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APPENDIX:

HIDDEN FLEXIBILITY: INSTITUTIONS, INCENTIVES AND THE MULTIPLE MARGINS OF SELECTIVITY IN FISHING

Supplementary Figures

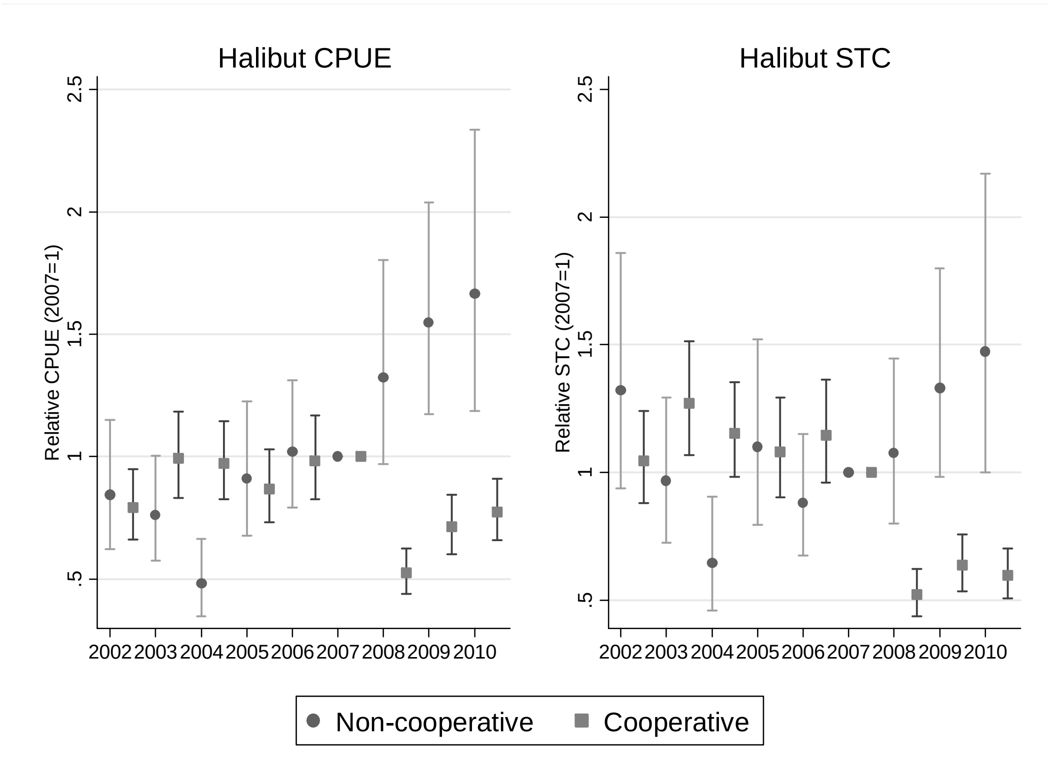

Figure A1: Relative rates of halibut CPUE and halibut STC with 2007 as the base year. Estimates are derived from exponentiating annual dummy variables (with 2007 as the omitted base year) from fixed effects Poisson regressions (Cameron and Trivedi 2005; Hausman, Hall and Griliches 1984) with daily observed vessel-level halibut bycatch as the dependent variable and with fishing time (first panel) or total catch on hauls with observer species composition sampling (second panel) as the exposure variable. Fixed effects are defined over combinations of vessel and week. 95% confidence intervals are presented using robust standard errors.

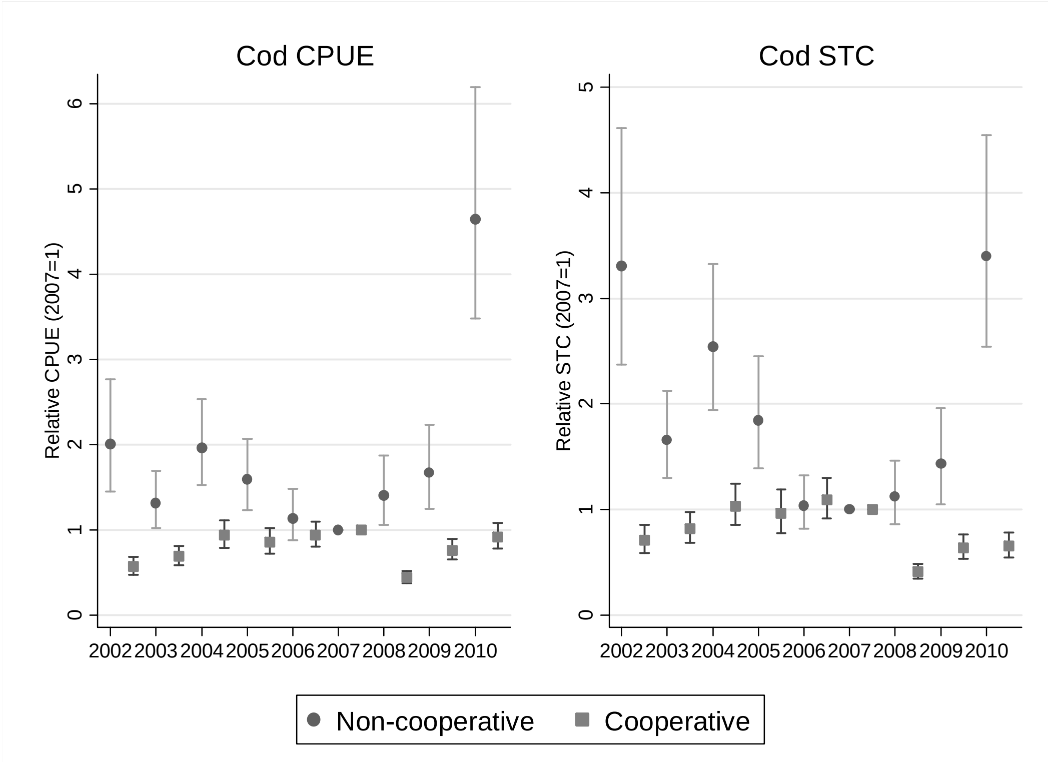

Figure A2: Relative rates of Bering Sea cod CPUE and cod STC with 2007 as the base year. Estimates are derived from exponentiating annual dummy variables (with 2007 as the omitted base year) from fixed effects Poisson regressions with daily observed vessel-level cod catch as the dependent variable and with fishing time on species-composed hauls (first panel) or total catch on species-composed hauls (second panel) as the exposure variable. 95% confidence intervals are presented using robust standard errors.

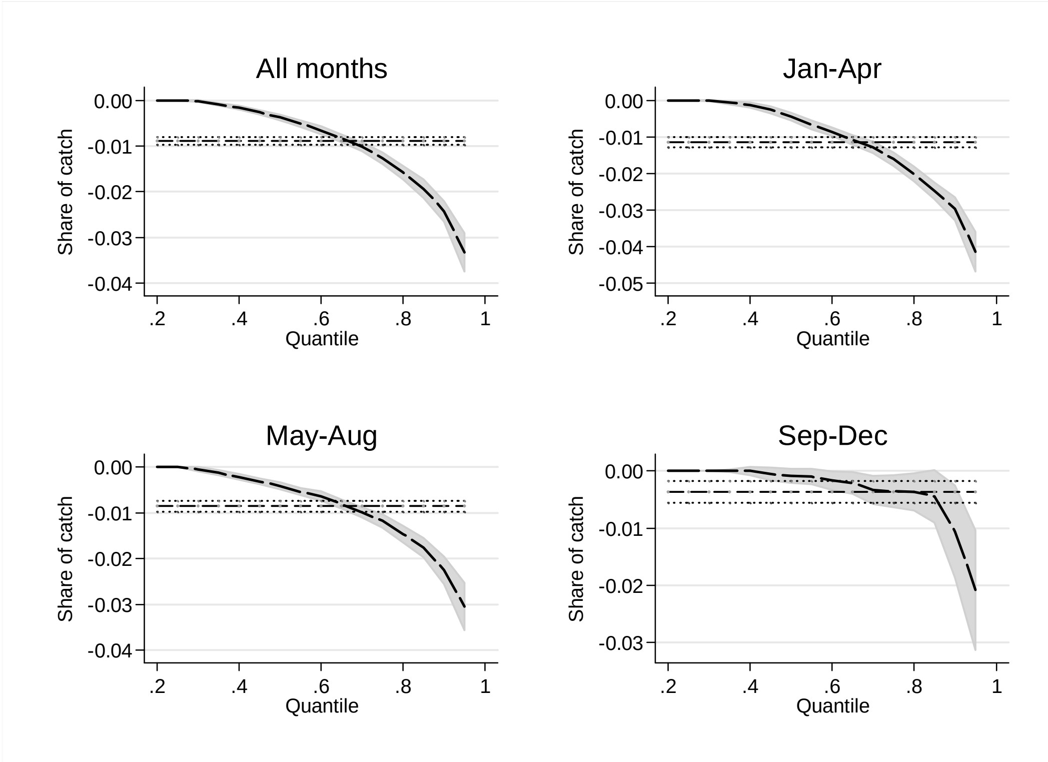

Figure A3: Reductions in the quantiles of halibut STC in the post-A80 period for cooperative vessels in the Bering Sea. The boldface broken line is the estimate of a dummy variable for 2008-2010 years in a quantile regression of halibut STC at the vessel-day level on a series of indicator variables for each vessel and month. Gray shading reflects a 95% confidence interval obtaining using a bootstrap from the Stata package gsqreg. The light broken line is an equivalent OLS (conditional mean) estimate with the dotted lines reflecting a 95% confidence interval.

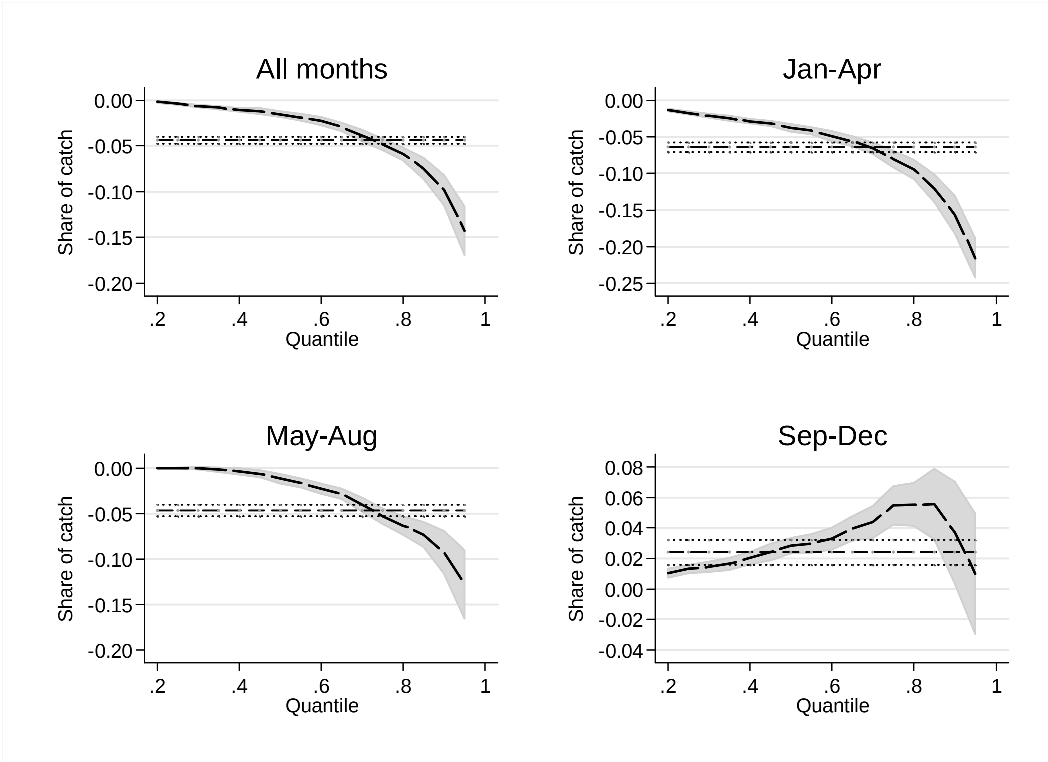

Figure A4: Reductions in the quantiles of cod STC in the post-A80 period for cooperative vessels in the Bering Sea. The boldface broken line is the estimate of a dummy variable for 2008-2010 years in a quantile regression of cod STC at the vessel-day level on a series of vessel and monthly dummy variables. Gray shading reflects a 95% confidence interval obtaining using a bootstrap from the Stata package gsqreg. The light broken line is an equivalent OLS (conditional mean) estimate with the dotted lines reflecting a 95% confidence interval.

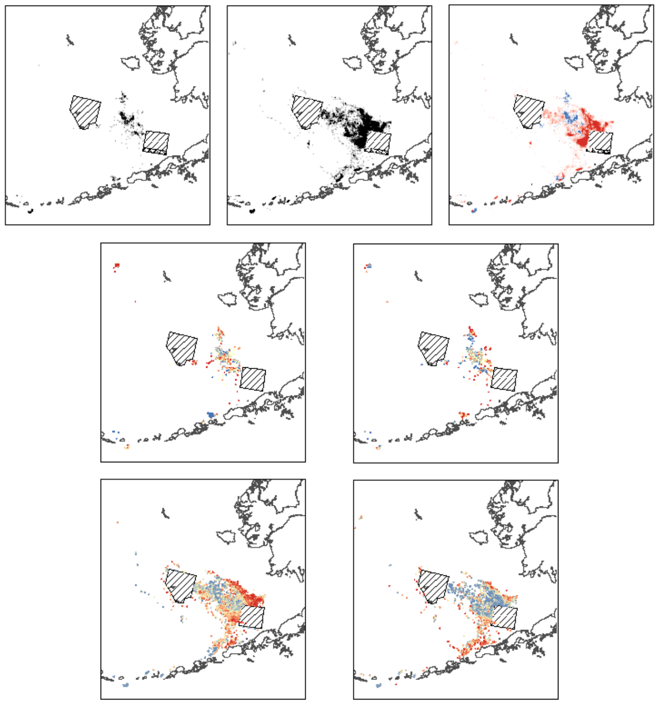

Figure A5: Distribution of fishing effort in the Bering Sea for cooperative vessels during the September-December fishery in comparison to areas of high and low catch rates of cod and halibut. The first two figures in the first row are kernel probability densities of the distribution of effort in 2005-2007 and 2008-2010 where black (white) areas indicate areas of greatest (lowest) density of fishing. The third panel is the difference of these densities where red (blue) indicate areas with increases (decreases) in relative effort in 2008-2010 and white indicates areas with no change. The second row reports kernel densities of mean cod and halibut STC in 2005-2007. The shading is by quintile of raster pixels with dark blue being the bottom 0-20%, red being the 80-100% bracket and yellow being the 40%-60% bracket. The third row is identical to the second but is for the years 2008-2010.

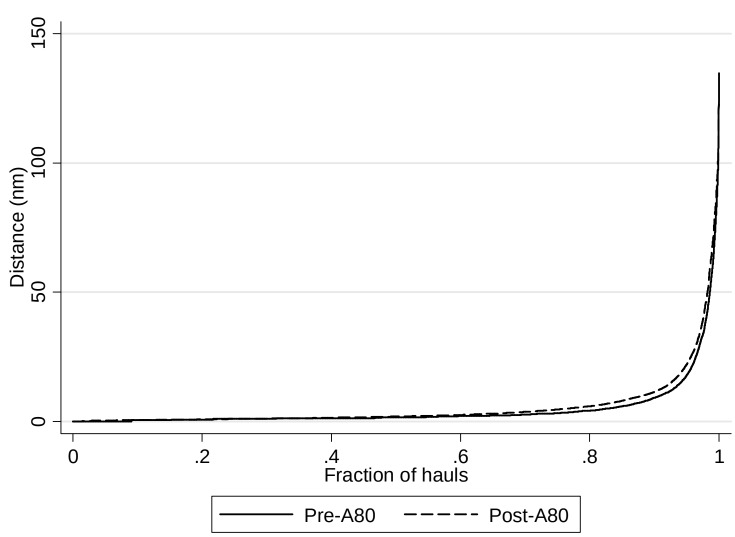

Figure A6: Quantile plot of inter-haul distances for cooperative members in the Bering Sea fishery.

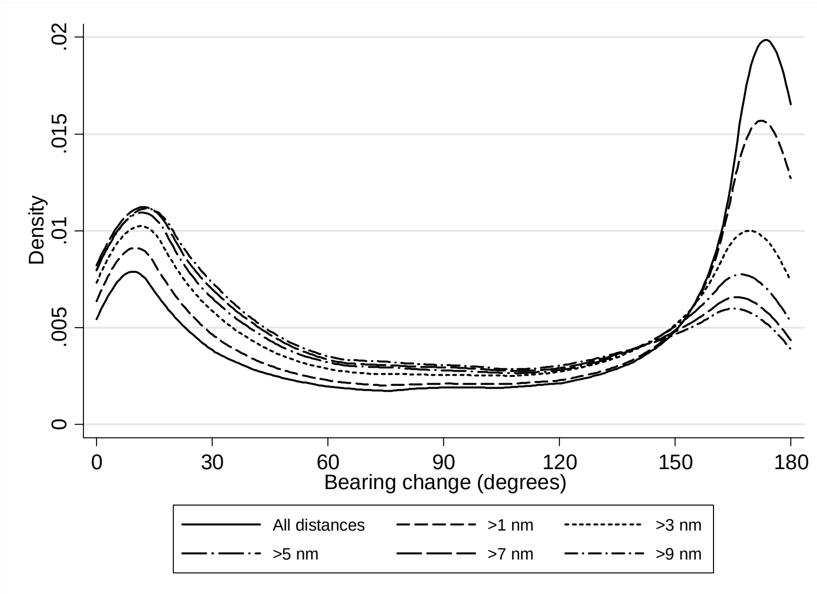

Figure A7: Kernel densities of absolute changes in bearing between consecutive trawls for cooperative members in the Bering Sea fishery.

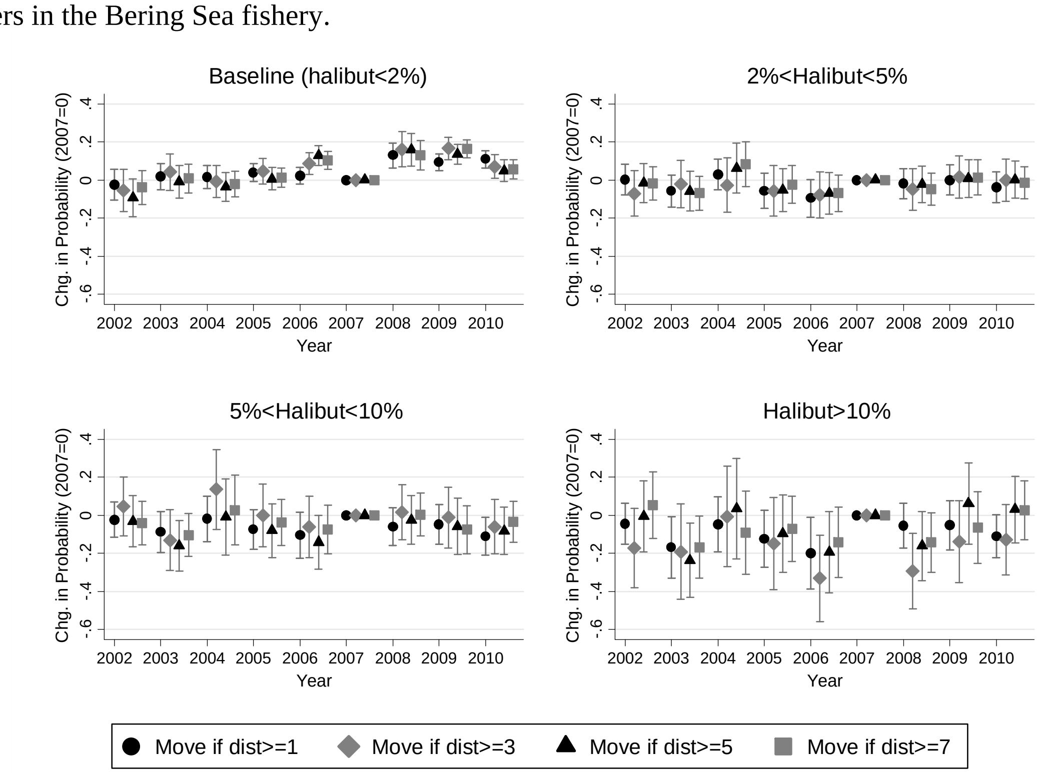

Figure A8: Estimates of the change in probability of movements of a given minimum distance relative to 2007 conditional on the percentage of halibut in the previous haul for non-cooperative members in the Bering Sea fishery. Estimates are derived from a linear probability model and error bars reflect 95% confidence intervals using heteroskedasticity robust standard errors.

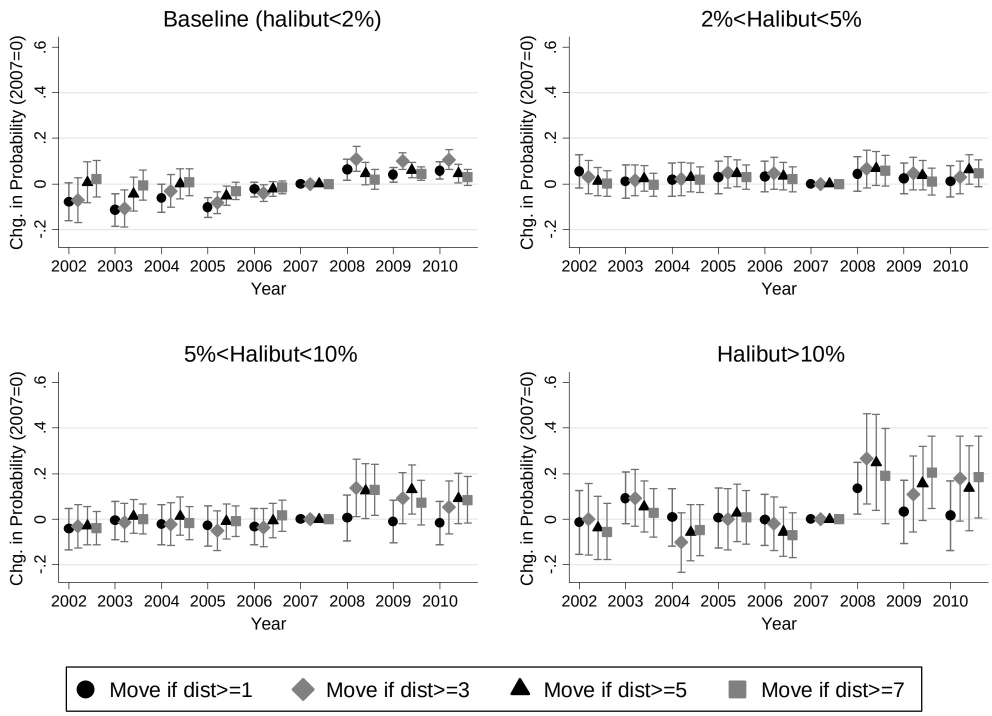

Figure A9: Estimates of the change in probability of movements of a given minimum distance relative to 2007 conditional on the percentage of halibut in the previous haul for cooperative members in the Bering Sea fishery for the January to April sub-season. Estimates are derived from a linear probability model and error bars reflect 95% confidence intervals using heteroskedasticity robust standard errors.

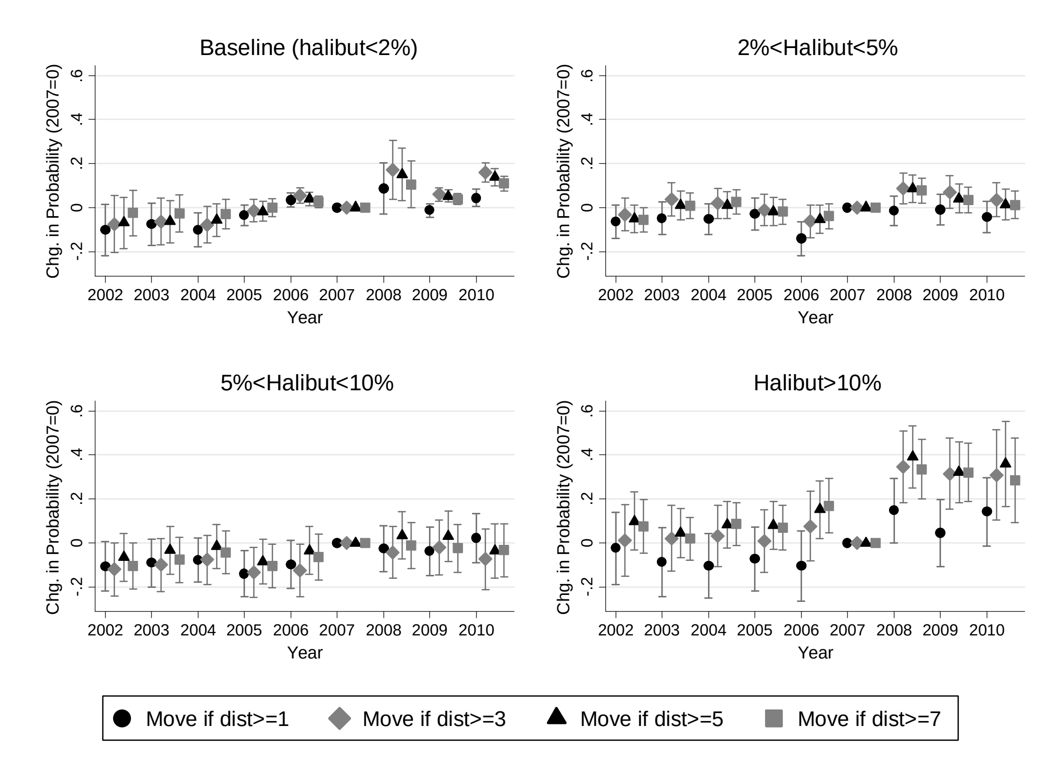

Figure A10: Estimates of the change in probability of movements of a given minimum distance relative to 2007 conditional on the percentage of halibut in the previous haul for cooperative members in the Bering Sea fishery for the May to August sub-season. Estimates are derived from a linear probability model and error bars reflect 95% confidence intervals using heteroskedasticity robust standard errors.

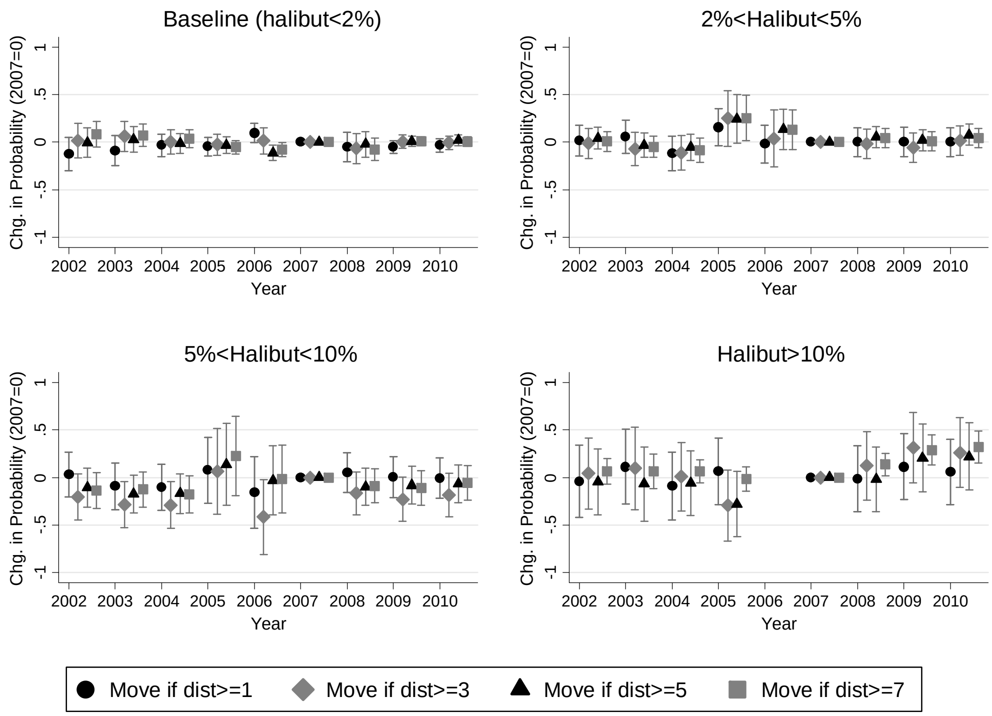

Figure A11: Estimates of the change in probability of movements of a given minimum distance relative to 2007 conditional on the percentage of halibut in the previous haul for cooperative members in the Bering Sea fishery for the September to December sub-season. Estimates are derived from a linear probability model and error bars reflect 95% confidence intervals using heteroskedasticity robust standard errors. Estimates for the lower right panel for 2006 are missing due to the absence of >10% events in that year.

A Brief Comparison of Pre and Post-A80 Participation Trends

The newfound security of quota for A80 target and prohibited species for cooperative members, along with the consolidation of the remaining common pool quota among a much smaller group of non-coop vessels, had a substantial impact on both the degree of participation and the intensity and distribution of effort through the season. Figure A12 shows the annual trends of participation by reporting the minimum-maximum range and median number of vessels with positive production from the BSAI in a given week of the year. Despite the considerable inter-year variability in pre-A80 years, there is a robust pattern of high initial participation in every year but with substantial volatility thereafter. Participation often fell substantially mid-season followed by a robust decline in participation in the final months of the year. This pattern reflects the complex sequencing of closures and retention restrictions in the fishery, in most cases driven by exhaustion of seasonal and species-specific allocations of halibut PSC quota. By comparison, overall annual post-A80 levels of vessel participation are unchanged in central tendency, although they are robustly higher in the last third of the available season; there is a dramatic reduction in the week-over-week variability of participation. Wilcoxon and t-tests find no significant shift in mean participation post-2008 while F-tests for a change in variance strongly reject the null hypothesis that the post-A80 variance is greater than the pre-A80 variance ($p<.01$). Seasonal allocations of quota under the common-pool system – which spread the season out at the cost of pulses of high and low activity – were replaced under A80 by annual quotas for A80 target and prohibited species with secure rights to shares of these quotas for vessels inside a cooperative. Given this newfound flexibility, vessel owners smoothed their participation over the season. Furthermore, reductions in halibut bycatch throughout the season allowed for a much more robust late-season fishery for yellowfin sole than in previous years. Finally, there is little evidence of immediate consolidation in the fishery. Unlike many newly rationalized fisheries, the A80 fleet was already under a relatively binding limited-entry regime before 2008 and there was seemingly no excess capacity in the fishery.

Figure A13 summarizes the intensity of participation across the season by graphing cumulative vessel-days, fishing hours and hauls for a subset of 13 vessels with full observer coverage and participation before and after A80. Two vessels are eliminated from the tally due to the fact that they either replaced a vessel post-A80 or sank early in the 2008 season. Limiting comparisons to full observer coverage vessels results in the loss of eight vessels (seven from within the cooperative and one outside it). A review of the data for vessels in co-ops shows that, based on cumulative vessel-days, the pace of fishing effort in the first half of the season is slightly slower post-A80 than beforehand. However, whereas the intensity of effort in the last half of the season used to decelerate in 2002-2007, the pace remains consistent until the final weeks of the season post-A80, so that overall vessel-days actually *increase* after A80. By contrast, the intensity of active fishing per day, as measured by actual trawling time, *declined* overall for cooperative vessels, with cumulative end-of-season fishing hours typically below 2002-2007 values. This reduction in intensity of fishing is especially notable in the first half of the season with 2008-2010 fishing hours per week being between 31 and 42% less than 2007 levels. Daily fishing hours per vessel fell by between 2.5 to 3.5 hours (25-33%) in 2008-2010 relative to 2007.[1] This reduction can be traced to two factors. First, the number of hauls per day dropped by .2 to .4 hauls post-A80 (a 9-13% reduction). Second, the average duration of each haul shrank by between 25 to 50 minutes – 16-27% shorter than in 2007.

The pattern for non-coop vessels is quite similar. There is actually a slight reduction in total vessel-days for the season, even with a considerably lengthened window of participation. This is driven in large part by a strong tendency of many vessels to participate only lightly in the late Atka mackerel seasons or exit the fishery – driven in large part by the small allocations of Bering Sea species accorded the non-coop vessels. The pattern of reduced intensity of effort in terms of fewer and shorter hauls noted for coop vessels is mirrored in non-coop vessels as well. The fact that this occurred in the non-coop fishery, despite a downgrading of the constituent vessels' quota in proportion to their pre-2008 share, suggests that there may have been some benefits to this sector as the result of being in common pool

[1] These estimates, and all others in this paragraph, come from annual dummy variables in an OLS regression with vessel and week fixed effects with 2007 as the omitted base category. Percentages come from an otherwise identical semi-log regression. The results are qualitatively robust to different choices of the pre-A80 base year.

setting with many fewer participants. It may also provide evidence of a de facto cooperation – made more likely by the fact that 5 of the 7 non-coop vessels come from a single company.

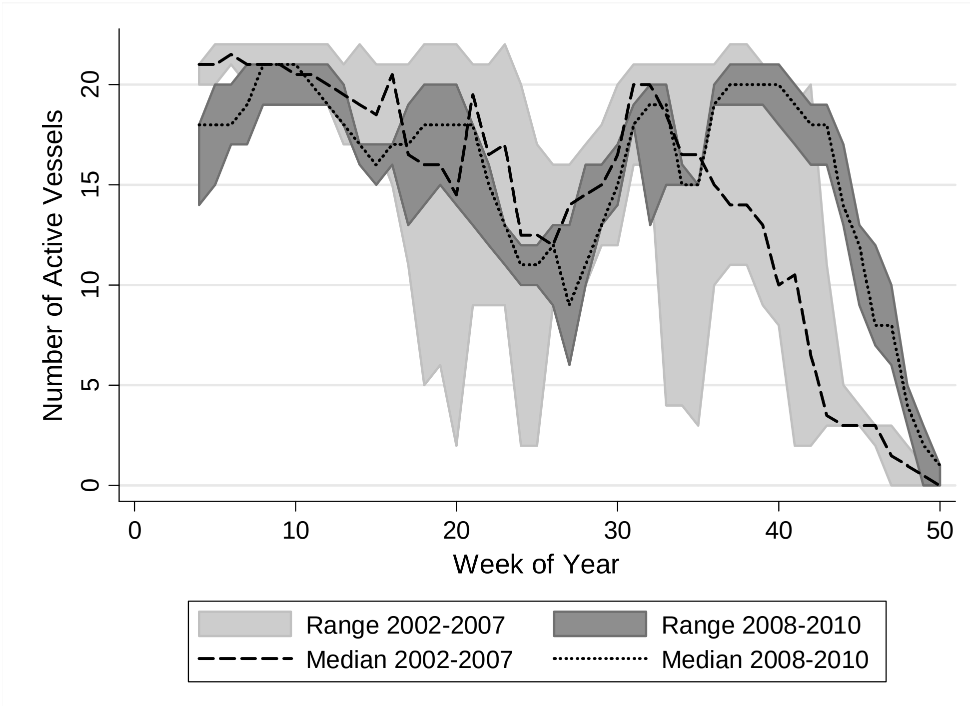

Figure A12: Number of vessels with BSAI production by week. The light and dark gray areas reflect the maximum and minimum levels of weekly participation in 2002-2007 and 2008-2010, respectively. The dashed and dotted lines reflect the median weekly participation level in 2002-2007 and 2008-2010, respectively.

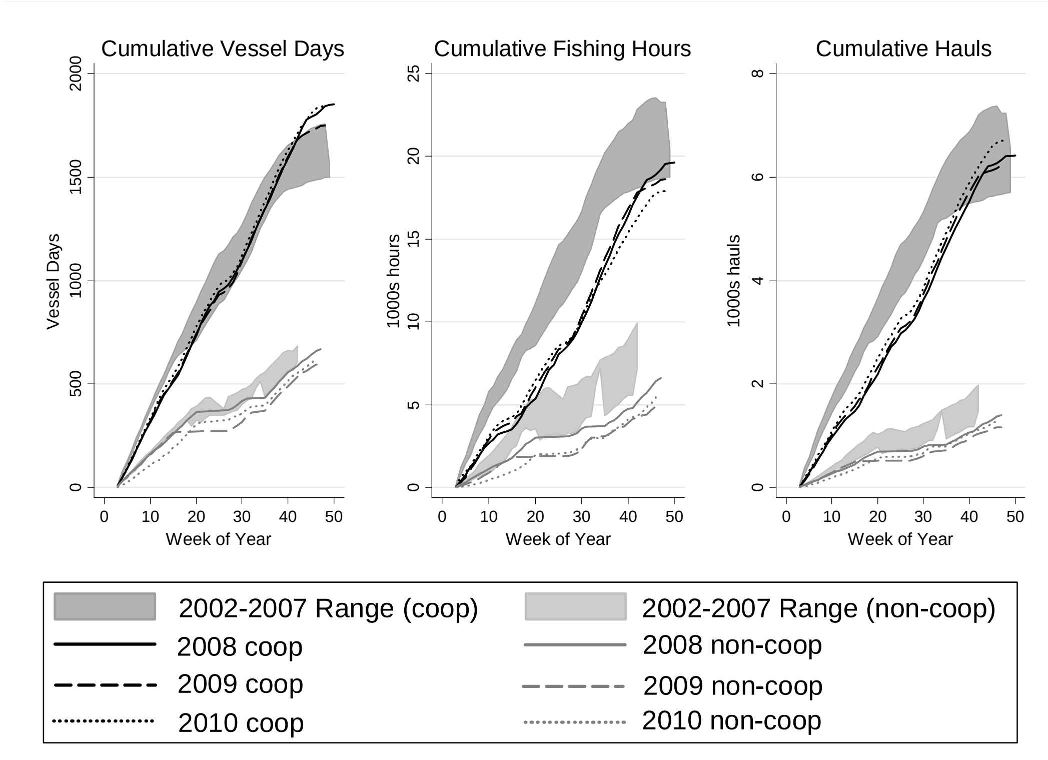

Figure A13: Cumulative effort for >124 foot vessels. Dark (light) gray shading indicates the max/min envelope of 2002-2007 for co-op (non-co-op) cumulative effort measures respectively.

References

Cameron, Adrian Colin, and P. K. Trivedi. 2005. *Microeconometrics : Methods and Applications*. New York, NY: Cambridge University Press.

Hausman, J., B. H. Hall, and Z. Griliches. 1984. "Econometric-Models for Count Data with an Application to the Patents R and D Relationship." *Econometrica* 52(4):909-38.