Mercury Advisories and Household Health Trade-offs

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DRAFT: COMMENTS WELCOME

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ABSTRACT

In 2001 the Food and Drug Administration formally advised pregnant women and households with young children to limit fish consumption due to dangers from methylmercury. Moderate fish consumption, however, provides many benefits and is the primary dietary source of omega-3 fatty acids. This tension has caused some in the scientific community to speculate that the net benefits of the public advisory may be negative. No revealed preference research yet exists to resolve this debate. This paper uses novel home-scan data and a changes-in-changes research design to examine the impact of the advisory on the distribution of household-level mercury, omega-3, and fish consumption. We find that the advisory induced at-risk consumers to reduce their mercury intakes. However, this reduction came from a broad-based reduction in all fish, rather than substitution from high mercury to low mercury fish. Consequently, there was also a significant reduction in omega-3 fatty acid intakes. The advisory may have generated net health losses.

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1. Introduction

In the last several years, concern has arisen that methylmercury from fish consumption may pose a significant threat to children's neurological development. In 2001, the US Food and Drug Administration (FDA) reacted to mounting evidence of risk by releasing an advisory instructing pregnant women and households with young or nursing children to limit fish consumption. However, as the advisory noted, a moderate amount of fish consumption provides significant health benefits to both adults and young children, particularly in the form of omega-3 fatty acids.

This inherent tension has caused many in the scientific and public health communities to speculate that a commercial fish advisory may cause net harm if individuals reduce methyl-mercury exposure by simply reducing consumption of all fish (Egeland and Middaugh 1997, Cohen et al. 2005). One should not assume that consumers responded to the advisory sensibly. People frequently make suboptimal decisions due to cognitive difficulties and bounded rationality (Thaler 1992, Kahneman 2003). For example, consumers often overvalue health risks (Viscusi 1990) and even remember repeated false statements and warnings as true (Skurnik et al. 2005, Schwartz et al. 2007).

Despite the health trade-off debate that surrounds the 2001 FDA action, no systematic revealed preference evidence on advisory response yet exists. This study fills that gap. We inform the discussion by analyzing advisory-induced household-level changes in fish consumption. We ask the following questions. Did at-risk households reduce mercury intake in response to the advisory? Did responding households differentially avoid high mercury fish? Most desirably, did responding households substitute out of high mercury fish into low mercury, high omega-3 fish? If the answer to this latter question is yes, the advisory produced a clear "win-win" for health outcomes.

We answer these questions using household-level IRI homescan data. We have *every* non-random weight supermarket fish purchase from nearly 15,000 households in the year before the advisory (2000) and the year after the advisory (2002). Detailed information on more than 5,300 unique products, including species type, combined with the scientific literature and extensive USDA testing, allows us to translate home fish consumption into household mercury and omega-3 intakes.

In order to identify the treatment effect of the advisory, we control for confounding factors using Athey and Imbens's (Econometrica 2006) changes-in-changes model. Changes-in-changes is a non-parametric extension of the commonly utilized difference-in-differences method, but instead of identifying an average treatment effect alone it identifies the entire distribution of treatment effects. This model overcomes several well-known theoretical and practical difficulties with the difference-in-differences model. Here, our treatment group is those considered at risk by the advisory: households with pregnant women, nursing children, and/or children under 6. Our control group is households with no children or pregnant women.

We find that at-risk consumers significantly reduced their mercury exposure, and there is a particularly strong decline at the upper tail of the per capita mercury intake distribution. In isolation this is positive for public health. However, there is a substantial countervailing omega-3 cost to this benefit. We find that at-risk consumers significantly reduced their omega-3 intake, and this decline occurs everywhere along the per capita omega-3 distribution, including the lower tails.

What can explain these simultaneous results? At-risk consumers reduced mercury exposure by reducing consumption of *all* fish, not by differentially avoiding high mercury fish or substituting away from high mercury species into low mercury, high omega-3 species. In addition to an aggregate decline in per capita fish volume, we see a reduction among targeted consumers for every major seafood sub-category analyzed. This includes declines for species like shrimp and salmon that represent clear win-wins for public health due to their low mercury and high omega-3 content. Despite the careful text of the advisory, households did not correctly evaluate risk trade-offs. Our results, coupled with published risk analyses, suggest the 2001 advisory may have resulted in a public health loss.

2. Omega-3s, Mercury, and the 2001 FDA Advisory

Omega-3 Fatty Acids

Moderate amounts of seafood consumption provide significant health benefits, largely due to omega-3 (n-3) fatty acids. Humans are unable to synthesize these polyunsaturated fatty acids, so they must be obtained externally. Nearly all dietary docosahexaenoic acid (DHA) derives from fish and shellfish consumption and seafood is an important source of eicosapentaenoic acid (EPA) as well (Mahaffey 2004). DHA is associated with improved fetal brain development, infants' visual development, and infants' neuro-behavioral development (Lauritzen et al. 2001, Neuringer et al. 1994, Oken et al. 2005). Recent evidence also supports a link between omega-3 fatty acids and fetal, infant, and childhood resistance to neurotoxins, including mercury. Finally, DHA and EPA fatty acids have been linked to reductions in stroke, improvements in immune system function, and decreased coronary heart disease in adults (Kris-Etherton et al. 2002).

Mercury

Levels of mercury circulating in the environment have increased considerably over the last century. Coal-fired electrical plants are currently the largest source of anthropogenic mercury. Mercury binds with sulfuric compounds in coal, and burning releases the mercury into the atmosphere. When atmospheric mercury is deposited into surface water, bacteria convert the mercury into organic methylmercury. It then enters a fish's bloodstream from water passing over gills and accumulates in the tissues. Methylmercury bio-accumulates up the food chain. Even in water where ambient mercury levels are extremely low, mercury concentrations may reach high levels in predatory species like tuna, mackerel, and shark.

For the general public, fish consumption is the primary source of exposure to mercury. Cooking and other forms of preparation do not mitigate exposure. Once consumed, mercury is a neurotoxin, which is absorbed into the bloodstream. In adults, abnormally high concentrations can contribute to brain damage, heart disease, blurred vision, slurred speech, and other neurological ailments. Such concentrations in adults are rare. However, the FDA maintains that even modest mercury concentrations pose a risk of significant harm to the developing neurological systems of fetuses, infants, and children. Consequences may include learning and attention disorders, or generally slow intellectual and behavioral development, as well as severe neurological illnesses such as cerebral palsy. Fetuses and nursing infants are at risk because mercury readily passes through the placenta, concentrates in umbilical tissues, and leaches into breast milk.

The 2001 FDA Commercial Fish Advisory

Until late 2000, U.S. government agencies formally maintained that mercury from fish consumption did not pose significant health threats and that benefits of seafood consumption outweighed risks. Public knowledge of mercury in commercial fish was also limited. FDA focus groups conducted in October 2000 indicated, "None of the [focus] groups showed much interest or concern about mercury as a hazard in fish before seeing the information pieces….There was little or no awareness in any group of a hazard due to low level mercury exposure from fish consumption that was not due to a specific [localized] pollution problem." (US FDA 2000)

The FDA formally released the new mercury advisory on January 12, 2001. The advisory singled out infants, small children, pregnant or nursing mothers, and women who may become pregnant. The advisory named several large fish that these targeted consumers should avoid entirely. More generally, it stated that consumers should limit their consumption of all fish, including canned fish, to no more than 12 ounces per week (less than two average meals). While the advisory focused on the risks of mercury in fish, it also stated that seafood is protein-rich, high in nutrients, and low in fat. In fact, the first line of the advisory noted that seafood "can be an important part of a balanced diet." Notably, the advisory also indicated that certain fish have lower levels of methylmercury than others and can be safely eaten frequently. However, it did not list low mercury species.

The FDA's outreach program consisted of a two-phase information campaign. Over the course of three months following the advisory, the FDA communicated its message by releasing pre-prepared newsprint and television press releases. Similar media kits were sent to weekly print news sources, parenting magazines, and women's health periodicals. Phase I of the information campaign also included letters to physicians and health organizations. Phase II was a methodologically similar, but less intense, "reminder" campaign conducted in 2002.

Advisory Response

This study provides the first systematic revealed preference evidence on consumer responses to the 2001 FDA Commercial Fish Advisory. In related research, Oken et al. (2003) evaluated time trends in fish consumption from April 1999 through February 2002 for women enrolled in a maternal nutrition study at a Massachusetts group practice. They gathered "semiquantitative" data on fish consumption frequency, based on patient recollections over periods from one to three months. Their analysis allowed for a structural break in a linear time trend after the FDA advisory, which was negative and significant. However, without a control group it is difficult to know to what extent this reduction was due to the advisory or to confounding factors such as an increased price of fish in 2001. Further, their questionnaire data lacked sufficient detail to recover mercury or omega-3 estimates or to meaningfully examine substitution across species.

Similarly, Shimshack, Ward, and Beatty (2007) explored CEX consumption data for the 'canned fish' category and found evidence for a significant reduction in consumption for that category after the advisory. However, that single-category study was unable to estimate mercury intakes, omega-3 consumption, and account for substitution possibilities and health tradeoffs among fish types. Cohen et al. (2005) summarized the findings of a Harvard Center for Risk Analysis expert panel on fish consumption. The panel developed dose-response relationships for fish consumption and stroke, heart disease, and prenatal neurobehavioral development. They then applied such relationships to hypothetical changes in fish, mercury, and omega-3 consumption following a national commercial fish advisory. No actual consumption data was analyzed.[1]

3. Data

Household-Based Scanner Data

Our research assesses the impact of the FDA advisory on household fish consumption. We analyze data from Information Resources, Inc.'s InfoScan Consumer Network database. Here, households scan universal product codes (UPCs) on purchased products upon returning home from shopping. Our sample contains data on *all* non-random weight seafood purchases for consumption within the household, including canned and shelf-stable products, refrigerated products, and frozen products.[2]

The use of household-based scanner data offers numerous advantages. First, the data are comprehensive. Our dataset contains purchases of more than 5,300 distinct seafood products from nearly 15,000 households. Second, the data contain detailed product descriptions, including species type. Species information allows us to combine consumption data with a scientific literature and extensive USDA product testing to translate a household's consumption into its mercury and omega-3 intakes. Product

[1] Other related studies measured responses of recreational anglers to localized safety advisories (Belton et al. 1986, May and Burger 1996). Jakus et al. (2002) used assumptions based upon such recreational demand studies to develop health and welfare benefits estimates of a striped bass advisory to Chesapeake Bay anglers.

[2] Approximately 60 percent of US seafood is consumed in the home (US National Academies 2005). One-third of all fish and shellfish consumption is cured or canned. We can find no systematic data on refrigerated and frozen consumption vs. random weight consumption for the remaining two-thirds. However, the four leading US seafood consumption categories are shrimp, canned tuna, salmon, and pollack. Together, these four categories represent about 70 percent of US consumption. Of these, only salmon has large random weight sales. There is no reason to assume *a priori* that advisory-induced consumption responses differ substantively between in-home non-random weight purchases and the less important random weight and away-from-home purchases.

information also allows us to determine how the advisory affected consumption of each fish type, facilitating investigations of substitution and differential responses across species. Third, the data are extremely accurate. In particular, household-level scanner data avoids the strategic bias, recall bias, and observer bias inherent in common survey or diary data collection techniques. Finally, the data are matched with a diverse set of demographic variables over a wide geographic range. Sampling weights allow us to recover a nationally representative sample.

Sample

Our sample covers the years 2000-2002, starting one year before the January 2001 advisory and extending two years past the advisory to allow time for information dissemination and consumer adjustment. The sample of interest contains 14,821 households with less than three adults and less than three children. To prevent identification of unusually large households, IRI does not provide complete demographic information for large households. We therefore omit them. To standardize comparisons across households, we scale all quantities by an adult-equivalence factor to yield per capita measures. Our method for constructing these factors follows USDA practice (Lino 2004).[3]

For every product purchased, we obtain volume in pounds, mercury in micrograms, and total omega-3 fatty acids in grams. Volume in pounds is directly provided by IRI. Mercury in micrograms is constructed by matching fish species, obtained from the detailed product descriptions at the UPC level, with the scientific

[3]To be consistent with the literature, we conduct adult-equivalence scale factors for total meat consumption. We use the 1999-2002 Consumer Expenditure Diary surveys to do so. Children under 6 consume approximately 24 percent of adult's consumption, children ages 6-11 consume 29 percent of an adult's consumption, and children ages 12-18 consume 61 percent of an adult's consumption.

literature on species-specific mercury concentrations. Omega-3 content in grams is created by matching fish species with the scientific literature on species-specific docosahexaenoic acid (DHA) and eicosapentaenoic acid (EPA) concentrations. Table 1 summarizes species-specific mercury and omega-3 information.

Once we obtain volume, mercury, and omega-3 quantities for each purchased product, we sum these data to reflect total quantities for each household/year combination. We sum over full years to minimize the impacts of important seasonality in fish consumption and prices. Nevo and Hatzitaskos (2005) provide evidence for such seasonality. We frequently obtain volume, mercury, and omega-3 quantities over *all* consumed fish for each household. However, when we are interested in a specific species or subset of species, we obtain volume, mercury, and omega-3 by summing over each household's consumption of that species or group of species alone.

4. Methods

Our goal is to assess the impact of the advisory on the mercury exposure, omega-3 intakes, and fish consumption of at-risk households. Since we have a panel dataset, it is perhaps tempting to assess these impacts by simply comparing at-risk households' pre-advisory mercury, omega-3, and consumption quantities with at-risk households' post-advisory mercury, omega-3, and consumption quantities. This simple comparison reveals a significant decrease in mercury intakes and a modest increase in omega-3 intakes between 2000 and 2002. However, we can not attribute changes in consumption after the advisory to the advisory itself. Prices fell substantially between 2000 and 2002, and other factors such as substitute prices, promotions, and advertising also changed.

Therefore, our research design must account for such confounding factors. The natural way to do so is to examine differential responses between control and experiment groups. We mimic this structure by examining differences between households explicitly advised to limit consumption by the advisory and households not targeted by the advisory. The natural experiment afforded by this difference removes the effect of confounding factors and allows us to isolate the effect of the advisory on at-risk households. Our treatment, or quasi-experimental, group is households with pregnant women, nursing children, or children under 6. Our quasi-control group is households with no children or pregnant women.[4]

Our specific methodological approach is Athey and Imbens's (2006) changes-in-changes model. Changes-in-changes is a non-parametric extension of the commonly utilized difference-in-differences method, but instead of identifying an average treatment effect alone it identifies the entire distribution of treatment effects. Further, this model overcomes several well known difficulties with difference-in-differences. Most notably, outcomes are theoretically consistent and not sensitive to scale. Changes-in-changes nests the standard difference-in-differences model.

The changes-in-changes model specifies that the outcome y for any individual in the absence of treatment depends only on an index of the unobserved characteristics u and time t. Formally,

$$y = h(u,t) \tag{4.1}$$

where h is a strictly increasing function of u. The realization of u for any particular individual may change over time, but the distribution of u within a group is assumed to

[4] Our results are robust to a wide range of control group definitions. We choose this control to most starkly distinguish treatment households with control households.

be constant over time. However, the distribution of u may be different across groups. This is important, as assignment to the treatment and control groups is non-random, since average consumption differs across the two groups even before the advisory. The time term t in the function h accounts for changes in confounding factors over time, which may interact with individual characteristics u. The goal of the estimator is to separately identify the effect of the treatment from the effect of these confounding factors.

The model uses variation across time in the distribution of outcomes for the control group to predict the counter-factual distribution of outcomes for the treatment group, in the absence of intervention. As a rough intuition, suppose that u was fixed over time periods $t = 0$ and $t = 1$ for two households, one treatment and one control, each with the same initial outcome, $y0$. Since h is monotonically increasing, the model specifies that the two household also have the same u, as $y = h(u,0)$. Absent treatment, those two households should also have the same consumption $y1$ in the second period, since $y1 = h(u,1)$ and u is fixed by assumption. Thus, the outcome for the control group is observed, and used to predict the counterfactual outcome for the treatment group. While this intuition is useful, for statistical purposes it is sufficient for the distribution of u to be fixed for each group over time, instead of fixing each household's particular value of u over time.

The CIC estimator is based purely on the empirical cumulative distribution functions of outcomes for the treatment and control groups. It is fully non-parametric and requires no particular specification for h, which is not directly estimated. Let F_0 and F_1 be the cumulative distribution functions of outcomes y for the control group in periods 0 and 1 respectively. Similarly, let G_0 and G_1 be the cumulative distribution functions of outcomes for the treatment group. Then, in the absence of treatment, Athey and Imbens (2006) prove that under the changes-in-changes assumptions,

$$G_1(y) = G_0\left(F_0^{-1}\left(F_1(y) \right) \right) \tag{4.2}$$

Substituting the empirically observed cumulative distribution functions for G_0, F_0, and F_1 into this theoretical relationship yields an estimate, $\hat{G}_1$, of the hypothetical distribution of treatment group outcomes in period 1 had treatment not occurred. This counterfactual estimate gives a baseline which accounts for confounding factors. The actually observed empirical cumulative distribution function, G_1, is affected by both treatment and confounding factors. So, the difference between the empirically observed cumulative distribution function for the treatment group in period 1, G_1, and the hypothetical counterfactual baseline distribution function, $\hat{G}_1$, generates an estimate of the pure treatment effect on the distribution of outcomes for the treatment group.

5. Results

Did at-risk households reduce mercury exposure in response to the advisory?

Did at-risk households reduce mercury exposure in response to the advisory? Figure 1 presents the 2000 vs. 2002 changes-in-changes estimates of the advisory impact for at-risk households' total per-capita mercury intakes from fish and shellfish.[5] Evidence indicates that the advisory induced a broad-based decline in per capita mercury consumption for the treatment group. On average, we find a 26 percent decline in target consumers' mercury exposure, with a 90 percent bootstrap confidence interval of

[5] In addition to 2000 vs. 2002 comparisons, we repeat all analyses for 2000 vs. 2001 as well. All results are similar to those presented in sign and significance, but tend to be smaller in magnitude.

[10%,45%].[6] We also see a particularly strong decline at the upper tail of the per-capita mercury distribution. In isolation, these results are very promising for public health.

Did at-risk households increase omega-3 intakes in response to the advisory?

If at-risk households intelligently substituted away from high-mercury fish into low mercury, high omega-3 fish, public health is clearly enhanced by the advisory. So, did at-risk households increase omega-3 intakes in response to the advisory? Figure 2 presents the 2000 vs. 2002 changes-in-changes estimates of the advisory impact for at-risk households' total per-capita omega-3 intakes from fish and shellfish. Evidence indicates that the advisory induced a broad-based decline in per capita DHA and EPA omega-3 consumption for the treatment group. On average, we find a 24 percent decline in target consumers' omega-3 intakes, with a 90 percent confidence interval of [8%,42%]. We also see that this decline occurs everywhere along the per capita omega-3 distribution, including the lower tails. There is a substantial countervailing cost to the mercury benefit.[7]

How did at-risk households change fish consumption in response to the advisory?

If at-risk households responded to the advisory by simply reducing consumption of all fish, not by substituting away from high mercury fish into low mercury high omega-3 fish, the countervailing costs to the mercury benefits may be substantial. Further, an aggregate decrease in fish volume could explain the previously revealed

[6] The bootstrap procedure re-samples households, in order to preserve the panel structure. Reported intervals are based on the bootstrap percentile method.

[7] It is possible that consumers responded to the advisory by avoiding fish consumption but increasing omega-3 supplements. This possibility is unlikely to meaningfully affect our results for two reasons. First, the omega-3 supplement market was small over our sample period. In 2002, only 2 percent of the US population had used fish oil supplements even once over the previous year (Kennedy 2005). Second, growth in the fish oil market was modest over our sample period. The market growth between 2000 and 2002 was approximately $20 million. For perspective, the market growth between 2002 and 2005 was approximately $260 million.

declines in both per capita mercury consumption and per capita omega-3 consumption for at-risk households. So, did at-risk households decrease total fish consumption in response to the advisory? Figure 3 presents the 2000 vs. 2002 changes-in-changes estimates of the advisory impact for at-risk households' total per-capita fish and shellfish consumption volume. Evidence indicates that the advisory induced a broad-based decline in per capita fish consumption for the treatment group. On average, we find a 26 percent decline in target consumers' aggregate fish consumption, with a 90 percent confidence interval of [13%,46%]. We also see that this decline occurs everywhere along the per capita volume distribution, including the lower tails. While the advisory had clear potential for public health gains through intelligent substitution, such substitution did not occur.

Did at-risk households differentially avoid high-mercury fish in response to the advisory?

The results summarized in Figures 1-3 indicate that the advisory did not generate a clear "win-win" for public health. Targeted households reduced aggregate fish and shellfish consumption, and did not significantly substitute away from high mercury seafood into low mercury, high omega-3 seafood. However, if at-risk households at least differentially avoided high mercury fish, the countervailing public health costs of the advisory may be mitigated.

So, did at-risk households differentially avoid high-mercury fish in response to the advisory? Table 2 presents the 2000 vs. 2002 mean changes-in-changes estimates of the advisory impact for at-risk households' per-capita consumption of commonly consumed seafood items. Mean results are representative of distributional outcomes. Evidence suggests that consumption declines for every major commonly consumed fish and shellfish type analyzed. After accounting for confounding factors, at-risk households' white tuna, light tuna, and pollack consumption fell 16 percent, 18 percent, and 17 percent respectively. At-risk households' shrimp and salmon consumption volume fell 39 percent and 50 percent respectively.

None of the category-specific consumption reductions are statistically different from one another, but the disaggregated analysis convincingly demonstrates that at-risk consumers reduced consumption of all fish, including the clear "win-win" species like shrimp and salmon. It does not appear that at-risk households differentially avoided high mercury fish in any practically meaningful way. The countervailing health costs of the advisory are significant.

6. Discussion

Our findings indicate that the 2001 commercial fish advisory reduced at-risk consumers' exposure to mercury. However, our results also indicate that the countervailing costs for omega-3s were very significant and broad-based. At-risk households responded to the advisory by reducing consumption of all fish, including species like shrimp and salmon that presented clear public health benefits due to low mercury and high omega-3 content.

Respondents did not consider risk trade-offs. Despite the careful and scientifically balanced text of the advisory, at risk households only considered mercury risks. Published risk analyses have indicated that the net benefits of commercial fish advisories are small, and very likely negative, if consumers did not intelligently substitute away from high mercury fish or differentially avoid high mercury fish (Cohen et al. 2005). Therefore, our results suggest that the 2001 advisory resulted in small or negative net public health benefits. Further, this paper provides evidence that cognitive limitations, risk perceptions, and other factors may imply that even carefully crafted advisories and information campaigns may have unintended consequences. Policy implications include the necessity for more active, balanced, and targeted health campaigns.

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Table 1. Mercury and Omega-3 Concentrations by Species

Seafood	Mercury (in μg/g)	Omega-3 (in g/100g)	Original Hg Source	Omega-3 Source
Anchovy	.043	2.05	NMFS (1978)	USDA (2006)
Catfish	.049	0.17	FDA `90-`04°	Ackman (2000)
Clams	.001*	0.35	FDA `90-`02°	Ackman (2000)
Cod	.095	0.31	FDA `90-`04°	Ackman (2000)
Crab	.060	0.36	FDA `90-`04°	Ackman (2000)
Crayfish	.033	0.17	FDA `02-`04°	USDA (2006)
Croaker	.180	0.24	FDA `90-`03°	Ackman (2000)
Eel	.213	0.96	EPA (1997)	Ackman (2000)
Flounder	.045	0.12	FDA `90-`04°	Ackman (2000)
Grouper	.465	0.30	FDA `02-`04°	Ackman (2000)
Haddock	.031	0.21	FDA `90-`02°	Ackman (2000)
Halibut	.252	0.38	FDA `90-`04°	Ackman (2000)
Herring	.044	2.34	NMFS (1978)	Ackman (2000)
Jack Mackerel	.267	1.23	EPA (1997)	USDA (2006)
Lobster	.240	0.36	FDA `91-`04°	Ackman (2000)
Mackerel	.069	2.29	NMFS (1978)	Ackman (2000)
Mahi	.144	0.22	EPA (1997)	Ackman (2000)
Mullet	.046	0.33	NMFS (1978)	USDA (2006)
Mussel	.030	0.79	Sunderland (2007)	USDA (2006)
Octopus	.029	0.16	EPA (1997)	USDA (2006)
Oyster	.013	0.19	FDA `90-`04°	Ackman (2000)
Perch	.140	0.32	FDA `90-`02°	USDA (2006)
Pike	.310	0.14	EPA (1997)	USDA (2006)
Pollack	.041	0.26	FDA `90-`04°	Ackman (2000)
Redfish	.001*	0.21	FDA `90-`02°	Ackman (2000)
Roughy	.554	0.04	FDA `90-`04°	USDA (2006)
Salmon, atlantic	.014	2.00	FDA `90-`02°	USDA (2006)
Salmon, canned	.001*	1.35	FDA `90-`02°	USDA (2006)
Salmon, chinook	.014	1.74	FDA `90-`02°	USDA (2006)
Salmon, chum	.014	0.81	FDA `90-`02°	USDA (2006)
Salmon, pink	.014	1.29	FDA `90-`02°	USDA (2006)
Salmon, sockeye	.014	1.23	FDA `90-`02°	USDA (2006)
Salmon, unknown	.014	1.46	FDA `90-`02°	USDA (2006)
Sardines	.016	0.98	FDA `02-`04°	USDA (2006)
Scallop	.050	0.37	NMFS (1978)	Ackman (2000)
Seabass	.219	0.15	FDA `90-`04°	Ackman (2000)
Shrimp	.001*	0.44	FDA `90-`02°	Ackman (2000)
Smelt	.108	0.89	FDA `90-`02°	USDA (2006)
Snapper	.189	0.26	FDA `02-`04°	Ackman (2000)
Sole	.045	0.19	FDA `90-`04°	Ackman (2000)
Squid	.070	0.54	NMFS (1978)	USDA (2006)
Sturgeon	.235	1.97	EPA (1997)	Ackman (2000)
Swordfish	.976	0.58	FDA `90-`04°	Ackman (2000)
Tilapia	.010	0.14	FDA `90-`02°	USDA (2006)
Trout	.072	0.62	FDA `02-`04°	Ackman (2000)
Tuna	.383	0.30	FDA `02-`04°	USDA (2006)
Tuna, canned	.118	0.20	FDA `02-`04°	USDA (2006)
Tuna, canned light	.118	0.20	FDA `02-`04°	USDA (2006)
Tuna, canned light oil	.118	0.13	FDA `02-`04°	USDA (2006)
Tuna, canned light water	.118	0.27	FDA `02-`04°	USDA (2006)
Tuna, canned oil	.118	0.13	FDA `02-`04°	USDA (2006)
Tuna, canned water	.118	0.27	FDA `02-`04°	USDA (2006)
Tuna, canned white	.353	0.56	FDA `02-`04°	USDA (2006)
Tuna, canned white oil	.353	0.25	FDA `02-`04°	USDA (2006)
Tuna, canned white water	.353	0.86	FDA `02-`04°	USDA (2006)
Tuna, white (albacore)	.357	0.81	FDA `02-`04°	Ackman (2000)
Turbot	.100	0.62	EPA (1997)	Ackman (2000)
Whitefish	.069	0.21	FDA `02-`04°	USDA (2006)
Whiting	.001*	0.24	FDA `90-`02°	Ackman (2000)

* indicates mercury concentrations were below detection levels. Table I is similar to Tables 2 and 3 in Maheffey (2004).° indicates that the FDA conducted its test of this species over these years, as reported by USHHS and the US EPA, "Mercury Levels in Commercial Fish and Shellfish," February 2006. Accessible online at www.cfsan.fda.gov/~frf/sea-mehg.html .

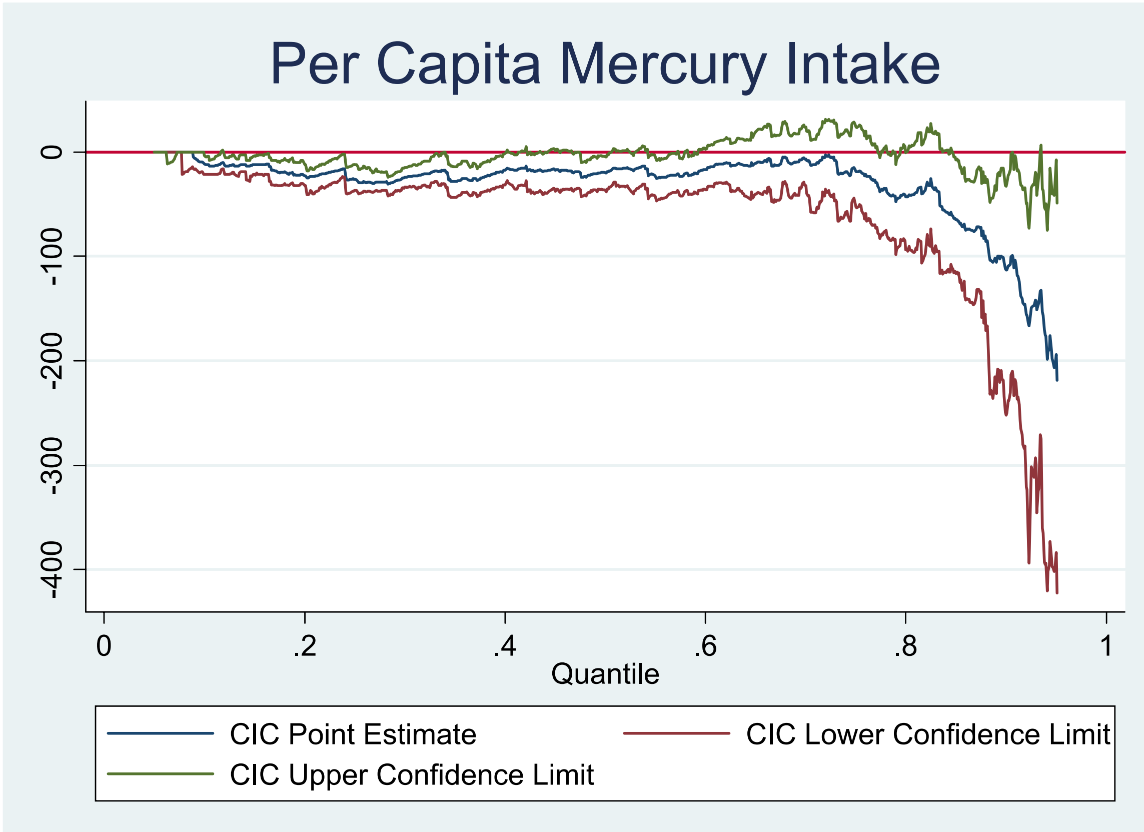

Figure 1. The graph presents the estimated impact of the advisory on the per capita mercury intake of the at-risk group. For each quantile along the distribution of at-risk consumers' mercury intake distribution, the point estimate is the advisory-induced change in the associated quantity. The upper and lower lines represent the bootstrapped 90 percent confidence interval for each estimate. For example, the quantity associated with the 90th quantile fell 113.36 micrograms with a confidence interval of [-251.97,-33.14].

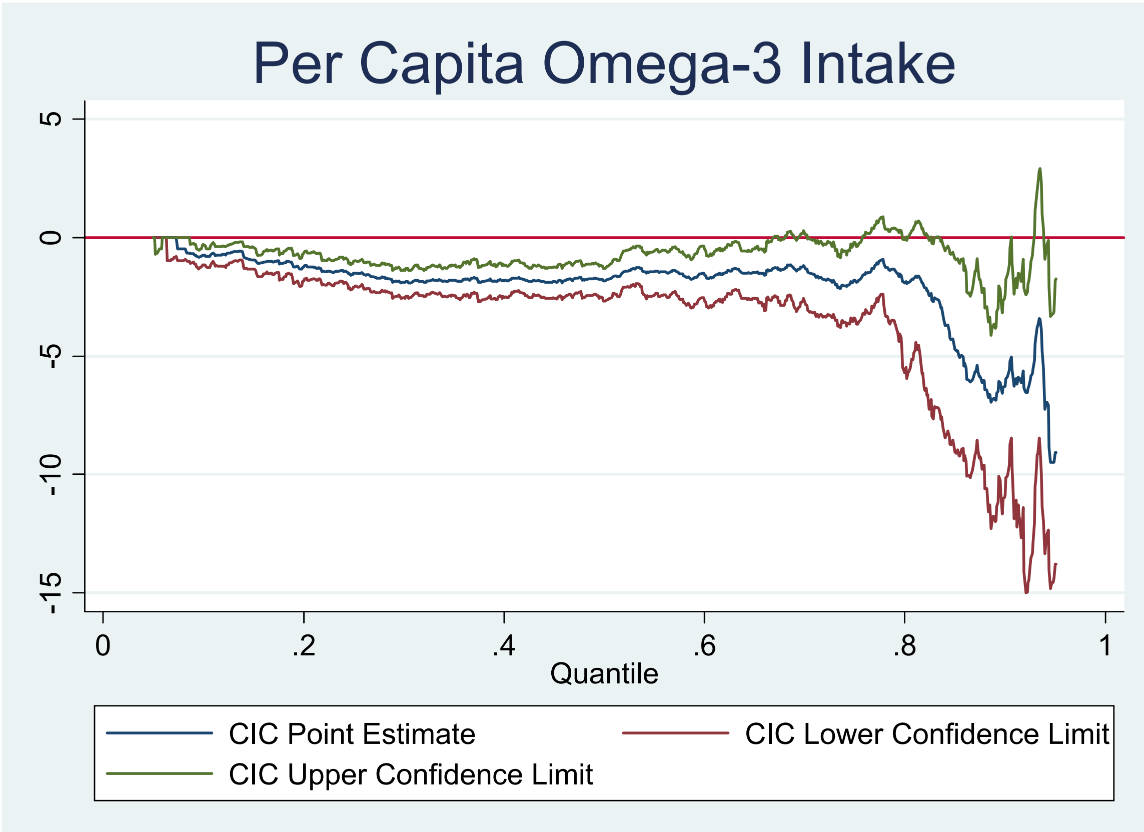

Figure 2. The graph presents the estimated impact of the advisory on the per capita omega-3 (DHA+EPA) intake of the at-risk group. For each quantile along the distribution of at-risk consumers' omega-3 intake distribution, the point estimate is the advisory-induced change in the associated quantity. The upper and lower lines represent the bootstrapped 90 percent confidence interval for each estimate. For example, the quantity associated with the 20th quantile fell 1.24 grams with a confidence interval of [-1.82,-0.67].

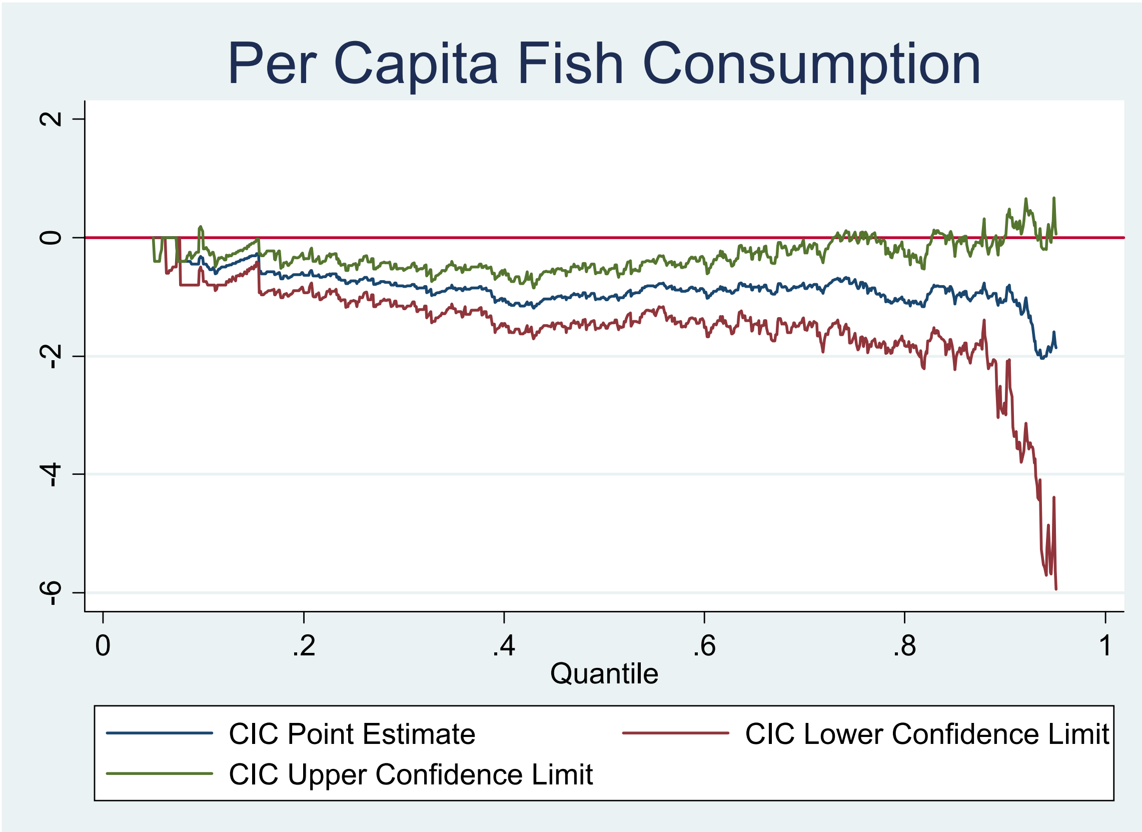

Figure 3. The graph presents the estimated impact of the advisory on the per capita fish consumption volume of the at-risk group. For each quantile along the distribution of at-risk consumers' fish volume distribution, the point estimate is the advisory-induced change in the associated quantity. The upper and lower lines represent the bootstrapped 90 percent confidence interval for each estimate. For example, the quantity associated with the 40th quantile fell 1.04 pounds with a confidence interval of [-1.45,-0.56].

Table 2. Mean Per-Capita Seafood Consumption Change (in pounds) by Category

Seafood Type	Mean Changes-in-Changes Point Estimate	Percent Change for Point Estimate	90 percent Confidence Interval
White Tuna	-0.07	-16%	[-0.20,0.07]
Light Tuna	-0.31	-18%	[-0.73,-0.01]
Pollack	-0.19	-17%	[-0.39,-0.01]
Shrimp	-0.11	-39%	[-0.25,0.01]
Salmon	-0.09	-50%	[-0.22,0.01]