\partial d_{it}}{\partial H_{it}} \left( \frac{\partial H_{it}}{\partial b_t} + \frac{\partial H_{it}}{\partial \lambda_1} \frac{\partial \lambda_1}{\partial b_t} I\{\lambda_{1i} > 0\} + \frac{\partial H_{it}}{\partial \lambda_{bi}} \frac{\partial \lambda_{bi}}{\partial b_t} I\{\lambda_{bi} > 0\} \right)$$

# Comparative statics: Bycatch Rate

- Total derivative w.r.t. bycatch rate in t

$$\begin{aligned}
 \frac{\partial d_{it}}{\partial H_{it}} \frac{dH_{it}}{db_t} &= \frac{\partial d_{it}}{\partial H_{it}} \left( \frac{\partial H_{it}}{\partial b_t} + \frac{\partial H_{it}}{\partial \lambda_1} \frac{\partial \lambda_1}{\partial b_t} I\{\lambda_{1i} > 0\} + \frac{\partial H_{it}}{\partial \lambda_{bi}} \frac{\partial \lambda_{bi}}{\partial b_t} I\{\lambda_{bi} > 0\} \right) \\
 &= \frac{\partial d_{it}}{\partial H_{it}} \left( -(\gamma + \lambda_{bi})q_{1t} - q_{1t} \cdot -(\gamma + \lambda_{bi}) \frac{\left( \frac{\partial d_{it}}{\partial H_{it}} \right) q_{1t}^2}{\int_0^T \left( \frac{\partial d_{is}}{\partial H_{it}} \right) q_{1s}^2 ds} I\{\lambda_{1i} > 0\} \right. \\
 &\quad \left. - b_t q_{1t} \cdot \frac{\left( d_{it} q_{1t} - \frac{\partial d_{it}}{\partial H_{it}} (\gamma + \lambda_{bi}) b_t q_{1t}^2 \right)}{\int_0^T \left( \frac{\partial d_{is}}{\partial H_{is}} \right) b_s^2 q_{1s}^2 ds} I\{\lambda_{bi} > 0\} \right)
 \end{aligned}$$

## Proposition 2: change in bycatch rate

- Suppose that the harvester maximize the ex-ante seasonal profit by choosing one from two fisheries in each period given the constraints:
- (1) Assuming that the main target individual quota is binding ( $\lambda_{1i} > 0$ ), an increase in the bycatch rate in a given period reduces the chance to participate in Fishery One in the period as a direct effect, but raises the chance as the shadow cost of the main target species individual quota drops.

## Proposition 2: change in bycatch rate

- (2) Assuming that the bycatch individual quota is binding ( $\lambda_{bi} > 0$ ), an increase in the bycatch rate in a given period reduces the chance to participate in Fishery One in the period as a direct effect, but the dynamic effect on the chance is indeterminate since the shadow cost may increase or decrease depending on the magnitude of catch rate, bycatch rate and bycatch costs.

## Corollary 2

- Assuming that the neither individual quota is binding, an increase in the bycatch rate in a given period reduces the chance to participate in Fishery One. (No dynamic effect).

# Dynamic Avoidance

- Suppose the main target quota binds.
- The total derivative of the decision in period  $t$  with respect to the bycatch rate in period  $r \neq t$  is

$$\begin{aligned} \frac{\partial d_{it}}{\partial H_{it}} \frac{dH_{it}}{db_r} &= \frac{\partial d_{it}}{\partial H_{it}} \left( \frac{\partial H_{it}}{\partial \lambda_1} \frac{\partial \lambda_1}{\partial b_r} I\{\lambda_{1i} > 0\} \right) \\ &= \frac{\partial d_{it}}{\partial H_{it}} \left( q_{1r} \gamma \frac{\left( \frac{\partial d_{it}}{\partial H_{it}} \right) q_{1r}^2}{\int_0^T \left( \frac{\partial d_{is}}{\partial H_{it}} \right) q_{1s}^2 ds} \right) \\ &> 0 \end{aligned}$$

More likely to target Fishery 1 if future bycatch rate increases!

# Proposition 3: Change in quota

- *Assuming that the main target species individual quota is binding ( $\lambda_{1i} > 0$ ), an increase in the main target species quota may facilitate the participation in Fishery One in any periods as the shadow cost of the main target species individual quota drops.*

$$\frac{dd_t}{dQ_{1i}} = \frac{\partial d_t}{\partial H_{it}} \frac{\partial H_{it}}{\partial \lambda_{1i}} \frac{\partial \lambda_{1i}}{\partial Q_{1i}} = \frac{\partial d_{it}}{\partial H_{it}} \left( \frac{q_{1t}}{\int_0^T \left( \frac{\partial d_{is}}{\partial H_{is}} \right) q_{1s}^2 ds} \right) \geq 0$$

More likely to target Fishery 1 if quota increases.  
=> Because shadow cost of quota gets lower.



# Note: Derivative of Indicator function

- The derivative of the indicator function at the threshold does not exist in a usual sense because of the discontinuity, but we can define it using Dirac Delta Function.

$$\frac{\partial d_{it}}{\partial H_{it}} = \delta(H_{it})$$

- where

$$\delta(x) = \begin{cases} 0 & \text{if } x \neq 0 \\ 1 & \text{if } x = 0 \end{cases}$$

- The comparative statics of participation are expressed as

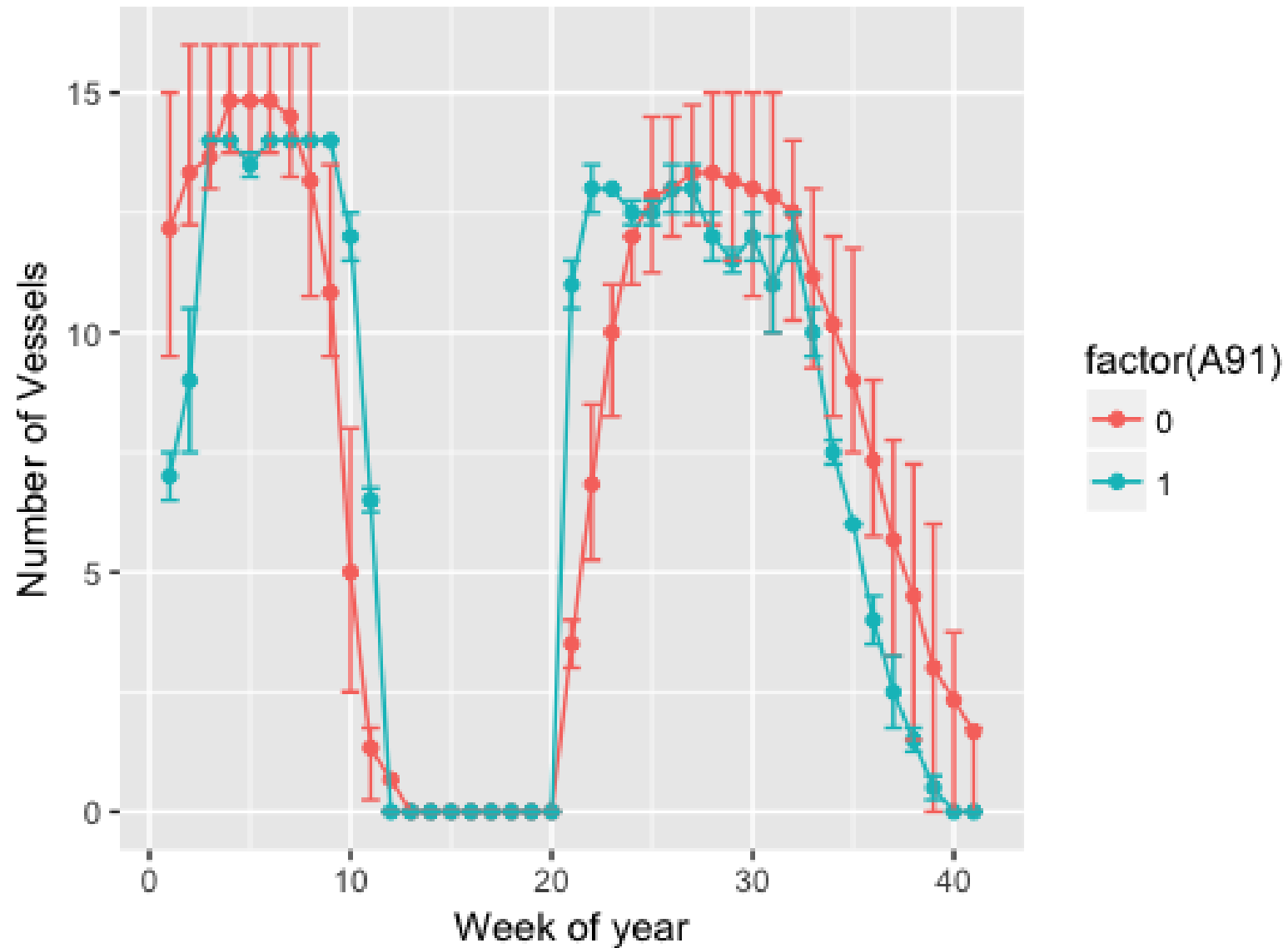
$$\frac{\partial d_{it}}{\partial x_{it}} = \frac{\partial d_{it}}{\partial H_{it}} \frac{\partial H_{it}}{\partial x_{it}}$$

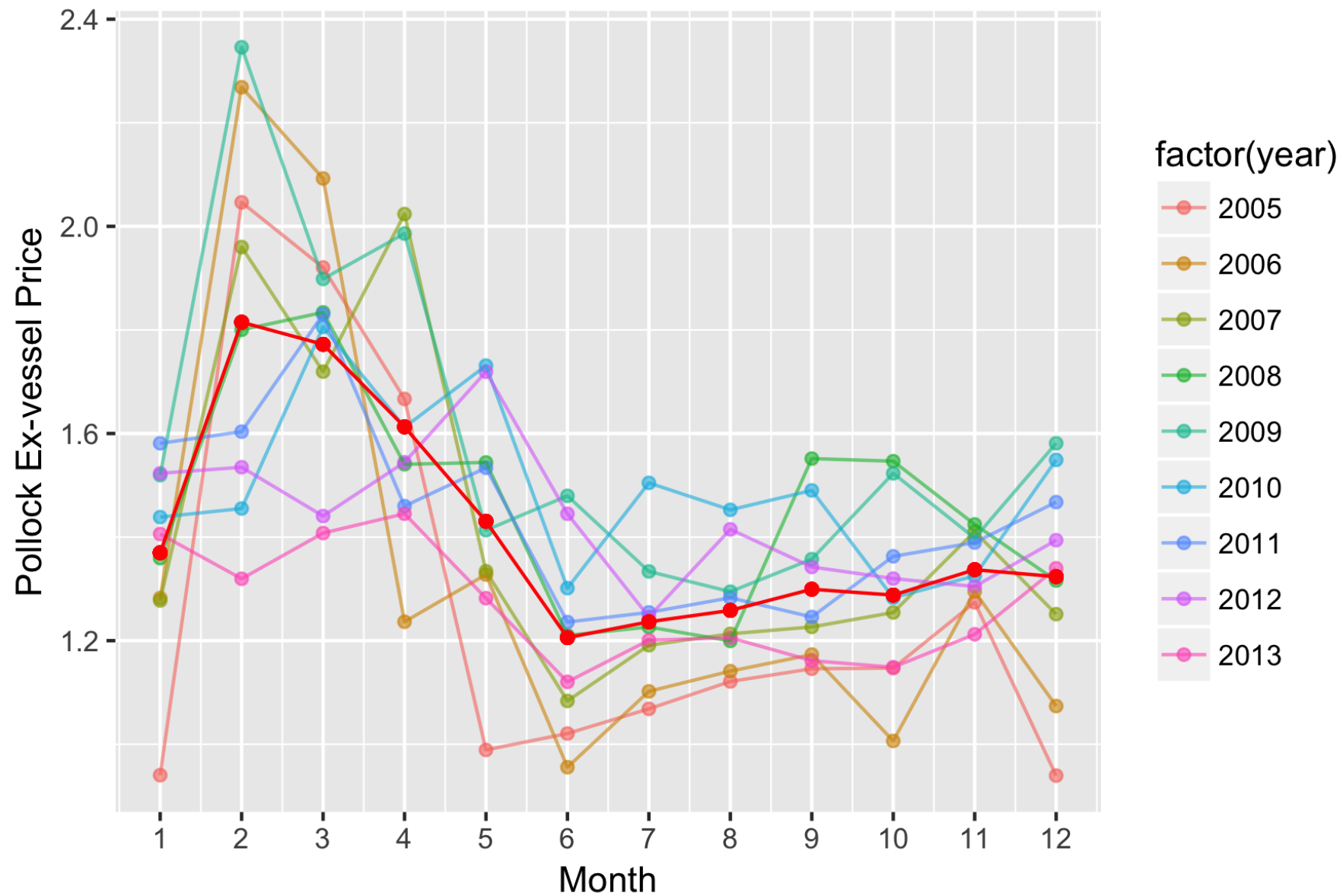
# Amendment 91

- Management for Chinook salmon bycatch implemented in 2011
- Limits on salmon bycatch
  - → individual bycatch quota
  - But they are not binding in general
- Time-and-area-based "hot-spot" avoidance
  - Bad Chinook bycatch performance vessels are restricted to access the fishing grounds.

Does this policy affect timing choice behavior?  
Through  $\gamma$  in the theoretical model.

## Number of Participation in pollock without 2011

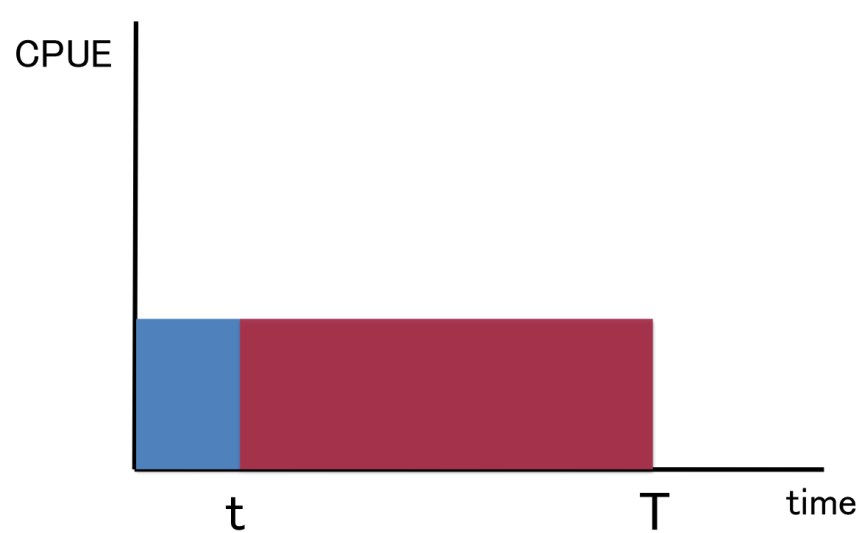
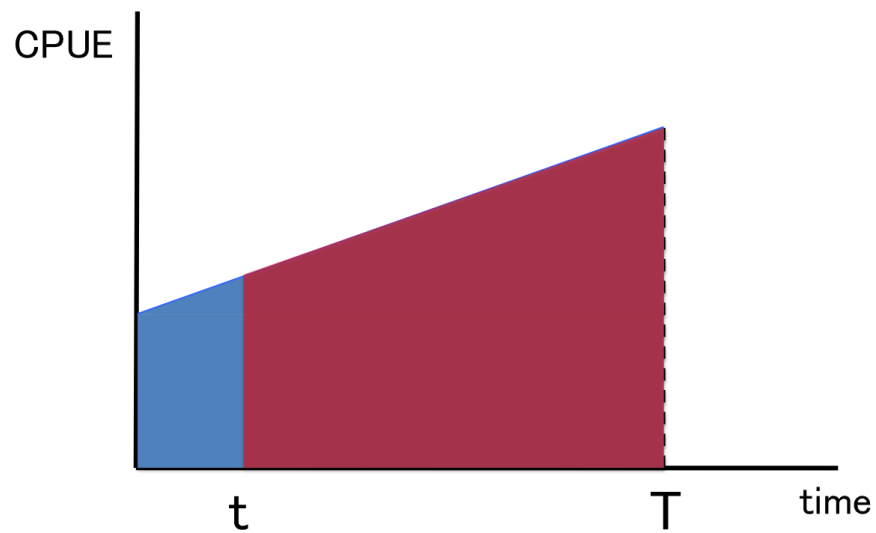
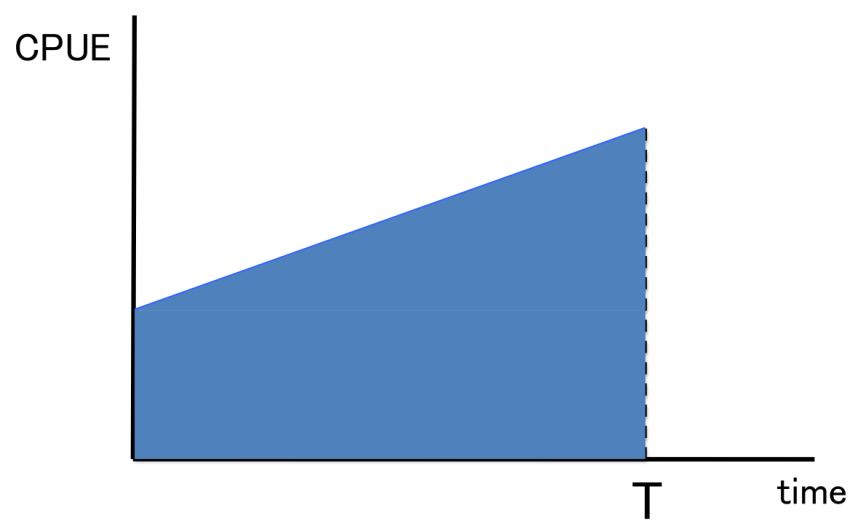
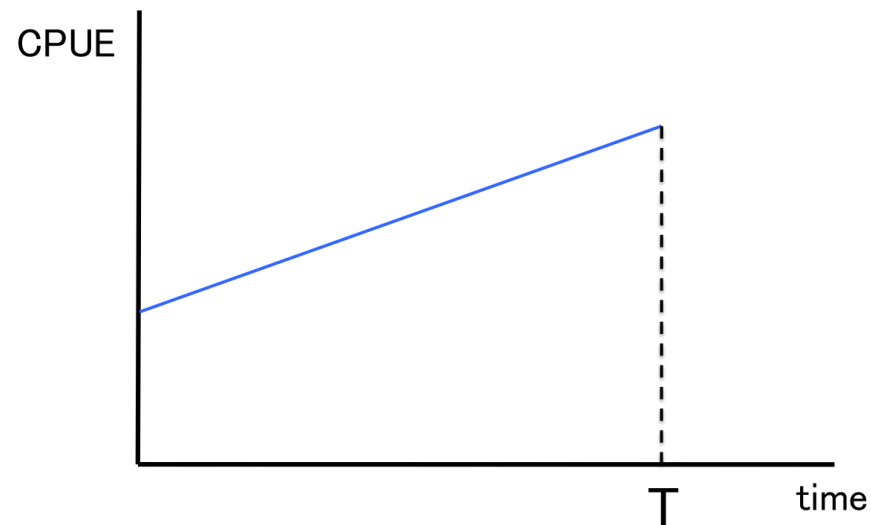




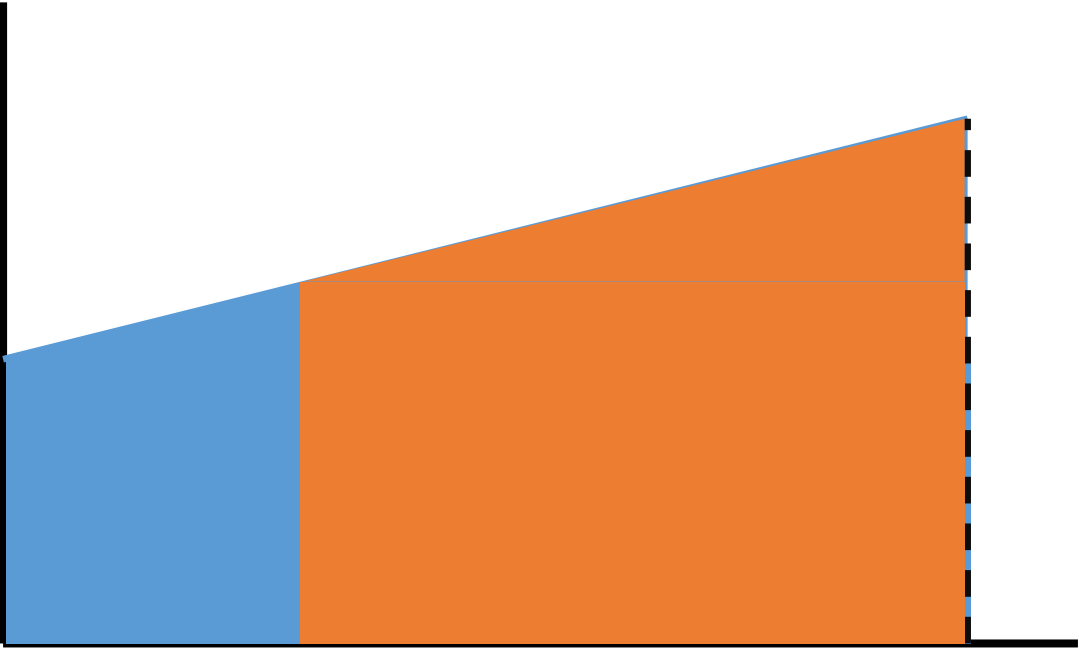
# Empirical Model: Quota Speed

- How do we incorporate the dynamic cost of quota usage ( $\lambda_1$  &  $\lambda_2$ )?
- In theory, the shadow cost is time-invariant (at the  $t=0$ )
- In reality, the realization of the catch makes harvesters recalculate 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



Weighted Time

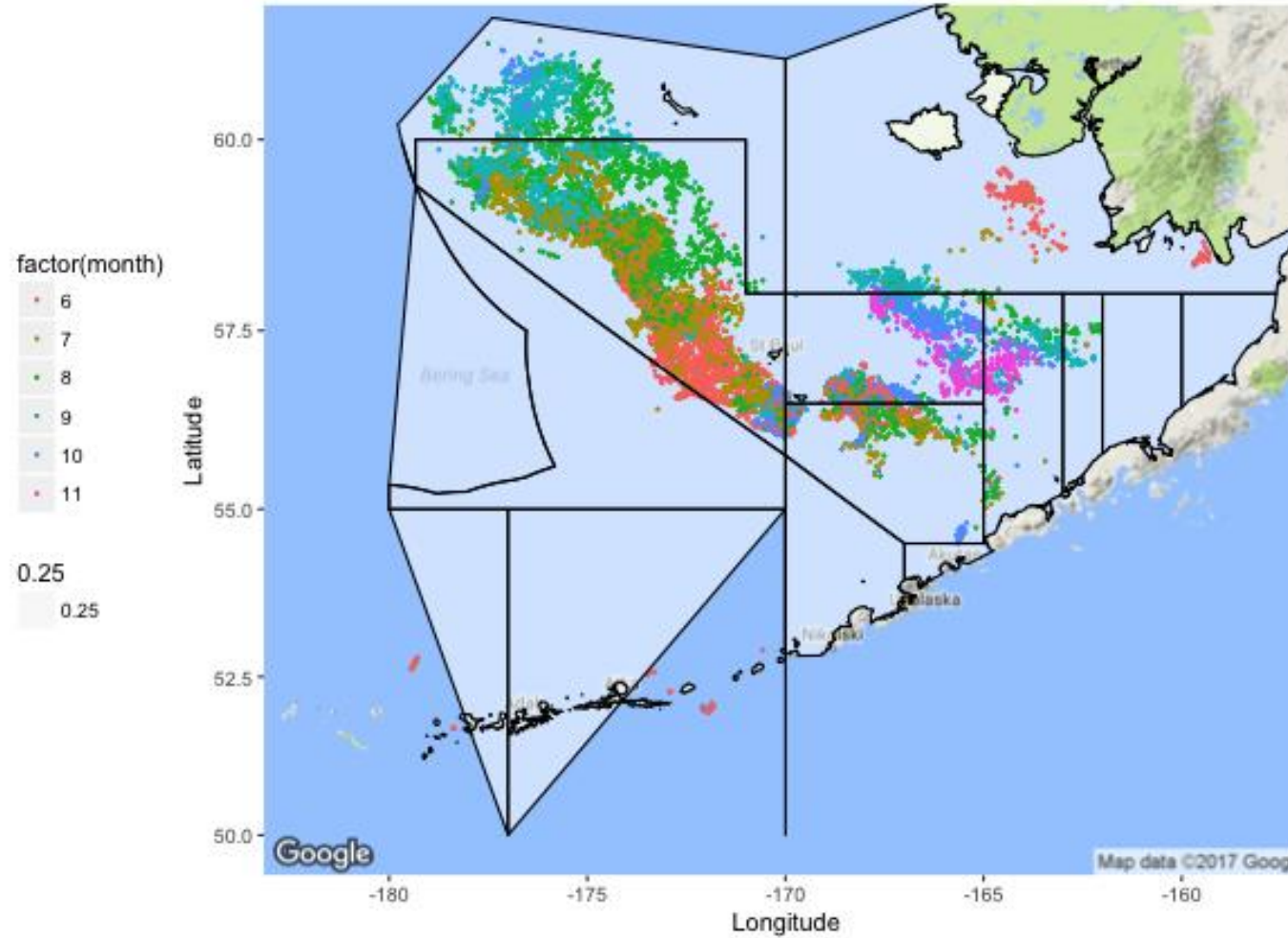
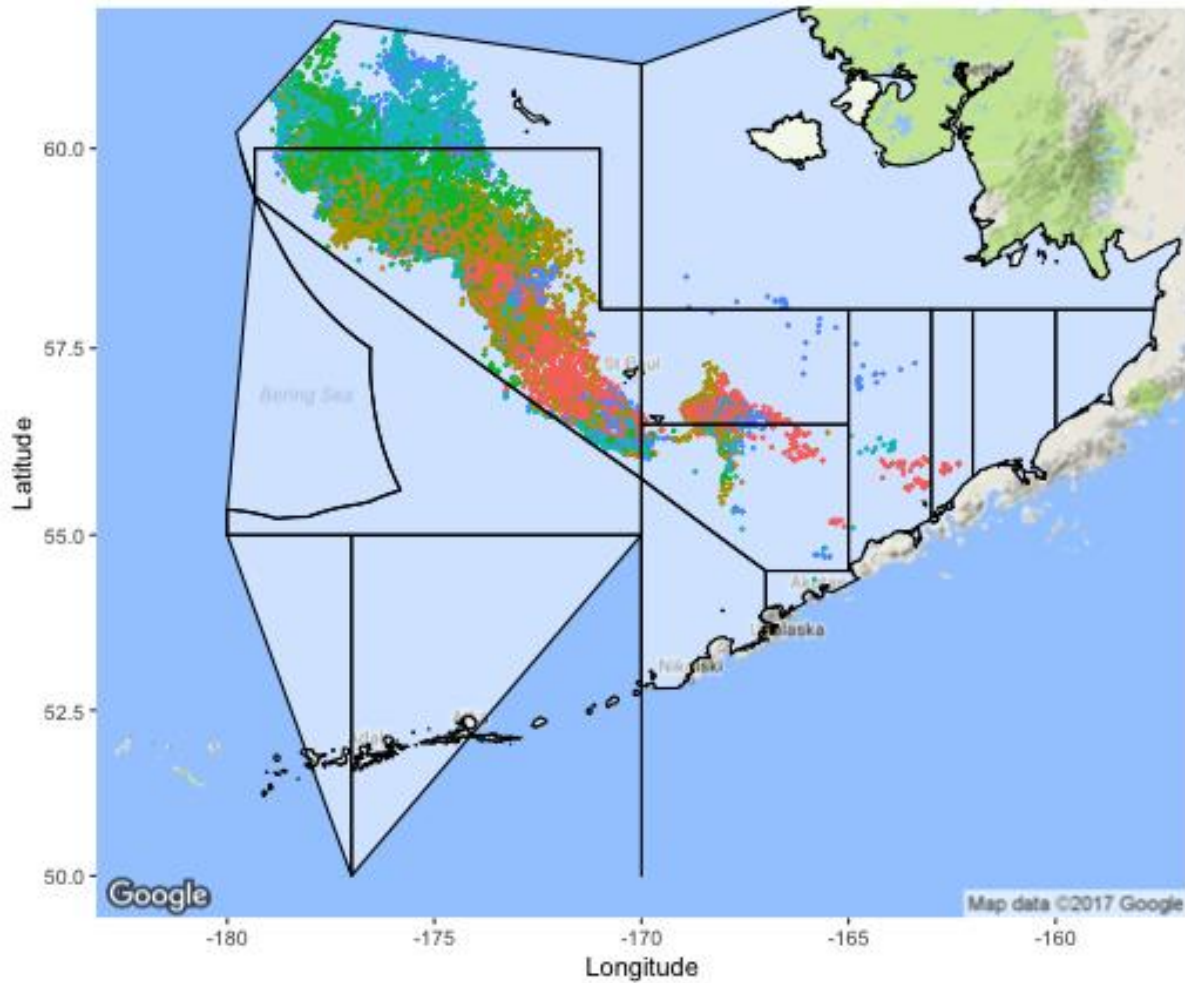


$t$

$T$

time

# Pre- and Post-A91







# Appendix: Chapter 3

# Full Table, A season

	(1)	(2)	(3)	(4)	(5)
	Choice: Fishery-location				
EREV (Poll)	0.00109 (1.91)	0.000853* (2.10)	0.00167 (1.95)	0.00190 (1.95)	0.00102 (1.90)
EREV (YFS)	-7.682 (-0.85)	-10.32 (-0.96)	-1.939 (-0.70)	-1.858 (-0.78)	
ECPR	0.793 (1.51)	1.060 (1.67)	1.292 (1.52)	2.054* (2.11)	1.785 (1.90)
Dist	-0.00345*** (-20.03)	-0.00330*** (-7.49)	-0.00458*** (-8.50)	-0.00571*** (-10.03)	-0.00576*** (-10.39)
EREV (Poll) x Qspeed	-0.0176 (-0.93)		-0.0314 (-1.07)	-0.0385 (-1.17)	
ECPR x Qspeed	9.559*** (4.44)		17.75*** (4.89)	19.60*** (5.21)	19.95*** (5.37)
Dist x Qspeed	-0.000474 (-0.98)		-0.00127 (-1.62)	-0.00141 (-1.68)	-0.00146 (-1.73)
EREV (Poll) x BQspeed	2.842*** (6.78)			5.697*** (5.96)	5.372*** (6.13)
ECPR x BQspeed	-3.523 (-1.60)			-4.510 (-1.17)	
Dist x BQspeed	0.00381*** (8.42)			0.00602*** (6.50)	0.00607*** (6.57)
Missing	-1.166*** (-5.75)	-1.333*** (-4.86)	-1.874*** (-5.03)	-2.000*** (-5.43)	-2.017*** (-5.50)
IV Poll		1.249*** (7.07)	1.781*** (7.80)	1.961*** (8.85)	1.966*** (9.15)
IV YFS		0.935*** (6.37)	1.369*** (6.73)	1.491*** (8.38)	1.526*** (8.91)
<i>N</i>	21696	21696	21696	21696	21696
<i>AIC</i>	4655.7	4760.9	4736.1	4632.2	4629.8

*t* statistics in parentheses

\*  $p < 0.05$ , \*\*  $p < 0.01$ , \*\*\*  $p < 0.001$

# Full Table, B season

	(1)	(2)	(3)	(4)	(5)
	Choice: Fishery-location				
EREV (Poll)	2.496*** (7.52)	-0.910 (-1.20)	-0.921 (-1.13)	-1.251 (-1.55)	-0.974 (-1.24)
EREV (YFS)	2497.1 (0.45)	3050.3 (0.02)	2504.2 (0.03)	2497.2 (0.01)	
ECPR	-1.398 (-1.23)	-5.467* (-2.52)	-6.751* (-2.45)	-5.065 (-1.53)	-6.832** (-2.96)
Dist	-0.00287*** (-11.52)	0.0390*** (15.77)	0.0402*** (14.54)	0.0397*** (14.86)	0.0396*** (15.08)
EREV (Poll) x Qspeed	-3.038** (-3.07)		-0.411 (-0.12)	-0.904 (-0.24)	-0.0805 (-0.03)
ECPR x Qspeed	-0.391 (-0.21)		0.745 (0.11)	-2.982 (-0.40)	
Dist x Qspeed	0.00108 (1.87)		0.0202 (1.72)	0.0176 (1.55)	0.0187 (1.76)
EREV (Poll) x BQspeed	-1.857 (-0.38)			37.40 (1.04)	
ECPR x BQspeed	12.99*** (3.54)			22.37 (0.35)	11.70 (0.30)
Dist x BQspeed	-0.000720 (-0.27)			-0.0611** (-2.78)	
Missing	-0.674** (-3.20)	-0.164 (-0.34)	-0.184 (-0.37)	-0.161 (-0.32)	-0.192 (-0.39)
Hake Vessels	0.244*** (15.20)	0.0534* (2.45)	0.0518* (2.33)	0.0554* (2.46)	0.0519* (2.33)
IV Poll		-9.478*** (-13.59)	-11.55*** (-7.16)	-11.38*** (-6.86)	-11.01*** (-8.07)
IV YFS		13.72 (1.12)	11.01** (2.60)	33.18*** (4.23)	13.32* (2.10)
<i>N</i>	19730	19730	19730	19730	19730
<i>AIC</i>	3629.3	2999.1	3002.1	3002.6	2999.4

*t* statistics in parentheses

\*  $p < 0.05$ , \*\*  $p < 0.01$ , \*\*\*  $p < 0.001$