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Are Mercury Advisories Effective?
Information, Education, and Fish Consumption

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ABSTRACT

Mercury exposure has emerged as one of the most prominent environmental health and food safety concerns. The primary danger is the consumption of contaminated fish by young children, nursing mothers, and pregnant women. To mitigate the risks, in January 2001 the FDA issued a national advisory urging at-risk consumers to limit fish consumption. Did the FDA advisory reduce mercury exposure to at-risk groups? We find that consumers most likely to be aware of and understand the advisory did significantly reduce fish consumption relative to a control group. Both education and newspaper readership are important determinants of consumption response among at-risk groups, suggesting that information acquisition and assimilation are key factors for risk avoidance. Some newspapers readers not specifically targeted by the advisory also responded. Disturbingly, we do not find a response to the mercury advisory among the relatively large group of at-risk households which met neither the education nor readership criteria.

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Mercury exposure is among the most prominent sources of health risk from environmental pollution. A 2001 Center for Disease Control (CDC) study found that one in ten American women of childbearing age has elevated levels of mercury in her blood. At current reference doses and margins of safety, the CDC findings suggest that every year at least 85,000 U.S. children are born at risk of neurological damage from mercury exposure. This paper examines the effectiveness of the most notable demand-side effort to limit the exposure of vulnerable groups.

Anthropogenic mercury is typically emitted as an air pollutant, which is bio-chemically transformed into methylmercury after deposition into surface waters. Methylmercury then enters fishes' bloodstreams and bio-accumulates up the food chain. Consumption of these contaminated fish by young children, nursing mothers, or pregnant women poses a significant threat to the health of developing children, the group most susceptible to mercury toxicity.

Because mercury persists in the environment and is emitted globally, even completely eliminating domestic emissions would not eliminate mercury risks in the near term. Reducing mercury exposure by avoiding excess fish consumption among at-risk individuals is therefore vital. Indeed, in January 2001 the Food and Drug Administration (FDA) issued a commercial fish consumption advisory that warned of the health hazards from mercury and urged at-risk individuals to limit fish consumption. Changes in consumption patterns following this first major national mercury advisory are the focus of our study.

To what extent did the FDA advisory reduce exposure to at-risk groups? We address the question by examining household-level fish consumption from the U.S. Consumer Expenditure Survey (CEX). Specifically, we analyze how certain groups' consumption of canned fish products changed in response to the advisory. Such a advisory can only be effective to the extent that consumers are aware of the advisory and are willing and able to assimilate the information into behavior. We therefore focus on news readership, education, and healthy behavior as potentially important response predictors. For example, since news readership is positively correlated with information acquisition, we investigate differential responses among readers and non-readers. Education may serve as a proxy for both information acquisition and assimilation, so we investigate differential responses among educated and less educated consumers. We also investigate health consciousness, since the literature suggests it serves as a proxy for risk preferences.

We find that news readership and education importantly affected advisory response, while health consciousness did not. News readers reduced consumption significantly as compared to non-readers. This held for all consumer categories, not just those targeted as at-risk. Access to information thus appears to be an important factor limiting response. Educated consumers also significantly reduced consumption compared to the less-educated. In this case, the response was limited to targeted at-risk groups. While readers responded broadly, the educated responded in a manner more consistent with advisory language. The least educated and least well-read among vulnerable groups also reduced fish consumption the least.

This is the first economic study of consumption responses to advisories for store-bought fish, the primary source of mercury exposure to the public. The most closely related research studies responses of recreational angler to localized safety advisories. See, for example, Belton *et al.* (1986) and May and Berger (1996). Using consumption response assumptions based on such recreational demand studies, Jakus, McGuinness, and Krupnick (2002) developed health and welfare benefits of a striped bass advisory to Chesapeake Bay anglers.

Our study also fits into a more general literature. First, it contributes to the debate regarding the effectiveness of consumption advisories. Adler & Pittle (1984) have a pessimistic view of the efficacy of such advisories in practice. It is debated whether even the famous surgeon general's warning for tobacco was in and of itself a "watershed event" (Fenn *et al.* (2001) and Sloan *et al.* (2002)). Second, our research contributes to the broader literature on consumption responses to health information. Experimental work by Viscusi *et al.* (1986) shows that, given information about product hazards, subjects undertake precautionary behavior broadly consistent with basic economic theory. Empirically, Foster and Just (1989) (milk), Brown and Shrader (1990) (eggs), and Kinnucan *et al.* (1997) (meat) all show that adverse health information leads to a consumption reduction. These empirical studies are all based on aggregate data. In contrast, our use of household-data allows us to disentangle response determinants related to information access and assimilation, such as education and news readership.

The paper proceeds as follows. Section I reviews mercury sources, health consequences, and key policy milestones. Section II summarizes our consumer expenditure data. Section III examines several methodological approaches, each with their own strength. Graphical analyses, non-parametric statistical tests, and a standard parametric analysis are included. Section IV presents our results by answering a series of key questions. Finally, section V concludes by interpreting our results for economics and policy.

I. Mercury Science & Policy

A. Sources and Consequences of Mercury Exposure

Environmental circulation of mercury has increased dramatically 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 then releases the mercury into the atmosphere. When atmospheric mercury is deposited into surface water, bacteria convert the mercury into organic methylmercury. It then readily enters a fish's bloodstream from water passing over gills and accumulates in the tissues. Methylmercury also 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 shark, tuna, and mackerel.

For the general public, fish consumption is the primary source of exposure to mercury. Cooking and other forms of preparation do not mitigate the risk. Once consumed, mercury is a potent neurotoxin, which is easily absorbed into the bloodstream. In adults, abnormally high concentrations can contribute to brain damage, blurred vision, slurred speech, and other neurological conditions. Such concentrations in adults are rare. However, even modest mercury concentrations can cause 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 like cerebral palsy. Even though they do not directly consume contaminated fish, fetuses and nursing infants are endangered because mercury readily passes through the placenta, concentrates in umbilical tissues, and leaches into breast milk.

B. Mercury & Public Policy

Mercury has recently drawn considerable regulatory scrutiny. For example, the Clear Skies Initiative was touted as "the first ever national cap on mercury emissions." Similarly, the EPA has established power plant mercury emissions standards as a top national priority. Unfortunately, even very strict standards cannot eliminate the hazard because mercury persists in the environment. Further, most large fish consumed domestically are caught abroad. For these reasons, demand-side consumer policy is, and will remain, essential for the protection of public health.

Major milestones in consumer policy are shown in Table 1.[1] As with most environmental health hazards, there was a period in which mercury consumption risks were thought to be minimal. Indeed, FDA scientists counseled in 1994 that "normal patterns of consumption" do not pose a health threat. This official stance persisted until mid-2000, when the FDA became alarmed by the cumulative findings of an EPA report (1997) and a National Academy of Sciences (June 2000) study that highlighted the dangers of consuming contaminated fish. In August of 2000, the FDA announced it was considering a new methyl-mercury advisory and solicited comment. This was an unusual response by the FDA; while agency inspections, approvals, and sanctions are common, this type of broad and direct consumer campaign was, and remains, very rare.[2]

The FDA formally released the new mercury advisory on January 12, 2001. The advisory named several large fish for targeted consumers to 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 (two average meals). The advisory singled out infants, small children, pregnant or nursing mothers, and women who may become pregnant. It states in part, "While it is true that the primary danger from methylmercury in fish is to the developing nervous system of the unborn child, it is prudent for nursing mothers and young children not to eat these fish as well."

The FDA's outreach program emphasized 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

[1] Table 1 and the accompanying discussion emphasize consumption advisories for fish commercially caught and marketed. EPA and state advisories for methylmercury contamination in locally, recreationally caught fish have been periodically issued as well. Due to their relatively limited scope and scale, we consider these recreational advisories of secondary importance. The interested observer may wish to check the EPA's 'Local Fish Advisory Programs' page at http://www.epa.gov/waterscience/fish/states.htm .

[2] FDA inspections can identify localized public health threats, and product- or location- specific consumption advisories are not infrequent. For example, the FDA recently publicized a number of branded almond recalls due to the possibility of *salmonella enteriditis* contamination. Advisories specifically advocating the reduction or elimination of certain foods are rare.

health organizations. Phase II was a methodologically similar, but less intense, "reminder" campaign conducted in 2002.

II. Data

A. CEX Diary Surveys

Our research assesses the impact of the FDA advisory on consumption of canned fish. We rely on the Bureau of Labor Statistics' Consumer Expenditure Survey (CEX) as our primary data source. This annual survey asks a cross-section of households to record all expenditures over a two-week period in daily diaries. The data is then summed to reflect total household purchases of each item over the sample period.

Using the CEX diaries has a number of advantages. First, CEX data is widely used for economic and statistical analyses. Second, the unit of observation is the household, allowing us to account for a diverse set of demographic and expenditure variables.[3] Third, CEX households are geographically diverse, and weighting allows the dataset to approximate a nationally representative sample. Finally, expenditure snapshots allow unbiased estimates of mean consumption changes over time, which are the crux of our analysis.

B. Sample & Definitions

Our sample of CEX diary data is for 1999-2002, covering the two years before and after the FDA advisory. Since the focus of the warning is on pregnancy and children, we restrict our analysis to households with a young child or with an adult no older than 45 years. To focus on a relatively homogenous sample, we exclude households with more than twelve members total, households with three or more adults, and households with multiple unmarried adults. Further, to avoid outliers or data entry errors, we eliminate households with incomplete diaries, those that report no in-home food purchases for the diary period, and the 17 observations with per-capita quantities more than 4 standard deviations above the mean for households with positive canned fish expenditures.

Much of our analysis focuses on identifying differential responses between groups targeted as at-risk by the advisory and those nominally unaffected by the advisory. This latter category in effect serves as a control group. We study the response of households with young or nursing children relative to this control. Since the warning also targets women who are pregnant or may become pregnant, we would ideally separately analyze this group as well. Unfortunately, our data does not allow us to identify these individuals directly. In order to avoid contaminating our control group with these individuals, we set aside the control demographic most likely to include them: childless married women less than 46 years of age.[4]

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[3] Datasets tracking landings and exports are available, but these contain no household-level data. Further, these aggregate statistics reflect institutional as well as household consumption and do not account for possible warehousing.

[4] Of course, women who already have young children may also be likely to have more children. They are, however, already categorized as targeted.

The final dataset contains 10,537 observations. Observations are approximately evenly distributed over the sample period. There are 5297 observations in the two years prior to the advisory and 5240 observations in the two years after the advisory.

The most direct measure of fish consumption in the CEX is expenditures on canned fish. We choose canned fish because it is widely consumed, it was specified in the advisory language, and data is readily available. To translate expenditures into quantities, we divide them by price. Since the CEX does not contain price information, we use the BLS regional average price for canned tuna by month.[5] We construct an adult-equivalence scaling factor for tuna consumption by regressing total in-home meat consumption on the number of adults, babies, young children, medium-aged children, and old children living in the household. Adults are normalized to one, and children are scaled accordingly.[6] Since the mercury advisory may induce changes in the decision to consume and the quantity conditional on consuming, our analysis considers three separate quantity variables: total consumption quantity, a consumption decision dummy, and quantity conditional on non-zero expenditures.

In addition to identifying broad consumption responses, we analyze how specific groups reacted to the advisory. We analyze the responses of readers relative to non-readers. Similarly, we compare consumption by educated households to less educated households. Finally, we compare health conscious consumers relative to other consumers. Thus, we include a dummy for newspaper or magazine purchases, a dummy for college graduates, and an ad-hoc proxy index for health consciousness. We consider households 'health conscious' if their food expenditure share of fresh fruits of and vegetables is larger than 70 percent of demographically similar households, and have no tobacco expenditures.[7]

C. Summary Statistics

Summary statistics and variable definitions are presented in Table 2. The table illustrates the stability of household demographic composition over time. All nine variables reflecting households' physical composition, news purchases, education, and health consciousness have similar means before and after the warning. Average changes are an order of magnitude smaller than their standard deviations. This suggests that variability in consumption behavior over time is unlikely to be attributable to variability in sample composition.

The statistics in Table 2 also show that average aggregate canned fish quantity was approximately 8.5 percent higher after the advisory than before. Specifically, quantities conditional on consuming rose by approximately 10 percent while the percentage of consumers purchasing canned fish fell by 1.2 percent. Shares, which incorporate both prices and quantities, remained relatively constant over time. Of course, additional factors beyond the advisory may have induced consumption changes. On average, the real price of canned fish fell and substitute prices rose. Information about the

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[5] Tuna has consistently comprised over 80% of canned fish consumption over the last decade. The ratio of canned tuna consumption to other canned fish has remained quite stable (NMFS).

[6] For example, a household with 2 adults and 1 young child would have an adult equivalence scaling factor of 2.24.

[7] We later check that our results are robust to the definition of the educated and health-conscious groups.

benefits of fish consumption (such as omega-3 fatty acids) may have changed. It is important to note that the ensuing analyses difference out these and other potential common shocks. We emphasize changing consumption patterns for relevant sub-populations *relative to* consumption changes for control sub-populations.

III. Empirical Methodology

Our empirical analysis addresses the following questions: After the FDA mercury advisory, did the groups directly targeted by advisory language respond? Did news readership influence consumption choices? Did education levels influence consumption choices? Did health consciousness influence consumption choices?

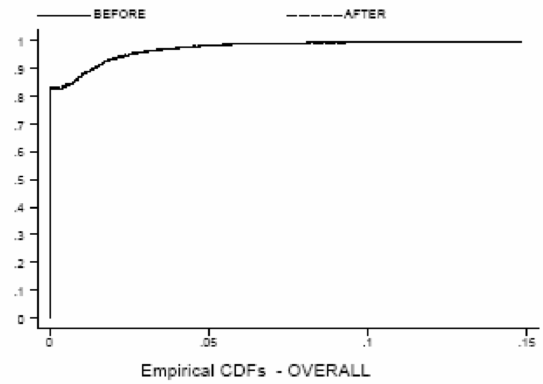
We approach these questions in three ways. First, we graphically illustrate changes in the empirical distribution of pre- and post-advisory consumption. Second, we formalize the results of the graphical analysis with non-parametric tests. These tests control for unobserved common shocks. Specifically, we test whether relative consumption patterns change, after sweeping out a control group shock. Third, we supplement the non-parametric approach with standard regression analyses. Regression essentially runs the comparison of means simultaneously accounting for potential unobserved correlation.

A. Distribution and Mean Comparisons
Comparing Cumulative Distribution Functions

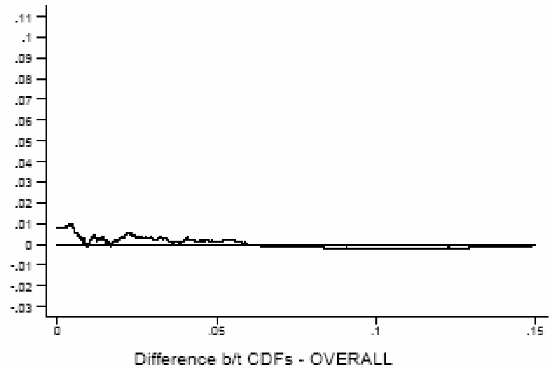
For each question, our analysis begins with a graphical presentation of fish expenditure shares. We compare post-advisory empirical cumulative distribution functions (cdfs) with pre-advisory cdfs. If, on average, households meaningfully altered their behavior after the advisory, the post-advisory cdf will differ from the pre-advisory cdf *ceteris paribus*.[8] To illustrate, Figure 1A plots the empirical cdf of overall shares in the two periods. The vertical axis represents the proportion of households consuming less than the amount represented on the horizontal axis. Since the area to the left of the cdf, to the right of the vertical axis and below probability 1, can be interpreted as a mean (here, mean fish expenditure shares), a broad shift to the northwest indicates that consumers reduced their consumption. Alternatively, a shift to the southeast would signify increased consumption. In Figure 1A, the two cdfs are virtually identical, so aggregate consumption patterns after the advisory are similar to aggregate consumption patterns before the advisory.

Figure 1.

[8] To be precise, the weighted empirical cdfs will differ. Throughout our analyses, all graphs will account for probability weights.



Panel A



Panel B

Given the scaling of our figures, changes are difficult to identify visually in absolute cdf graphs such as Figure 1A. For this reason, we plot the vertical difference between post- and pre- consumption periods in graphs such as Figure 1B; this is the main type of figure we will present. For these difference graphs, the integral between the horizontal zero-axis and the cdf difference curve can be interpreted as the reduction in mean consumption between the pre- and post- advisory periods. The areas above the axis indicate a reduction in mean consumption after the advisory, and the areas below the axis contribute to an increase. In Figure 1B, areas both above and below the horizontal axis are small and approximately equal to one another. It appears that overall mean fish expenditure shares did not change significantly after the advisory.

Statistical Tests

Since the information in the graphs represent differences in means, we can use simple statistical methods to formally test the intuition gleaned from these graphs. We test the mean reduction in the share of food expenditures allocated to fish. Under a null hypothesis of no change, an appropriate comparison of means (CM) test statistic is $(\bar{X}_0 - \bar{X}_1)/\sqrt{(\sigma_1^2/N_1)+(\sigma_0^2/N_0)}$, where subscript 0 indicates 'pre-advisory', subscript 1 indicates 'post-advisory,' $\bar{X}$ indicates mean fish expenditure share, σ^2 indicates variance, and N indicates sample size.[9] Asymptotically, this test statistic has a standard normal distribution under the null hypothesis.

Of course, changes in fish consumption over time may not be fully attributable to the mercury advisory. For example, canned fish and substitute prices changed. Information about the potential benefits of fish consumption for cardiovascular health and protein attainment may also have changed. As a consequence, we sweep out shocks common to groups by computing the double difference in means (DDM). For example, we will examine consumption responses of demographic groups directly targeted by the advisory language, after netting consumption changes for demographic groups unaffected by mercury and the advisory.

[9] To be precise, this is the unweighted test statistic. Throughout our analyses, all statistical tests will account of probability weights.

Formally, we examine the *inter*-group difference of the *intra*-group changes in mean consumption. The DDM test statistic for a target group's mean change in consumption, after sweeping out common shocks reflected in non-target behavior, is: $((\bar{X}_{0T}-\bar{X}_{1T})-(\bar{X}_{0NT}-\bar{X}_{1NT}))/\sqrt{(\sigma_{1T}^2/N_{1T})+(\sigma_{0T}^2/N_{0T})+(\sigma_{1NT}^2/N_{1NT})+(\sigma_{0NT}^2/N_{0NT})}$, where subscript T indicates the target group of interest and subscript NT indicates the control non-target group.[10] The DDM statistic asymptotically follows a standard normal distribution under the null.

B. Regression Methods

We supplement the previous non-parametric analysis with a standard regression analysis, consistent with the mainstream demand literature. The more structured empirics provide efficiency gains and correlation controls. We run regressions on quantity to ensure robustness of our results to the consumption measure, since the previous analyses examine expenditure shares.[11]

The choice of explanatory variables is motivated by basic demand theory; price, substitute prices, total food expenditure, region, and household demographics influence consumption decisions. As in the double-difference graphical and comparison of means analyses, we initially control for common shocks. Here, we include time dummies for the pre- and post-advisory periods. We then perform a more structured parallel analysis which includes canned fish prices and an index of substitute prices as covariates. In all cases, since households vary in size, we demographically scale our variables for household composition differences. See Pollack and Wales (1981). The basic idea is to adjust explanatory variables by the adult-equivalent measure discussed in Section 2.

As with many household level consumption datasets, we observe a large number of zero purchases. Here, zeros may arise in two ways. One possibility is infrequency of purchase, since the diary expenditure survey represents only a snapshot of a given household's canned fish consumption. A second possibility is abstention from the good entirely. To capture the dichotomous consumption choice, we begin the analysis with a standard probit regression. Of course, conditional on purchasing canned fish, we are also interested in the impact of the FDA warning on the quantity purchased. Therefore, we run a second stage continuous regression. We allow the same covariates to influence both the discrete consumption and the continuous quantity decision, but we do not impose cross-equation restrictions on the covariates of interest.

The error term in this conditional demand equation is potentially correlated with the error term in the probit equation. In this case, our model is exactly that suggested by

[10] The graphical analog to this test, not presented in the interest of space but potentially useful for a reader's intuition, is a "double-difference" graph. The generated curve would indicate differences in the target group's pre- and post- advisory consumption after 'sweeping out' common shocks measured by changes in non-target (control) consumers' expenditure shares. In practice, the graph would entail subtracting the non-target group's (cdf) difference graph from the target group's (cdf) difference graph.

[11] We perform complementary analyses using absolute quantities as the dependent variable in the regression and shares of food expenditure as the dependent variable in the non-parametric analysis. Since demand for canned fish is inelastic and price was lower after the advisory, one would expect expenditure shares to fall while quantities rise. This is clearly a source of concern in single-difference comparisons. However, the non-parametric double-difference tests and the regression differences should be immune to this bias, since they are both designed exactly to sweep out common shocks of this sort.

Blundell and Meghir (1987) for the case of a good with non-negative desired demand.[12] Mathematically, this is equivalent to Heckman's (1976) selectivity model. See Deaton and Irish (1982) for a discussion, and Fry and Pashardes (1994) for an application. To summarize, our empirical model can be represented by:

$$C = X\beta + \varepsilon_C$$
$$D = X\Gamma + \varepsilon_D$$
$$Q = \begin{cases} C & if \quad D > 0 \\ 0 & otherwise. \end{cases}$$

for observed quantity Q, binary consumption decision D, and continuous quantity choice C.

To quantify the impact of the FDA advisory, we test whether pre-advisory parameters are significantly different from post-advisory parameters. To assess significance, we use standard χ^2 tests for null hypotheses of the form $\gamma_{k0}=\gamma_{k1}$ (for coefficients γ, explanatory variables k, pre-advisory period 0, and post-advisory period 1). Rejection of the null is indicative of a change in consumption for the subgroup indicated by variable k.

We estimate four specifications. Specifications 1 and 2 examine the entire sample, whereas specifications 3 and 4 highlight pre- versus post-advisory changes by removing the year immediately prior to and immediately after the advisory. We employ these latter specifications to allow for potential lags in consumer responses. Specifications 1 and 3 employ time specific constant to sweep period-specific common shocks. In contrast, specifications 2 and 4 do not include time dummies, but rather try to explain variation not attributable to the advisory by including prices and substitute prices. Of course, the specifications with time dummies allow for non-price consumption shocks, such as information on the benefits of omega-3 fatty acids.

IV. Empirical Results

Graphical results are presented in Figures 2-5 (in text), and statistical test results are summarized in Table 3. Regression results are presented in Table 4, and a summary of pre- versus post-advisory coefficient changes are presented in Table 5. In this section, will we discuss the results by answering a series of questions. We conclude the section by examining some sensitivity experiments.

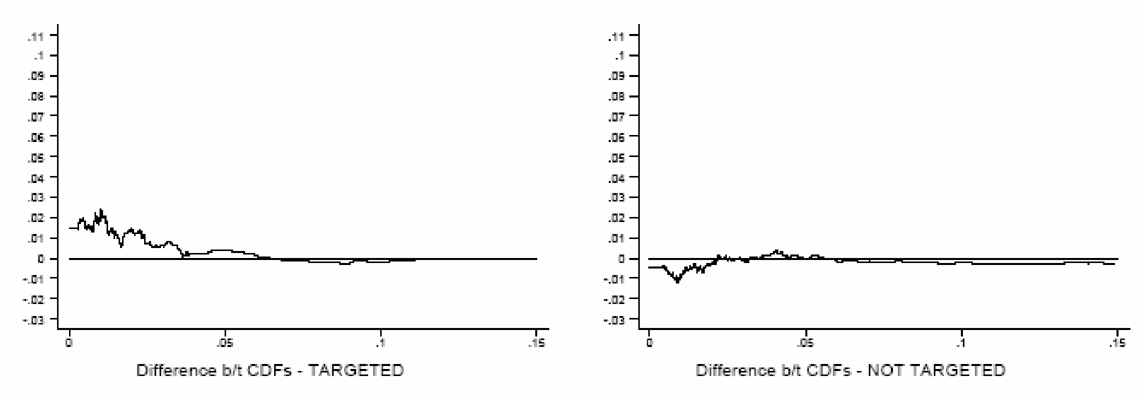
Did the target group respond to the FDA advisory?

As a whole, the response by households with young or nursing children was modest. Panel A of Figure 2 shows a general reduction for the target group at most expenditure share levels. Recall that the integrated area between the cdf and the horizontal axis is equal to the mean. Here, the net integrated area is positive; the sample mean clearly falls after the advisory. In contrast, Panel B shows little change for the non-

[12] Another possible source of zero expenditures is the standard Tobit-style censoring where observation error may drive consumption to zero. We believe that this is not a major concern in our analysis. However, in the sensitivity section, we check robustness to this assumption.

target control group. Comparing Panel B to Panel A, we see that mean expenditure share for the target group relative to the control group has fallen.

Figure 2.



Panel A **Panel B**

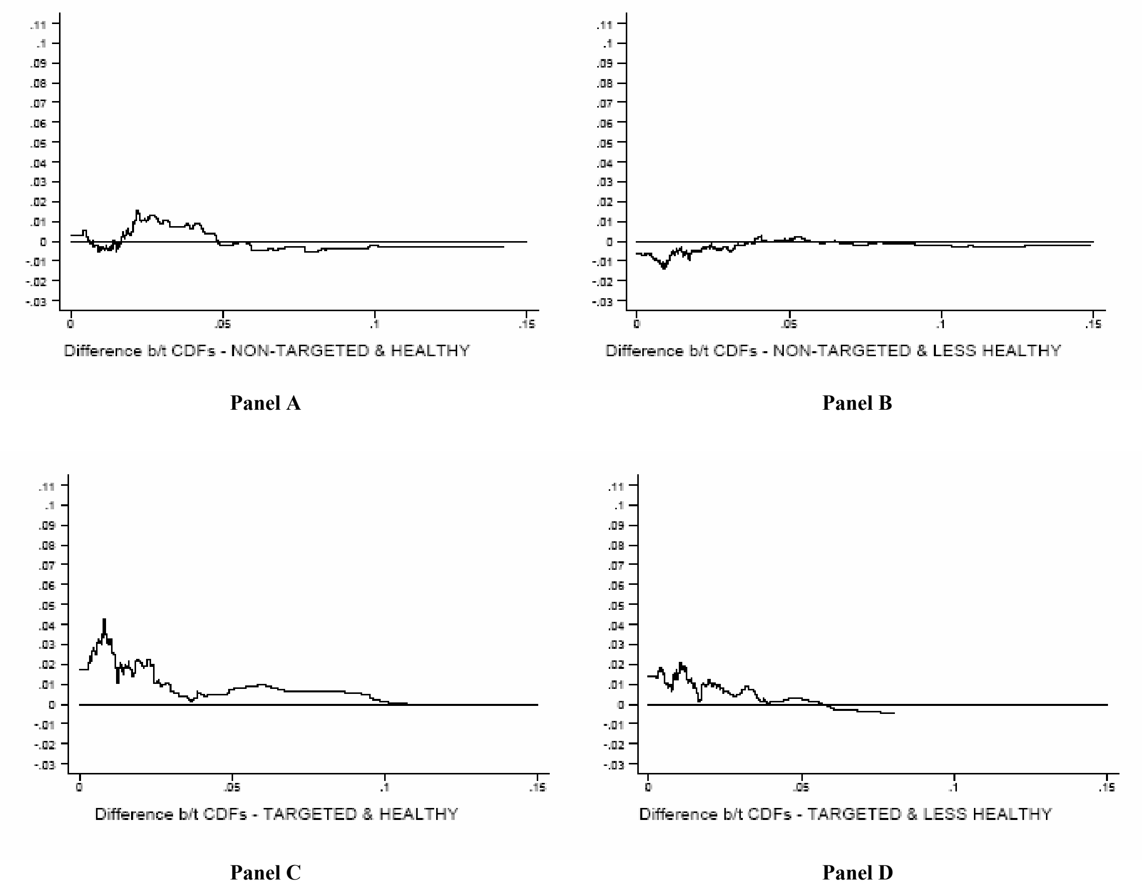
The DDM statistic is simply the normalized numerical value of the difference in the means for the target and non-target (here, the control) group. Despite the visual evidence for a differential response between the groups, the DDM statistic of 1.4 is not statistically different from zero at conventional levels of significance. Similarly, the regression results in Tables 4 and 5 show no statistically significant consumption response by target households relative to the non-target control group. Looking at the row marked *Children (targeted)* in Table 5, the pre- versus post-advisory coefficient changes are insignificant in all specifications.

Did health-conscious consumers respond to the advisory?

No. We find no evidence that health-conscious households as a group responded to the advisory. Recall that we define these households by a criterion of healthy diet and tobacco abstinence. Panel A of Figure 3 illustrates the change in consumption patterns for healthy households in the non-target group, while Panel B represents less healthy households in the non-target group. In neither panel do we observe much net integrated area; there is little change in mean consumption behavior. So, it is not surprising that the DDM statistic finds no significant difference attributable to health-consciousness in the non-target group. The DDM is -0.02. Similar results hold for the target group. Panel C and Panel D of Figure 3 represent consumption changes by healthy and less healthy target groups, respectively. While both Panels show a reduction in mean consumption, there is no obvious visual difference between them. The corresponding DDM statistic of 0.82 is also insignificant.

Regression results are consistent with these findings. In Table 5, the row marked *Healthy* summarizes sign patterns and significance levels for the various specifications. In all cases, we do not find a significant change from the pre- to post-advisory periods in the coefficient on the health-consciousness dummy. Similarly, we find no significant changes in the incremental impact of health-consciousness for the target group, summarized in the interaction row marked *Healthy & Child*.

Figure 3.

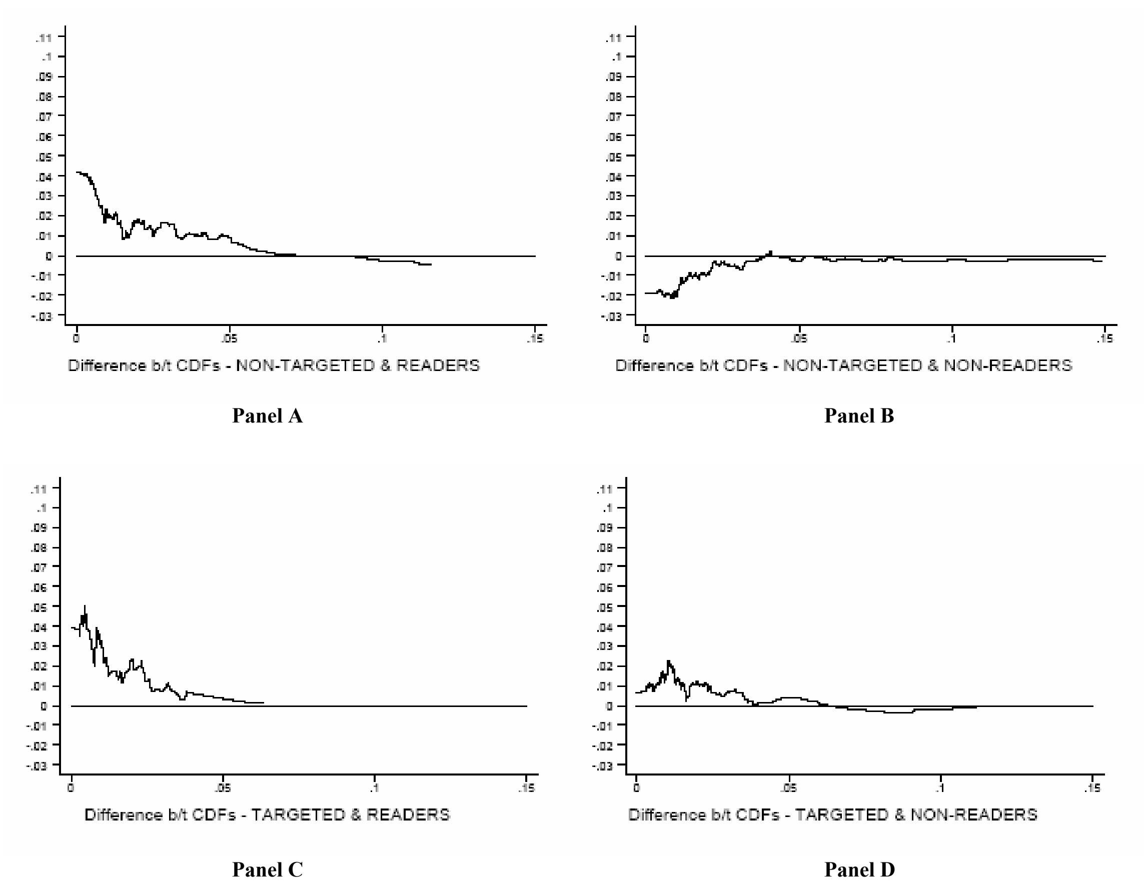


Did readers respond to the advisory?

Yes. Households purchasing newspapers or magazines reduced fish consumption after the advisory. Panel A of Figure 4 indicates that consumption fell after the advisory among readers in the non-target group. In contrast, Panel B shows that consumption slightly rose among non-targeted non-readers. Our traditional DDM statistic weakly supports the intuition that non-target readers reduced consumption relative to non-target non-readers. The test statistic of 1.52 is significant for a one-sided test. We do, however, find strong evidence that readership reduced the number of consumers. In this case, the test statistic is 2.93. Among the target group, the comparison of Panels B and C similarly reveals a relative reduction in consumption by readers. The DDM statistic is not significantly different from zero. However, we also cannot reject the hypothesis that the target and non-target groups respond in the same way.

The regression coefficients also show a significant drop in consumption among readers as a group. Looking at Table 5, we see that the *Reader* row shows a coefficient drop in every specification for both the binary and continuous consumption decisions. These drops are always statistically for the primary regressions (1 and 3) that include time dummies to sweep out common shocks, analogously to the DDM tests. The row marked *Reader & Child* reflects changes in the *additional* impact of membership in the target group on readers. In no case is this significant. Therefore, we find that readers, as a group, reduced consumption after the advisory relative to non-readers. However, there is no detected difference among readers across the target and non-target groups.

Figure 4.

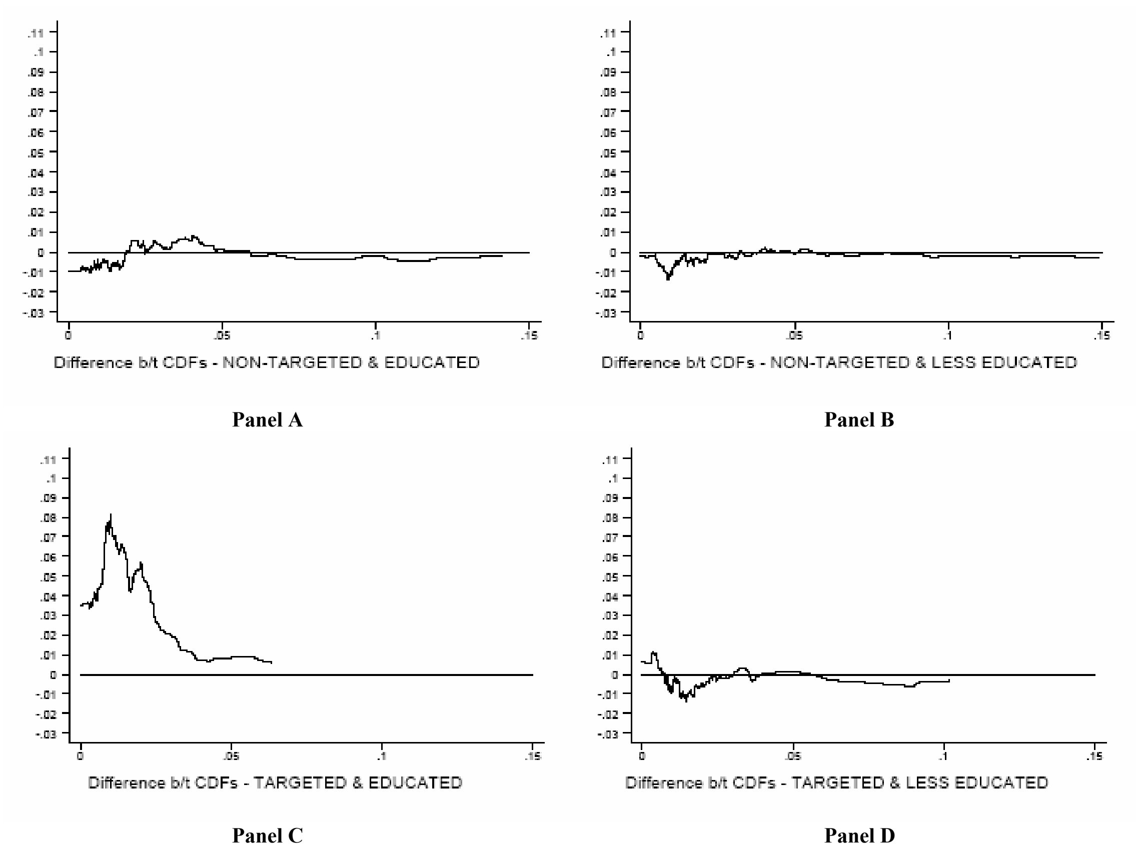


Did educated households respond to the advisory?

Yes. Educated households responded strongly, but only if they are in the target group. First, examine Panels A and B of Figure 5. Neither educated nor less educated non-target households seem to change consumption. In contrast, Panel C shows a sharp drop in consumption among educated households with young or nursing children. Panel D shows little change for less-educated households with young or nursing children. Comparing Panel C to D, we see a very strong impact of education for the response of the target group relative to the non-target group. The DDM statistic of 2.97 confirms this intuition. We find a highly significant reduction of educated consumers relative to the less educated, within the target group.

Regression results tell a similar story. In Table 5, the interaction row marked *Educated and Child* summarizes evidence about the impact of education on response patterns of targeted households, beyond any general impact of education. In all specifications, we find a statistically significant effect for both the number of consumers and the mean consumption quantity. Educated households with young or nursing children strongly reduced consumption after the advisory, relative to the control group. Contrast these results to the row marked *Educated*, which reflects the overall impact of education across all consumers. We generally do not observe a statistically significant change in coefficients. In specification 2, which does not include time-period specific time dummies to account for non-price shocks, the change is significant at the 10 percent level.

Figure 5.



Panel A

Panel B

Panel C

Panel D

Sensitivity Experiments

Are the results of the preceding section reasonable? While they are consistent across graphical, non-parametric, and regression analyses, it is desirable to check sensitivity to assumptions. We provide evidence of robustness to choices of proxy-variable definitions, model structure, error specification, and the precise nature of the 'event'.

When the threshold for "educated" is defined as a college degree, we found a strong differential response compared to less educated target consumers. Increasing the threshold to some graduate education amplifies this difference. However, upon decreasing the threshold to high school graduation, the difference with the less educated group is no longer statistically significant.

Our definition of 'health conscious' is *ad hoc.* However, the results are not sensitive to the choice of proxy variable. We experimented with a wide variety of plausible indices and thresholds without finding any differential response between healthy and unhealthy consumers.

Our primary DDM test statistics and regressions (specifications 1 and 3) emphasize differential consumption changes between a group and a control. This allows us to sweep out common shocks not attributable to the mercury advisory. This adds robustness to the analysis. However, sharper results may be obtained by assuming there are no unobserved common shocks. In the comparison of means, we could have simply reported the single difference results without reference to a control group. In the regression, the analogous approach is employed in specifications 2 and 4, which omit time-varying constants but include prices. For parameters of interest, we get the same qualitative results whether we use the single or double difference results.

The error specification in our regression model assumes a mean-zero error, implying that the sample average is a consistent estimate of true market demand. If zero-censoring of the dependent variable due to observation error is a concern, a Tobit correction would be in order. Therefore, we ran a supplementary Cragg (1971) correlated double-hurdle model to address this concern. Results for this specification were quite similar to those reported.

Another possible concern is that our study's 'event' (the January 2001 advisory) is not properly defined. For example, perhaps consumers were broadly aware of the dangers of mercury prior to the announcement. Such widespread awareness is at least possible, since a number of states had issued advisories for recreational fish before the FDA action. One might also be concerned that the possibility of a FDA advisory was widely publicized long before the actual release. However, experiments indicate that these concerns are unsupported. For example, there are no differential responses among those in the 8 states that issued their own commercial advisories and those in other states. Further, target groups' consumption remained unchanged or increased between each of pre-advisory years (1997/1998, 1998/1999, 1999/2000). We also detected no systematically differential response among educated and uneducated target consumers prior to the advisory itself.

There are other sound reasons to believe the event is properly defined. First, the FDA issued the advisory within months of initially considering action. Second, FDA focus groups conducted in October 2000 (two months before the advisory) 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." (FDA 2000) Finally, if consumers had already reacted to the mercury hazard, it would be difficult to reconcile the observed differential responses after the advisory between educated and less educated consumers.

V. Discussion & Conclusion

We find that some targeted consumers significantly reduced canned fish purchases as a result of the FDA mercury advisory of January 2001. In particular, college educated consumers in the target group responded strongly. Among households with young and nursing children, approximately 14 percent fewer educated households purchased any canned fish after the advisory. Further, mean purchased quantity fell approximately 25 percent for this group. In contrast, we detected no statistically significant response among the less educated.

We also found that those who purchased newspapers or magazines also significantly reduced post-advisory consumption. Among households that purchased newspapers or magazines in the diary period, approximately 16 percent fewer households purchased any canned fish after the advisory. Mean purchased quantity feel more than 21 percent. However, we found no differential response among targeted readers and non-targeted readers.

Access to information and ability to assimilate information appear to be important limiting factors in the advisory response. We view newspaper readership as a reasonable proxy for exposure to information about the presence of mercury in fish, and readers responded. We also view college education as a reasonable proxy for the ability to assimilate information appropriately, and educated individuals responded only if targeted by the advisory.

Another possible interpretation for differential responses among educated and less educated target consumers would be a systematic difference in risk preferences. This seems less plausible. First, there is no empirical connection between risk preferences and education. See, for example, Halek and Eisenhauer (2001). Second, although healthy behaviors are correlated with risk preferences, we find no differential advisory responses between healthy and unhealthy households.[13]

While consumption responses followed the advisory, can they be attributed to the policy? The responses are very consistent with increased information about mercury hazards. Further, FDA focus groups found no public awareness of the relevant risks two months prior to the advisory. Although we do not know whether individual responding consumers were aware of the advisory *per se*, there is no doubt that the advisory resulted in much greater general public awareness of mercury risk. In this sense, an advisory can be effective through promoting awareness, even if indirectly.

Targeted consumers likely to be aware of and understand the advisory do tend to reduce fish consumption. Mercury advisories and education programs can therefore be an effective policy tool for reducing the contaminant exposure of nursing and young children. However, those targeted consumers least likely to be knowledgeable about the advisory did not significantly reduce consumption. Unfortunately, this group of non-college educated, non-readers is also likely the least well-equipped to withstand negative health shocks from mercury. Given our results, a broader and more targeted educational outreach program would likely be effective at reducing consumption among this group. Possible outreach methods include health-advertising campaigns, in-store advisory signs, or advisory labels. Mathios (2000) showed that mandatory labeling induces important consumption responses, and Teisl *et al.* (2002) showed that point of consumption labeling is particularly effective for canned fish.[14]

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[13] Viscusi *et al.* (1999) found that smokers had systematically different risk preferences than non-smokers. Our health measure incorporates this; households with tobacco purchases are automatically classified as 'unhealthy.'

[14] Teisl *et al.* (2002) examined the impact of "dolphin-safe" eco-labeling on tuna consumption.

More broadly, we find that well-informed consumers do actively respond to environmental risk warnings. Prominent advisories may be an effective and low-cost method of reducing public health damages, particularly if targeted towards less educated and informed consumers. On a more cautionary note, however, our results also indicate that informed individuals may respond more broadly than intended, as non-targeted readers reduced fish consumption after the mercury advisory. While this may be a rational or even optimal response, it is not consistent with the stated intent of the advisory. Therefore, advisories and outreach programs should be carefully crafted with such spillovers in mind.

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Table 1. Consumer Policy Milestones

Time Period	Consumer Advisory Policy Event
Sept. 1994	FDA Releases 'FDA Consumer' … "Eating commercially available fish should not be a problem."
Dec. 1997	EPA Releases 'Mercury Study Report to Congress' … "A snapshot of our current understanding of mercury."
1998-2000	Interest groups and the EPA debate the appropriate reference dose for mercury exposure and policy decisions.
June 2000	National Academy of Sciences (NAS) Releases 'Toxicological Effects of Methylmercury' … "60,000 U.S. children may be at risk."
Aug-Dec 2000	FDA debates existence and language of new consumer advisory, soliciting comments from consumer advocates, public health professionals, environmental groups, and industry organizations. Focus groups conducted.
Jan 2001	FDA issues new consumption advisory. Pregnant women, women of childbearing age, and young children should limit consumption of all fish, and should not eat fish known to contain high levels of mercury.
Jan-Mar 2001	Phase I of FDA Mercury Advisory Education Plan.
Jan-Dec 2002	Phase II of FDA Mercury Advisory Education Plan.

Table 2. Summary Statistics [1]

Variable	Description	ENTIRE SAMPLE Mean	ENTIRE SAMPLE Std. Dev.	PRE-ADVISORY Mean	PRE-ADVISORY Std. Dev.	POST-ADVISORY Mean	POST-ADVISORY Std. Dev.
PURCHASED?	Dummy; '1' if canned fish purchased in 2-week diary period, '0' otherwise	0.168	0.374	0.169	0.375	0.167	0.373
QUANTITY	Canned Fish Quantity (lbs.)	0.264	0.758	0.252	0.724	0.275	0.789
	Quantity Conditional on Consuming (lbs.)	1.57	1.17	1.49	1.12	1.64	1.21
SHARE	Canned Fish Expenditure Share	.004	0.017	.004	0.016	.004	0.017
	Share Conditional on Consuming	.026	0.033	.025	0.032	.027	0.034
PRICE	Real Regional Price (per lb.)	1.94	0.155	2.02	0.139	1.86	0.133
SUB PRICE	Index of Substitute Prices – Base Period Normalized to 1	1.09	0.057	1.04	0.030	1.14	0.034
FOOD	Real In-home Food Expenditures ($100s)	1.15	0.967	1.15	0.974	1.14	0.961
AGE	Age of Respondent	38.8	13.4	38.6	13.4	38.9	13.3
CHILDREN	Dummy; HH with Young/Nursing Child?	0.303	0.458	0.306	0.461	0.300	0.458
READER	Dummy; Newspaper or Magazine Purchase?	0.242	0.428	0.249	0.432	0.235	0.424
EDUCATED	Dummy; Respondent College Graduate?	0.299	0.458	0.290	0.454	0.308	0.462
HEALTHY	Dummy; Particularly Healthy Household?	0.225	0.418	0.225	0.418	0.225	0.418
RCHILD	Reader/Children Interaction	0.078	0.268	0.081	0.273	0.074	0.262
ECHILD	Educated/Children Interaction	0.097	0.296	0.093	0.290	0.101	0.301
HCHILD	Healthy/Children Interaction	0.076	0.266	0.079	0.270	0.074	0.262
PERSONS	Number of Equivalent Adults	1.90	0.906	1.91	0.908	1.90	0.905

[1] Summary Statistics Weighted in Standard Manner. 'Persons' is not directly a variable in the model, but is used for demographic scaling.

Table 3. Statistical Test Summary: Distributional and Mean Comparisons

	Pre-Advisory N	Post-Advisory N	Percent Fall in Mean Expenditure Share	Comparison of Mean Exp. Share Test Statistic	Percent Fall in Number Consuming	Comparison of Mean # Consuming Test Statistic
Overall	5297	5240	-3.26	-0.439	0.95	0.219
TARGET VS. NON-TARGET						
Target Households	1676	1652	12.0	1.165	7.79	1.093
Non-Target Households	3621	3588	-7.83	-0.846	-2.82	-0.518
Target Net of Non-Target Household (DDM)				1.389		1.201
NEWS READERSHIP						
Non-Target Households: Readers	897	844	14.75	0.941	23.64	2.277**
Non-Target Households: Non-Readers	2724	2744	-13.85	-1.257	-12.39	-1.945**
Non-Target Households: Readers Net of Non-Readers (DDM)				1.517		2.925**
Target Households: Readers	447	407	32.10	1.722*	21.04	1.481
Target Households: Non-Readers	1229	1245	7.43	0.621	3.38	0.411
Target Households: Readers Net of Non-Readers (DDM)				0.902		1.064
EDUCATION						
Non-Target Households: Educated	1059	1084	-5.74	-0.331	-5.64	-0.586
Non-Target Households: Less Educated	2562	2504	-8.56	-0.787	-1.41	-0.215
Non-Target Households: Educated Net of Less Educated (DDM)				0.078		-0.383
Target Households: Educated	527	559	55.76	3.296**	17.64	1.448
Target Households: Less Educated	1149	1093	-8.02	-0.624	3.16	0.360
Target Households: Educated Net of Less Educated (DDM)				2.969**		0.994
HEALTH						
Non-Target Households: Health Conscious	777	788	-9.00	-0.453	1.94	0.166
Non-Target Households: Less Health Conscious	2844	2800	-7.42	-0.710	-4.11	-0.668
Non-Target Households: Healthy Net of Less Healthy (DDM)				-0.102		0.458
Target Households: Health Conscious	446	415	24.39	1.168	9.29	0.660
Target Households: Less Health Conscious	1230	1237	6.66	0.572	7.30	0.884
Target Households: Healthy Net of Less Healthy (DDM)				0.815		0.117

Table 4. Regression Results

Variable	BINARY CONSUMPTION DECISION				QUANTITY CONDITIONAL ON CONSUMING DECISION			
	Spec. 1	Spec. 2	Spec. 3	Spec. 4	Spec. 1	Spec. 2	Spec. 3	Spec. 4
FOOD	0.390**	0.038**	0.431**	0.420**	0.660**	0.889**	0.738**	1.01**
	(0.020)	(0.018)	(0.028)	(0.025)	(0.040)	(0.047)	(0.063)	(0.061)
PRICE	-	-0.010	-	-0.011	-	-0.141	-	-0.121
		(0.043)		(0.064)		(0.093)		(0.142)
SUB PRICE INDEX	-	-0.088	-	-0.048	-	-0.074	-	-0.037
		(0.084)		(0.117)		(0.178)		(0.258)
AGE OF RESPONDENT	0.001	0.002	0.001	0.001	0.002	0.004	0.001	0.003
	(0.001)	(0.001)	(0.001)	(0.001)	(0.002)	(0.002)	(0.002)	(0.003)
CHILDREN (TARGETED) 0	0.065*	-0.012	-0.000	-0.058	0.099*	-0.011	0.057	-0.094
	(0.033)	(0.027)	(0.046)	(0.038)	(0.059)	(0.056)	(0.081)	(0.083)
CHILDREN (TARGETED) 1	0.025	0.005	0.016	-0.026	0.056	-0.012	0.049	-0.056
	(0.033)	(0.027)	(0.046)	(0.037)	(0.057)	(0.056)	(0.076)	(0.079)
READER 0	0.060*	0.003	0.047	-0.009	0.084	-0.023	0.099	-0.043
	(0.032)	(0.026)	(0.044)	(0.036)	(0.055)	(0.054)	(0.077)	(0.078)
READER 1	-0.042	-0.049*	-0.069	-0.094**	-0.067	-0.112*	-0.099	-0.166**
	(0.035)	(0.029)	(0.049)	(0.039)	(0.062)	(0.060)	(0.082)	(0.085)
EDUCATED 0	-0.029	-0.034	-0.039	-0.029	-0.020	-0.032	-0.023	-0.049
	(0.035)	(0.042)	(0.046	(0.038)	(0.061)	(0.060)	(0.080)	(0.081)
EDUCATED 1	0.025	0.036	0.016	0.019	0.084	0.109*	0.014	0.068
	(0.033)	(0.041)	(0.045	(0.037)	(0.057)	(0.057)	(0.077)	(0.079)
HEALTHY 0	0.010	-0.012	-0.007	-0.012	0.003	0.003	-0.030	0.029
	(0.039)	(0.032)	(0.055)	(0.045)	(0.070)	(0.068)	(0.100)	(0.099)
HEALTHY 1	-0.032	-0.019	-0.060	-0.047	-0.012	-0.000	-0.062	-0.076
	(0.038)	(0.032)	(0.054)	(0.045)	(0.067)	(0.068)	(0.093)	0.100
READER & CHILD 0	-0.079*	-0.037	-0.056	-0.011	-0.132*	-0.068	-0.153	0.007
	(0.046)	(0.041)	(0.064)	(0.055)	(0.078)	(0.085)	(0.109)	(0.123)
READER & CHILD 1	-0.038	-0.035	-0.023	-0.004	-0.063	-0.067	-0.045	-0.016
	(0.051)	(0.045)	(0.071)	(0.062)	(0.088)	(0.094)	(0.123)	(0.135)
EDUCATED & CHILD 0	0.034	0.056	0.089	0.087	0.052	0.061	0.138	0.130
	(0.048)	(0.042)	(0.067)	(0.058)	(0.082)	(0.088)	(0.114)	(0.127)
EDUCATED & CHILD 1	-0.077*	-0.095**	-0.122*	-0.134**	-0.177**	-0.235**	-0.240**	-0.342**
	(0.047)	(0.041)	(0.068)	(0.059)	(0.082)	(0.089)	(0.121)	(0.129)
HEALTHY & CHILD 0	0.015	0.029	-0.023	-0.014	0.068	0.044	0.026	-0.094
	(0.052)	(0.045)	(0.077)	(0.067)	(0.092)	(0.096)	(0.141)	(0.147)
HEALTHY & CHILD 1	0.054	0.034	0.136*	0.117	0.031	0.037	0.164	0.218
	(0.054)	(0.048)	(0.077)	(0.067)	(0.094)	(0.103)	(0.137)	(0.148)
CONSTANT 0	-0.437**	-	-0.399**	-	-0.889**	-	-0.884**	-
	(0.065)		(0.087)		(0.117)		(0.150)	
CONSTANT 1	-0.397**	-	-0.394**	-	-0.803**	-	-0.798**	-
	(0.063)		(0.087)		(0.113)		(0.148)	
TIME INVARIANT CONSTANT	-0.633**	-1.39**	-0.615**	-1.41**	-	-2.40**	-	-2.64**
	(0.058)	(0.039)	(0.093)	(0.054)		(0.177)		(0.189)

Figures in parentheses are robust standard errors.
** - Significant at $\alpha = .05$, * - Significant at $\alpha = .10$.

Notes:
a. 0 in the variable name indicates ‘pre-advisory’ and 1 indicates ‘post-advisory’
b. Each regression specification uses a maximum likelihood procedure mathematically identical to Heckman’s Selectivity model.
c. Specifications 1 and 2 examine the entire sample. Specifications 3 and 4 highlight pre- vs. post- advisory changes by removing the year immediately before the advisory and the year immediately following the advisory.
d. Specifications 1 and 3 employ time variant constants to sweep out any period-specific common shocks. Specifications 2 and 4 impose more structure on the model; prices and substitute prices are included as covariates, and other potential time-variant common shocks are assumed to be small.
e. Each specification includes 4-1 regional dummies and 4-1 race dummies. We omit these control results to conserve space.
f. Wald tests for all coefficients being 0 generate χ^2 statistics of 310, 442, 183, and 375.

Table 5. Tests for Equivalence of Pre-Advisory and Post-Advisory Coefficients

	BINARY CONSUMPTION DECISION				QUANTITY CONDITIONAL ON CONSUMING DECISION			
Variable	**Spec. 1**	**Spec. 2**	**Spec. 3**	**Spec. 4**	**Spec. 1**	**Spec. 2**	**Spec. 3**	**Spec. 4**
CHILDREN (TARGETED)	-	+	+	+	-	-	-	+
	.38	.59	.79	.51	.59	.99	.95	.72
READER	-	-	-	-	-	-	-	-
	.03**	.15	.07*	.09*	.07*	.24	.08*	.26
EDUCATED	+	+	+	+	+	+	+	+
	.26	.06*	.39	.34	.21	.08*	.74	.28
HEALTHY	-	-	-	-	-	-	-	-
	.43	.88	.48	.58	.87	.98	.81	.46
READER & CHILD	+	+	+	+	+	+	+	-
	.55	.98	.72	.94	.56	.99	.51	.90
EDUCATED & CHILD	-	-	-	-	-	-	-	-
	.10*	.01**	.03**	.01**	.05**	.02**	.02**	.01**
HEALTHY & CHILD	+	+	+	+	-	-	+	+
	.60	.93	.14	.17	.78	.96	.49	.14

+ indicates that coefficients increased after the advisory, - indicates the reverse.
Numbers are p-values.
** - Significant at α = .05, * - Significant at α = .10.

Notes:
a. Specifications 1 and 2 examine the entire sample. Specifications 3 and 4 highlight pre- vs. post- advisory changes by removing the year immediately before the advisory and the year immediately following the advisory.
b. Specifications 1 and 3 employ time variant constants to sweep out any period-specific common shocks. Specifications 2 and 4 impose more structure on the model; prices and substitute prices are included as covariates, and other potential time-variant common shocks are assumed to be small.

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