Estimation of heterogeneous responses to size variation in the Bering Sea pollock fishery

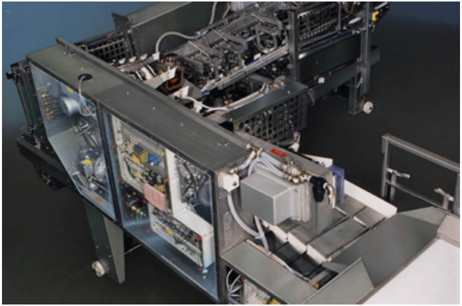
Y. Allen Chen [1] Alan C. Haynie [2]

[1]University of Washington; Pacific States Marine Fisheries Commission under contract to Alaska Fisheries Science Center

[2]Resource Ecology and Fisheries Management Division, Alaska Fisheries Science Center, National Marine Fisheries Service, National Oceanic and Atmospheric Administration

July 14, 2016

- Is a haul containing small fish worth the same as a haul containing big fish, even if the total weight is the same?



- Equipment used to process higher-valued products may require larger fish (e.g. Baader 192 requires 800g minimum).

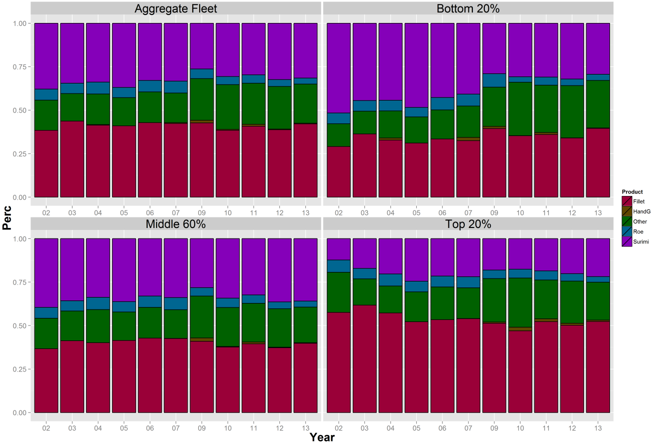
- Gear differences are related to price changes (for example in Northern Atlantic Bluefin Tuna (Pintassilgo et al. MRE 2002)).
- Also, price-size relationship is observed to be different across fisheries (Sjoberg MRE 2015).

Price per produced metric ton, 2003-2013, 2014$

	1st Quartile	Mean	3rd Quartile
Fillet	3,095.3	3,478.7	3,855.9
Other	1,359.8	1,664.8	1,887.1
Roe	9,602.0	12,735.0	16,213.0
Surimi	2,070.0	2,820.0	3,425.0

- On average: Roe > fillet > surimi > other.
- Roe is not a substitute product, but rather occurs with specific fish (at a specific time).

Different vessels choose different products



- Some vessels produce a greater proportion of fillet, and others surimi.
- We lose these incentives if we aggregate and assume vessels have identical production.

- Do we observe heterogeneous harvesters in the U.S. Bering Sea pollock fishery? Are price incentives different within a single fishery?

- How do we know how many different types of harvesters there are, and which harvesters belong to each group type?

- Let the data tell us.

- Estimate a system of revenue share equations derived from a production relationship.
- Production function of product prices, as well as input characteristics such as fish size, variance of fish size in haul, and CPUE of haul.

$$
\begin{aligned}
log(Revenue)_{it} = \mathrm{c}_r \; &+ \Sigma_j \left(\alpha_j\right) \ln\left(\mathrm{p}_{i,t,j}\right) \\
&+ (1/2)\, \Sigma_j \Sigma_k \beta_{j,k} \ln\left(\mathrm{p}_{i,t,j}\right) \ln\left(\mathrm{p}_{i,t,k}\right) \\
&+ \Sigma_m \left(\gamma_m\right) \ln\left(\mathrm{v}_{i,t,m}\right) \\
&+ (1/2)\, \Sigma_m \Sigma_l \delta_{m,l} \ln\left(\mathrm{v}_{i,t,m}\right) \ln\left(\mathrm{v}_{i,t,l}\right) \\
&+ \Sigma_j \Sigma_m \theta_{j,m} \ln\left(\mathrm{p}_{i,t,j}\right) \ln\left(\mathrm{v}_{i,t,m}\right)
\end{aligned}
$$

- The revenue share equations are derived from partial derivatives of the production relationship, subject to homogeneity and symmetry conditions.

$$
\begin{aligned}
s_{i,t,j} &= \alpha_j \ + \Sigma_k \beta_{j,k} \ln\left(p_{i,t,k}\right) + \Sigma_m \theta_{j,m} \ln\left(v_{i,t,m}\right) \\
&= \alpha_{i,j} \ + \sum_{g=1}^{G} \theta_{g,j,Z} \ln\left(Z_{i,t}\right) 1\left(i \in g\right) \\
&+ \Sigma_k \beta_{j,k} \ln\left(p_{i,t,k}\right) + \Sigma_m \theta_{j,m} \ln\left(v_{i,t,m}\right) + \ \mu_{i,t,j} \\
&\Sigma_j \alpha_j \ = \ 1, \ \ \Sigma_j \theta_{j,m} \ = \ 0, \ \ \Sigma_j \beta_{j,k} \ = \ 0, \\
&\Sigma_m \theta_{j,m} \ = \ 0, \ \ \Sigma_k \beta_{j,k} \ = \ 0, \\
&\beta_{j,k} \ = \ \beta_{k,j}, \ \ \delta_{m,l} \ = \ \delta_{l,m}
\end{aligned}
$$

As adapted from (Lin and Ng 2012):

1. We first determine if parameter heterogeneity is reasonable (use Pesaran and Yamagata 2008).
2. Then, for a given number of groups, we determine individual harvester group membership.
3. After assigning individual membership, we iteratively test for subsample parameter homogeneity in order to determine the true number of groups.

1. Determine group membership by iteratively placing each vessel in the group that minimizes their individual sum of squared residuals.
2. Reestimate the group parameters, and continue until no vessels change groups.

$$SSR_i^g = \sum_{j=1}^{J}\sum_{t=1}^{T}(s_{i,t,j} - \alpha_j - \hat{\theta}_{g,j,Z}\ln(Z_{i,t}) - \Sigma_k \hat{\beta}_{j,k}\ln(p_{i,t,k}) - \Sigma_m \hat{\theta}_{j,m}\ln(v_{i,t,m}))^2$$

1. Then test for subsample parameter homogeneity under the null hypothesis that the individual parameter is equal to the subsample group parameter.
2. The test statistic, from Pesaran and Yamagata, is distributed standard normal, and is modified to include the cross-equation correlations between the error terms.

$$H_0: \quad \theta_{i,Z} = \theta_Z \ \forall \ i$$

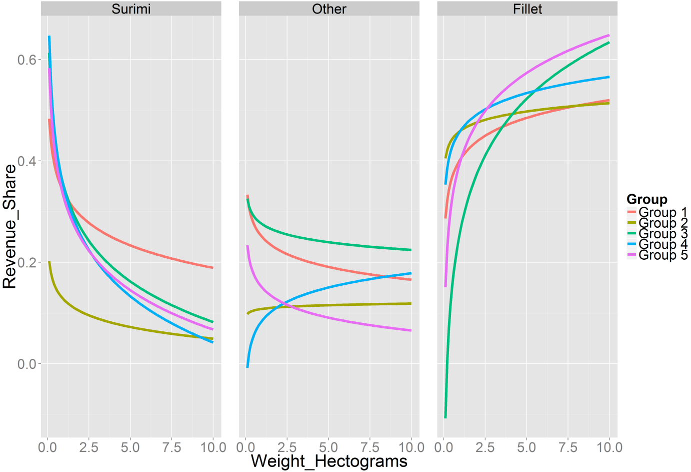
$$S_i = \sum_{i}^{N} \left(\hat{\theta}_{i,Z} - \hat{\theta}_{SUR,Z}\right)' \frac{M_i Z_i' \left(S_{OLS}^{-1} \otimes I_{(J+1)T}\right) M_i Z_i}{\sigma_i^2} \left(\hat{\theta}_{i,Z} - \hat{\theta}_{SUR,Z}\right)$$

$$\sigma_i^2 = \frac{(M_1 y_i - \hat{\theta}_{SUR,Z} M_1 Z_i')' \left(S_{OLS}^{-1} \otimes I_{(J+1)T}\right) (M_1 y_i - \hat{\theta}_{SUR,Z} M_1 Z_i')}{JT - 1}$$

$$\frac{1}{\sqrt{N}} \sum_{i=1}^{N} \frac{S_i - k}{\sqrt{2k}} \sim \ N(0,1)$$

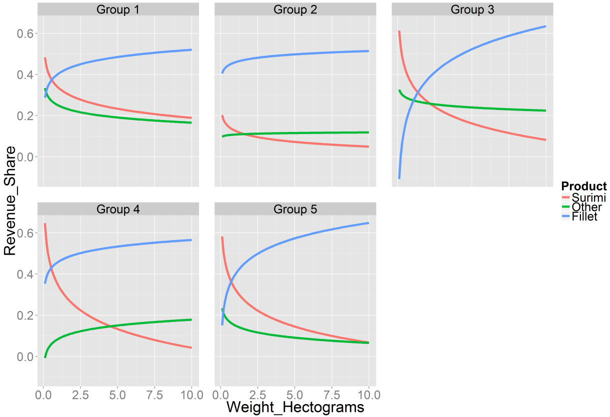
G=5	Beta	SE
Fillet WPF	0.050	0.015
Other WPF	-0.036	0.009
Surimi WPF	-0.063	0.015
Dispersion test	0.51	
R^2	0.848	
N*T	443	
Group 2		
Fillet WPF	0.023	0.012
Other WPF	0.004	0.007
Surimi WPF	-0.033	0.008
Dispersion test	0.45	
R^2	0.964	
N*T	651	
Group 3		
Fillet WPF	0.161	0.021
Other WPF	-0.021	0.010
Surimi WPF	-0.115	0.021
Dispersion test	0.39	
R^2	0.814	
N*T	437	

Group 4		
Fillet WPF	0.046	0.020
Other WPF	0.040	0.011
Surimi WPF	-0.131	0.020
Dispersion test	1.65	
R^2	0.870	
N*T	500	
Group 5		
Fillet WPF	0.107	0.011
Other WPF	-0.036	0.006
Surimi WPF	-0.111	0.013
Dispersion test	0.61	
R^2	0.832	
N*T	866	

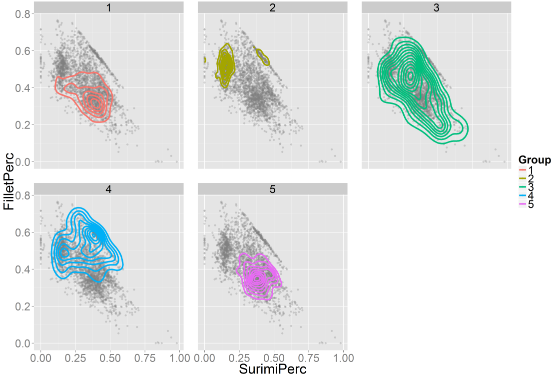


- As size increases revenue share of fillet increases, while surimi decreases. This is true for all group types.

Price estimation: results

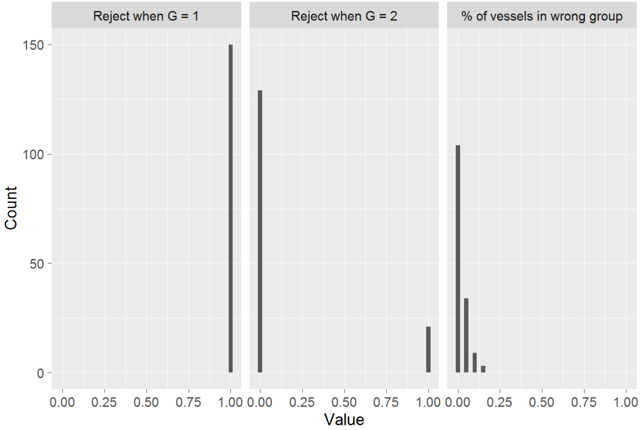


- These relationships are heterogeneous across vessel groups.
- Some vessels substitute between surimi and fillet as size changes.
- Other vessels do not change composition no matter the size.

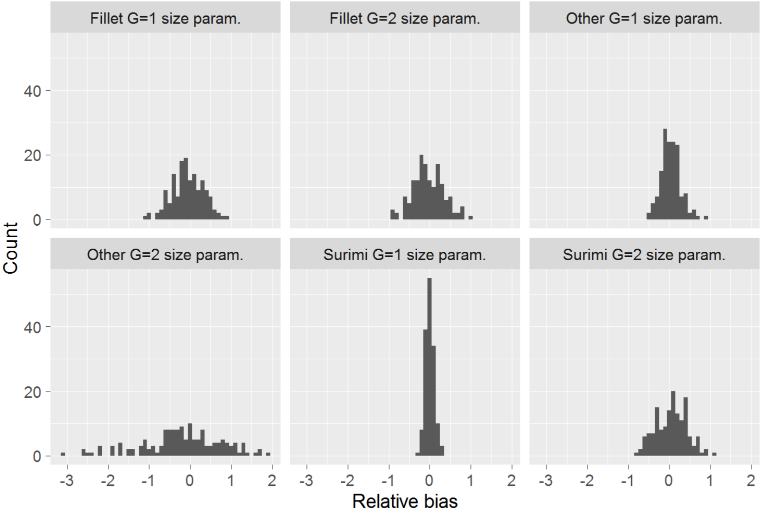


- Groups one and two do not respond to size;.
- Group three will opportunistically produce surimi or fillet as size changes.
- Groups four and five primarily produce fillet or surimi, but opportunistically substitute as size changes.

- Monte Carlo suggests probability of type I error high, only fails to reject 0.86 (when the significance level is 0.05). Overestimate number of groups.
- Type II error reasonable, rejects when it should.
- On average 2 percent of vessels misplaced.



- Estimates relatively unbiased.
- Relative bias a function of the size of the true parameter.



- We find evidence that heterogeneous price-size responses exist within the U.S. Bering Sea pollock fishery.
- By letting the data tell us group membership and the true number of groups, we see different groups produce different products.
- Because size selectivity ends up changing the size structure of the biomass, choice of size can create winners and losers among heterogeneous harvesters.