Appalachian State University

Department of Economics Working Paper

Number 16-17 | September 2016

Measuring the Impact of Improved Traceability Information in Seafood Markets Following a Large Scale Contamination Event

William L. Huth
University of West Florida

O. Ashton Morgan
Appalachian State University

John C. Whitehead
Appalachian State University

Department of Economics
Appalachian State University
Boone, NC 28608
Phone: (828) 262-2148
Fax: (828) 262-6105
www.business.appstate.edu/economics

Measuring the Impact of Improved Traceability Information in Seafood Markets Following a Large Scale Contamination Event

William L. Huth
Department of Marketing and Economics
University of West Florida
whuth@uwf.edu

O. Ashton Morgan
Department of Economics
Appalachian State University
morganoa@appstate.edu

John C. Whitehead
Department of Economics
Appalachian State University
whiteheadjc@appstate.edu

Abstract:

We fuse and jointly estimate revealed and stated preference data over the BP *Deepwater Horizon* oil spill time horizon to analyze the potential for a new seafood traceability system to mitigate long-run decreases in product demand following a major contamination event. Findings indicate that traceability information flows that provide more precise information to oyster consumers regarding the location of harvest ameliorate consumers' perceived risk of eating oyster meals after the spill, leading to a significant increase in demand. Further, the magnitude of the increase is greater than the negative long-term post-spill effects, leading to overall welfare gains. However, any price increase associated with the information will mitigate the initial welfare gains. Overall, our findings suggest that the potential success of a new seafood traceability system depends on the implementation costs and the extent to which price increases are passed onto consumers.

Keywords: Traceability, oyster consumers, consumer surplus, contamination event, risk preferences.

Introduction

When consumers make utility maximizing decisions regarding the purchase of a bundle of food products, price and several other product attributes are known to the individual. Yet, environmental attributes that are related to the production or harvesting of a product are often not possible for the consumer to evaluate. The availability or absence of information flows regarding environmental attributes may impact consumers' perceived risk of consuming the good. As risk preferences across consumers will likely differ, consumers will choose a different bundle of goods, which will maximize utility as long as their perceptions of quality attributes are correct. So, consumers purchase and consume the goods that yield the highest value as long as they are accurately able to judge the quality attributes. Based on this, consumers may place a positive value on environmental attribute information flows that provide a signal regarding the quality of a good, especially in the aftermath of a contamination event.

A traceability system in food production and distribution has the potential to provide such a signal of product quality to potential consumers. In the United States traceability is defined formally as the ability to trace the history, application, or location of that which is under consideration (ISO 9000:2000 clause 3.5.4). As applied to seafood, traceability refers to a system that traces a product's genealogy and forward history, from harvest to consumption. Essentially seafood traceability can be thought of as a system for maintaining and disseminating detailed information on a particular seafood product throughout each step of harvest, processing, distribution and sales. Applying a term from the fishing industry, traceability allows seafood to be traced from "boat to throat." Until recently, the most significant legislation governing seafood traceability was The Public Health Security and Bioterrorism Preparedness and Response Act

(Public Law 107-188 2002). Under this act, as of 2006 all "persons who manufacture, process, pack, transport, distribute, receive, hold or import food in the United States" are required to keep records identifying their suppliers of particular food products and immediate buyers. In addition, the National Shellfish Sanitation Program (NSSP), which is overseen by the U.S. Federal Drug Administration (FDA), requires a shellfish tagging system that aids in product recalls triggered by reports of illnesses related to shellfish consumption.

On January 4, 2011, the Food Safety Modernization Act (FSMA) was signed into law in the U.S. While there are several components to the new law, essentially FSMA shifts the food-safety focus from reaction and response to prevention. Under FSMA, FDA has new powers to conduct more frequent and targeted inspections of domestic food production facilities to verify whether facilities are properly implementing preventive controls. Further, FDA now has the authority to issue a mandatory product recall if a company fails to voluntarily recall unsafe food. The Centers for Disease Control and Prevention (CDC) also receive new responsibilities under FSMA. They are expected to enhance federal, state, and local surveillance systems for foodborne illness so that outbreaks can be identified and controlled more quickly while also gaining the scientific knowledge to prevent future ones.

One component of FSMA that relates directly to this research charges FDA with improving traceability within the U.S. food supply. FSMA requires FDA to ultimately establish a product tracing system to quickly track and trace food in the U.S. While a comprehensive traceability program will not prevent food from being contaminated, the system should strengthen FDA's ability to trace contaminated food back to the source to allow the agency to investigate food safety concerns more quickly and thoroughly (McEntire et al., 2010). Also, it has been suggested that a traceability system enables a more rapid and effective trace-forward system that would help to quickly identify specific facilities throughout the supply chain and narrow the scope of recalls (McEntire et al., 2010). The complexity and variety of traceability suggests that systems can vary across different dimensions. For instance, the characteristics of a system can vary according to its *depth* (how far backward or forward the system tracks), *breadth* (the amount of information maintained on a product) and *precision* (the degree of assurance that the system can track a product's path and or characteristics).

One important way that the effectiveness of a traceability system is likely revealed is immediately following a contamination incident that heightens consumers' risk perceptions regarding product quality. Just a matter of months before FSMA came into force, the 2010 BP *Deepwater Horizon* oil spill sent 4.9 million barrels of crude oil into the Gulf of Mexico over a three-month period. Following the spill, the National Oceanic and Atmospheric Association (NOAA) closed both recreational and commercial fishing in affected federal waters between the mouth of the Mississippi River and Pensacola Bay, Florida. At its peak, 88,522 square miles, or 37 percent of Federal waters were closed to recreational and commercial fishing in the Gulf, registering the BP spill at twenty times the size of the *Exxon Valdez* spill.[1,2] Due to concerns over potential health-risks associated with consumption of contaminated seafood, the federal government also declared a fisheries disaster for Louisiana, Alabama and Mississippi.

---

[1] Details of the spill impacts can be retrieved from < http://www.noaanews.noaa.gov/stories2011/20110419_gulfreopening.html>

[2] Producing almost two-thirds of all oysters consumed in the U.S., oysters harvested from the Gulf of Mexico (eastern oysters) are an economically important commercial fish species for both producers and consumers. For producers, between 2001 and 2010 landings of Gulf oysters ranged from 16 million to 27 million pounds. Ex-vessel revenue ranged from $61 million to $75 million ($2010), accounting for about 10% of total ex-vessel revenue generated by Gulf of Mexico fisheries (personal communication, National Marine Fisheries Service).

Collecting revealed and stated preference (RP/SP) data on consumer behavior both before and after the spill provides a unique opportunity to investigate the potential for improved seafood traceability information to mitigate heightened consumer risk perceptions, and provide associated consumer welfare benefits, following a major contamination incident. We develop a model of oyster consumer demand using RP/SP data drawn from an online survey of consumers. At the time of the post-spill survey (approximately 7 to 8 months after the spill) a partial ban on harvesting oysters from Louisiana was still in place. We examine both the breadth and precision element of a traceability system by informing respondents that, while a partial harvesting ban remains, through a traceability system, the harvest location of all oysters is known and available to the consumer at purchase. The dataset allow an investigation of the efficacy of new traceability information to mitigating long-term welfare losses as a result of a large spill event.

Since Shulstad and Stoevener (1979) measured the welfare losses incurred by Oregon hunters in reaction to news of mercury contamination in pheasants, research in the food safety literature generally suggests that information regarding potential product contamination is subjectively evaluated by consumers and impacts risk perceptions, attitudes, and ultimately behavior. In many instances, changes in risk perception can cause consumers to react defensively, reducing demand for the product and creating a loss in welfare even, or avoidance costs (Swartz and Strand 1981; Smith, van Ravenswaay, and Thompson 1988; Brown and Schrader 1990; and Wessells and Anderson 1995). Research has also considered the effect of positive counter-information treatments on risk perceptions and consumer behavior. Generally studies find that counter-information treatments designed to reassure consumers about a product's safety following an event typically have a negligible effect on consumer demand, so welfare losses persist (see for example, Smith, van Ravenswaay, and Thompson 1988; Brown and Schrader 1990; and Parsons et al. 2006). However, research has also indicated that other treatments, such as mandatory seafood inspection programs, that guarantee a product's quality, have a more positive impact on demand following concern over a product's consumption health risk. For example, Parsons et al. (2006) found that a mandatory seafood inspection program, guaranteeing seafood a Grade A seal of approval significantly increased seafood demand following the harmful algae bloom event. This result supported findings by Wessells and Anderson (1995) who examined consumer willingness to pay (WTP) for different seafood safety assurances, and found that consumers are willing to pay a premium for mandatory inspections by federal agencies. Wessells et al. (1996) also found that positive information about seafood (such as a mandatory seafood inspection program or learning about preparation of seafood) increases seafood demand.

The impact of a traceability information system has been directly examined in the red meat sector, providing mixed results with regard to consumers' valuation of traceability information in food products. For example, Hobbs et al. (2005) used an experimental auction to assess the WTP of Canadian consumers for traceability assurance for beef and pork products, finding that a traceability system, in the absence of quality verification, has a negligible value to consumers. However, other studies have indicated that consumers are willing to pay a premium for traceability and other product assurance information. For example, Dickinson et al. (2005) also considered consumers' WTP for traceability in red meat in the U.S., Britain, Japan, and Canada and found that consumers were willing to pay a non-trivial premium for beef and pork traceability. They further discussed that their results could suggest that consumers would be willing to pay for traceability systems in other food markets but this would need to be examined. Dickinson and Baily (2002) used an experimental auction to examine traceability, transparency, and extra assurances (TTA). They find that many consumers, although not all, would be willing to pay for TTA characteristics in red meat. Finally, Dickinson and Baily (2005) found that U.S. consumers were willing to pay between 9% and 28% for attributes other than traceability alone (such as guarantees on additional animal treatment and meat safety).

While these studies demonstrate that some consumers value traceability information systems in the red meat sector, there are no studies that rigorously evaluate the mitigating impacts of seafood traceability systems. As such, while the costs of designing and implementing a new traceability system under FSMA can be evaluated, the benefits, in the form of increased consumer welfare due to more accurate product harvest location information are less clear. Of interest in this research is whether a traceability system (characterized by an *ex ante* information provision) effectively ameliorates consumer risk perceptions following a contamination event and impacts marketplace behavior.

This research extends the work by Morgan, Whitehead, and Huth (2016) and Morgan et al. (2016). Morgan, Whitehead, and Huth (2016) use pre-spill data only to examine consumer responses to different risk information treatments. They incorporate unobserved heterogeneity into the RP/SP framework by estimating a latent class model and find that homogenous classes of consumers respond differently to oyster consumption health-risk information treatments. The main finding is that while the average oyster consumer reduces consumption when presented with information regarding the potential risks of raw oyster consumption, the latent class model shows that some oyster consumer groups will continue to expose themselves to the health risks. From a policy perspective, the results indicate that future policy-based research should examine how different sample subgroups respond to the same policy treatment in order to understand the efficacy of treatments in altering behavior. Morgan et al. (2016) use the RP/SP data before and after the spill to examine the effects of the BP oil spill on consumer behavior. They also examine heterogeneous behavior through a latent class model. They find that short- and longer-term behavioral impacts of the spill vary across classes of consumer. Specially, while one consumer group responds to the spill by reducing oyster demand, two other groups increase post-spill consumption. They reconcile this result by suggesting that these groups perhaps exhibit less risk-averse behavior. For subgroups, time does not mitigate their response behavior, as their responses continue 8 months after the event. As such, the negative/positive impacts are also felt in the longer term. This research extends this earlier work using RP/SP data on oyster consumer behavior before and after the spill, by providing an investigation of the efficacy of new traceability information on reducing long-term spill impacts on demand. As FDA investigates specific characteristics of an effective traceability system, our results will provide feedback on mitigating the welfare losses due to a large-scale oil spill event.

Survey, Sampling, and Study Design

We developed two internet-based surveys of oyster consumers (aged 18 and over), sampled from the U.S. Center for Disease Control-designated "case states."[3] These are Florida, Alabama, Mississippi, Louisiana, Texas, and California.[4] The pre-spill online survey was administered by Online Survey Solutions, Inc. (OSS) in March and April, 2010, with the final observation

[3] CDC case states are states in which there are documented cases of *V. vulnificus*-related deaths.
[4] Due to a request from Georgia Sea Grant, we also sampled consumers from that state.

collected on April 20, 2010 - the day of the BP *Deepwater Hoizon* explosion, but before any public announcement regarding a spill was made. The post-spill survey was administered on November and December, 2010, approximately 7 to 8 months after the *Deepwater Horizon* spill. The pre-spill survey gathered data on oyster eaters' attitudes, preferences; awareness and perceptions of oyster consumption health risk; knowledge about oyster consumption health risk; and relevant demographic data. The post-spill survey asked respondents questions designed to elicit oyster consumer attitudes regarding the spill, seafood safety concerns, expectations regarding the length of the oyster harvest ban in Louisiana, and stated preference consumption behavior based on expected ban length and the imposition new traceability system.

In both surveys, respondents were asked the same four initial RP/SP questions. The first was a revealed preference meal count regarding respondents' current annual consumption frequency. To aid the respondent in determining the annual amount, they were asked how many months in a year they typically consumed an oyster meal, and then, in a typical month in which they ate oyster meals, about how many oyster meals did they eat.[5] The survey software then computed the annual number of meals and respondents were offered the opportunity to adjust the number if desired. Next, in both surveys, respondents were asked whether, compared to the number of meals they revealed they consume in a typical year, they expected to eat more, less, or the same number of oyster meals next year. Respondents were then prompted to state how many more or less as required. In estimation, inclusion of a stated preference count under existing conditions provides a means to control for potential hypothetical bias in individual responses. Further, after each SP question, respondents were given a follow-up question asking them to state their

[5] Respondents were informed that oyster meals included any meal in which the main course was oysters, or oysters were an important ingredient in the dish (like gumbo), or meals in which they are an oyster appetizer. Pictures were also displayed to provide examples of oyster meals.

perceived chances of getting sick from eating these meals.[6] Also, in both surveys, respondents were asked to state whether they would eat more, less, or the same number of meals under both a price increase and a price decrease scenario (while being informed that the price of all other food products remained the same), where the price changes were varied randomly across respondents.[7]

In the post-spill survey, respondents were also asked stated preference meal counts under different information treatments. In the first treatment, respondents were informed that following the *Deepwater Horizon* oil spill, the State of Louisiana Health and Hospitals "CLOSED" several Louisiana shellfish harvest areas to the harvest of oysters and other molluscan shellfish. While some shellfish harvest areas have since reopened, the ban on oyster harvesting from many of Louisiana's shellfish harvest areas currently remains in place. Respondents were then asked to imagine that the Louisiana ban on harvesting oysters from affected areas lasts for about another x months, where x was randomly assigned and varied across respondents from a list of four possible values; namely, "1 month", "3 months", "6 months", or "9 months". Then, supposing that the average price of their oyster meals stays the same, respondents were asked their expected annual oyster meal count. Again, respondents were then prompted to state how many more or less as required. This was followed by a question regarding their expected chance of getting sick from consuming those meals.

In eliciting behavioral changes with respect to a traceability system that specifies the location of the harvesting state, all respondents were presented with a traceability scenario:

[6] Respondents were prompted to choose from a five-point Likert scale of "Not very likely at all; Somewhat unlikely; I don't know; Somewhat likely; Very likely."
[7] Each respondent received a price increase of $1, $3, $5, or $7, or a price decrease of either $1, $2, $3, $4.

> "***Seafood traceability*** can be thought of as a system for maintaining and making available detailed information on a particular seafood product throughout each step of harvest, processing, distribution, and sales. In land based agriculture traceability is termed "farm to fork". Here it might be termed "harvest to home" as the path from the harvest bed to the final consumer is recorded and traceable."

Respondents were then told to assume that the Louisiana ban continues for the same period of time as in the previous SP question, but now there's a traceability system in place making the labeling of the location of catch for all oyster products mandatory such that the state of harvest is always known to the consumer. Again assuming that the average price of an oyster meal is unchanged, respondents were asked to state their count for expected annual oyster meals consumed.

Respondents were then asked a follow-up SP question as to the number of annual oyster meals they expect to consume, having been told that the Louisiana ban on oyster harvesting from all affected areas is lifted right now but again, the traceability system is in place. The final SP question asked respondents to state their expected number of annual oyster meals with the ban lifted, a traceability system in place, but now due to the of the additional costs incurred by oyster producers to label their product, the program will result in an increase in the price of an average oyster meal for all consumers.[8] Table 1 provides a summary of the text used in all SP treatments.

[8] The price increase was randomly assigned to consumers from $1, $3, $5, or $7.

In total, there were 382 individuals that completed both surveys. Table 2 provides sample definitions and descriptive statistics for variables used in the analysis for the sample. The majority of respondents are female (53 percent) and Caucasian (79 percent). The average respondent age is 49 years, earning an average household income of $72,000. As expected, most respondents prefer to eat raw oyster meals (66 percent), as opposed to cooked in some fashion. They were then asked how long did they expect the Gulf oyster harvest ban to last? In terms of the existing ban on oyster harvesting, over 32% of respondents expected the ban to last another year while 55% expected the ban to last one year or more (see Table 3).

Theoretical Model

The online survey instruments collect RP and SP data for analysis in an oyster demand model. The RP data is based on actual annual number of oyster meals consumed and the SP data is used to stimulate a change in oyster meals consumed resulting from price changes and the provision of different information treatments. As the surveys did not elicit respondents' pre- or post-spill meal prices, estimating changes in oyster meal prices as a result of the spill was not possible.[9] The lack of an adequate measure of how the spill impacted meal prices would therefore constrain any meaningful welfare analyses involving pre-and post-spill data. To address this, we developed a separate model of Eastern oyster ex-vessel prices using monthly oyster price and oyster landings data. Results from a random effects panel model on ex-vessel prices indicated that the BP oil spill caused a supply shock that increased oyster prices in 2010, but prices then fell back to pre-spill levels in 2011. Assuming that the price of an Eastern oyster meal in a state is

[9] Pre- or post-spill meal prices were not elicited because previous research had shown that it makes little difference in estimation whether the full meal price or a randomly assigned change in price is used as an independent variable in RP/SP demand models (Parsons et al. 2006; Haab et al. 2010).

proportional to the ex-vessel price, and adjusting for various markup factors, we estimated that the mean increase in oyster meals due to the BP was approximately $2 per meal.[10]

As the dependent variable is a nonnegative integer with a high frequency of low meals consumed, a linear count panel data specification is estimated. A basic count model is assumed and is written as

$$\Pr(x_{it}) = \frac{e^{-\lambda_{it}}\lambda_{it}^{x_{it}}}{x_{it}!}, x_{it} = 0,1,2,\ldots \quad (1)$$

The natural log of the mean number of meals is assumed to be a linear function of prices, socie-demographic indicators, the perceived chance of becoming sick from consuming oysters, and scenario dummy variables. To allow for variation across oyster consumers that cannot be explained by the independent variables, we assume that the mean number of meals also depends on a random error, u_{it}. The RP/SP Poisson demand model is:

$$ln\lambda_{it} = \beta_0 + \beta_1 P_i + \beta_2 y_i + \beta_3 \boldsymbol{s} + \beta_4 c_i + \beta_5 SP + \beta_6 BAN + \beta_7 TRACE + \beta_8 TRACE_{PREM} + \mu_i \quad (2)$$

where *P* is the price of an oyster meal; *y* is income; ***s*** is a vector of socio demographic variables, *c* is the perceived chance of getting sick from eating oyster meals; individuals are individuals are indexed i = 1, …, 382; and t = 1, …,12 denotes annual oyster meal demand under a pre-spill RP status quo treatment, post-spill RP status quo, pre-spill SP status quo, post-spill SP status quo, pre-spill SP price increase, pre-spill SP price decrease, post-spill SP price increase, post-spill SP price decrease, post-spill SP information treatment on a Louisiana oyster harvesting ban, post-

[10] A full description of the model and results can be found in the Appendix of Morgan et al. (2016).

spill traceability information with the harvesting ban imposed, post-spill traceability information with the harvesting ban lifted, and post-spill traceability with an associated oyster meal price increase in the pseudo-panel data. Dummy variables *BAN* (*BAN* = 1 when t = 9 and 10), *TRACE* (*TRACE* = 1 then t = 10, 11, and 12), and $TRACE_{prem}$ ($TRACE_{prem}$ = 1 when t = 12) are demand shift variables for the information, ban, and traceability treatment scenarios. All SP price measures are adjusted by the estimated $2 post-spill increase. The *SP* dummy variable is included to test for hypothetical bias. *SP* = 1 for hypothetical meal data (t = 3, …, 12) and 0 for revealed meal data (t = 1 and 2). $\beta_0 - \beta_8$ are coefficients to be estimated in the model. Pooling the data suggests that panel data methods be used to account for differences in variance across sample individuals, i, and scenarios, t. The distribution of meals conditioned on u_{it} is Poisson with conditional mean and variance, λ_{it}. If $\exp(\lambda_{it})$ is assumed to follow a gamma distribution, then the unconditional meals, x_{it}, follow a negative binomial distribution (Hausman, Hall, and Griliches 1984).

To further investigate underlying factors that drive behavior in response to the traceability treatments, we run a second model that interacts the two traceability treatments with a GULF dummy variable that takes a value equal to one if the respondent knows that they consume Gulf oysters, zero otherwise. The model is written as:

$$ln\lambda_{it} = \beta_0 + \beta_1 P_i + \beta_2 y_i + \beta_3 \boldsymbol{s} + \beta_4 c_i + \beta_5 SP + \beta_6 BAN + \beta_7 TRACE + \beta_8 TRACE_{PREM} + \beta_9 TRACE_{GULF} + \beta_{10} TRACE_{PREM\_GULF} + \mu_i \quad (3)$$

With the semi-log functional form, the baseline average per-person per-meal consumer surplus (CS) estimate is:

$$CS_{SP=0} = \frac{1}{-(\beta_1)} \tag{4}$$

The baseline economic benefit per annual oyster meals consumed for the representative consumer as measured by average annual per-person CS is:

$$CS_{SP=0} = \frac{\hat{x}}{-(\beta_1)} \tag{5}$$

where $\hat{x}_{SP=0}$ is the annual number of predicted meals for the representative oyster consumer with controlling for potential hypothetical bias (corrected model) and all independent variables are set at sample means (Bockstael and Strand 1987).

In the corrected model, the annual per-person CS as a result of new traceability information with an associated price increase (*I*) is:

$$CS_{SP=0} = \frac{(\hat{x} \mid I=1)}{-(\beta_1+\beta_{10})} \tag{6}$$

All CS estimates are calculated together with 95% confidence intervals constructed using a bootstrapping procedure (Krinsky and Robb 1986). The procedure generates 10,000 random variables from the distribution of the estimated parameters and generates 10,000 consumer surplus estimates. The estimates are sorted in ascending order and the 95% confidence intervals are found by dropping the bottom and top 2.5% of the estimates.

Results

Table 4 presents the regression results from two random effects Poisson oyster demand models (the standard model and the interactive model). These are standard pooled RP/SP models that examine the effect of traceability treatments after a large contamination event on oyster demand for the average consumer. As it stands to reason that there may be some unobservable factors that influence each respondent's responses to the information treatments, random effects allow the error term to be correlated across responses for each observation.

Beginning with the standard model, as expected, the coefficient on oyster meal price is negative and statistically significant, so the sampled oyster consumers are behaving in line with economic theory. The price coefficient implies a per-person, per-meal consumer surplus estimate of $19.18 (with a 95% confidence interval ranging from $18.58 to $19.76). The annual expected number of meals consumed and price coefficient can be used to estimate baseline per-person consumer surplus estimates (see Equation 5). Table 5 reports baseline CS estimates for all four pre- and post-spill RP/SP treatments. Prior to the spill, per-person annual CS estimates range from $389 to $419. After the spill, annual CS falls to between $336 and $352.

In terms of the socio-demographic characteristics, the negative coefficient on income indicates that oyster meals are inferior goods. Male and Caucasian individuals tend to consume more oyster meals while the age of the consumer does not influence consumption behavior. As expected, those perceiving a greater chance of getting sick from consuming oyster meals eat fewer meals. In line with other research, consumers of raw oysters, as opposed to oysters cooked in any way, tend to consume more meals (Morgan et al. 2013).

The coefficient on BAN is not statistically significant so the expected length of the remaining ban does not seem to be important in altering behavior. In terms of the impact of the spill, the negative coefficient on RP2 demonstrates that actual annual meal counts declined significantly after the spill compared to the year before the spill occurred. This is clearly an expected result and supports several studies that have shown a decrease in demand for goods following a contamination incident (Swartz and Strand 1981; Smith, van Ravenswaay, and Thompson 1988; Wessells, Miller, and Brooks 1995). However, through collecting stated preference responses before and after the spill, we can also analyze the spill's long-term impact on behavior. Comparing the coefficients on SP1 and SP2 indicates that the spill had a significant impact of reducing long-term demand expectations. A Wald test (W=-0.026 with a probability value = 0.000) indicates that there was a significant decrease in post-spill demand expectations relative to pre-spill. The significant addition of this research to the food safety literature is that we can then analyze the potential for new seafood traceability information to mitigate these long-term post-spill demand effects.

The coefficients on the two traceability treatments, with and without a price premium, are both statistically significant. First, the coefficient on TRACE indicates that a traceability system in place that informs the consumer of the state of harvest reduces post-spill risk perceptions, and increases oyster meal consumption. As such, our results suggest a value to location traceability information in the seafood sector following a large contamination event, and from a welfare perspective, the additional traceability information increases consumer surplus per person, per meal, by $0.58 (with a 95% confidence interval ranging from $0.36 to $0.81). Based on our estimate of 845,000 Gulf of Mexico oyster consumers, this equates to approximately $9.5 million in aggregate welfare for gains Gulf of Mexico oyster consumers as a result of a new traceability system.[11] Comparing the size of the TRACE coefficient to the magnitude of the change in stated preference behavior suggests that the positive effects of the traceability information treatment on expected demand more than offsets the negative long-terms impact of the spill.

Finally, we examine the overall impact of the traceability treatment on consumer behavior, and in particular, on our average annual consumer surplus estimate. The coefficient on TRACE_PREM is negative and statistically significant. On its own, this implies that the associated price premium causes the demand curve to become flatter (more elastic). So overall, the traceability treatment significantly increases post-spill demand, shifting the demand curve out to the right, while the price change pivots the demand curve counter-clockwise. Combined, the traceability information and associated price increase reduces annual per-person consumer surplus (relative to baseline) to $221. 7 (with a 95% confidence interval ranging from $203.0 to $240.4).

[11] Our estimate of 467,000 Gulf of Mexico oyster consumers is based on average annual landings of 22 million pounds of oysters. With a 100-pound sack containing about 250 oysters and the average oyster meal containing about 6 oysters, this equates to consumers eating about 9.3 million Gulf of Mexico oyster meals annually. Sampled respondents indicate they consume an average of 11 meals per year (see Table 1). This implies 845,000 Gulf of Mexico oyster consumers.

To further investigate underlying factors that drive behavior in response to the traceability treatments, we run a second model that interacts the two traceability treatments with respondent knowledge of consuming Gulf oysters. Findings from the interactive model indicate that the traceability information has a greater impact on reassuring Gulf oyster consumers of the consumption risks following the spill. This intuitively makes sense as these consumers know that they eat Gulf oysters but perhaps do not know a more precise harvest location. The traceability information would provide this, therefore, the reassurance translates into an increase in demand for this group. However, again, as with the average oyster consumer, these consumers will not pay a premium for the information. Rather, any price increase associated with the traceability information causes a decrease in oyster meal demand.

Conclusion

In a utility maximizing decision, consumers purchase and consume the goods that yield the highest value as long as they are accurately able to judge the quality attributes. Based on this, consumers may place a positive value on environmental attribute information flows that provide a signal regarding the quality of a good, especially in the aftermath of a contamination event. Under the 2011 Food Safety Modernization Act (FSMA), FDA is expected to establish a product tracing system to quickly track and trace food in the U.S. The complexity and variety of traceability suggests that systems can vary across different dimensions. The characteristics of a system can vary according to its *depth* (how far backward or forward the system tracks), *breadth* (the amount of information maintained on a product) and *precision* (the degree of assurance that the system can track a product's path and or characteristics).

There are no studies that rigorously evaluate the mitigating impacts of seafood traceability systems. As such, while the costs of designing and implementing a new traceability system under FSMA can be evaluated, the benefits, in the form of increased consumer welfare due to more accurate product harvest location information are less clear. Of interest in this research is whether a traceability system across both the depth and precision dimensions effectively ameliorates consumer risk perceptions following a contamination event and impacts marketplace behavior. Specifically, drawing on data from surveyed oyster consumers in the aftermath of the BP *Deepwater Horizon* oil spill, we developed a revealed and stated preference model of oyster meal demand to examine the behavioral responses to a seafood traceability system such that the harvest location of all oysters is known and available to the consumer at purchase.

The research adds to the existing body of literature by utilizes the timing of the BP oil spill to develop an oyster demand model that jointly estimates revealed and stated preference data. In this context, joint estimation has the advantage of allowing the measurement of preferences outside of an individual's historical experience while anchoring the stated preference responses to actual behavior immediately following a large-scale contamination event.

The principle findings are that following the spill, a traceability system that more precisely identifies the oyster harvest causes a significant increase in oyster meal demand. From a total welfare perspective, the traceability information increases demand of the average oyster consumer and aggregate consumer surplus increases by approximately $5.9 million. However, the average consumer will not pay a premium for the information. If the cost of providing the additional information is passed onto the consumer, then at least some of the initial welfare gains are mitigated.

We also investigated potential heterogeneity with regard to consumer response to the traceability information. Specifically, we were interested in examining the traceability responses of a subgroup of consumers that purchased Gulf oysters. An interactive model demonstrated that more precise harvest location information has a greater impact on ameliorating risk concerns for this subgroup of consumers following a large contamination event. As such, the information had a greater impact on behavior of this subgroup relative to the average consumer, but again, any welfare gains are potentially lost when accompanied by a price increase.

Overall, following a large-scale contamination event such as the BP spill in the Gulf of Mexico, our results indicate that there are welfare gains to a new seafood traceability system under the FSMA that can more precisely inform consumers to the location of harvest (or catch) of seafood products. However, the success of a seafood traceability system to reduce heightened risk perceptions regarding product quality following a large scale contamination event will depend on both the cost of implementing the system and the extent to which price increases are passed on to consumers. Finally, from a benefit-cost perspective, as FDA investigates specific characteristics of an effective traceability system, our results will provide feedback on the potential welfare gains following a large-scale contamination event. However, these gains represent just one potential benefit of a new system. There are clearly other benefits that can also be explored and measured, plus any future research will need to examine the expected costs of implementing such a system to estimate the potential net benefits.

References

Bockstael N.E., and I.E. Strand. 1987. "The Effect of Common Sources of Regression Error on Benefit Estimates. *Land Economics* 13:11-20.

Brown, D.J., and L.F. Schrader. 1990. "Cholesterol Information and Shell Egg Consumption." *American Journal of Agricultural Economics* 72:548-555.

Dickinson, David L., and DeeVon Bailey. 2002. "Meat Traceability: Are U.S. Consumers Willing To Pay for It?" *Journal of Agricultural and Resource Economics* 27(2): 348-364.

Dickinson, David L., and DeeVon Bailey. 2005. "Experimental Evidence on the Willingness-to-Pay for Red Meat Traceability in the United States, Canada, the United Kingdom, and Japan." *Journal of Agricultural and Applied Economics* 37(3): 537-48.

Hausman, J., B.H. Hall, and Z. Griliches. 1984. "Econometric Models for Count Data With an Application To The Patents-R&D Relationship." *Econometrica* 52(4):909-938.

Hobbs, J.E., D. Baily, D.L. Dickinson, and M. Haghiri. 2005. "Traceability in the Canadian Red Meat Sector: Do Consumers Care?" *Canadian Journal of Agricultural Economics* 53: 47-65.

Krinsky, I. and A. Robb. 1986. "Estimating the Statistical Properties of Elasticities." *Review of Economics and Statistics* 68:715-719.

McEntire, J.C., Arens, S., Bernstein, M., Bugusu, B., Busta, F.F., Cole, M., Davis, A., Fisher, W., Geisert, S., Jensen, H., Kenah, B., Lloyd, B., Mejia, C., Miller, B., Mills, R., Newsome, R., Osho, K., Prince, G., Scholl, S., Sutton, D., Welt, B., and Ohlhorst, S. 2010. Traceability (product tracing) in food systems: an IFT report submitted to the FDA, volume 1: technical aspects and recommendations.

Morgan, O. Ashton, J.C. Whitehead, W. Huth, G. Martin, and R. Sjolander. 2013. "A Split-Sample Revealed and Stated Preference Model to Examine Homogenous Subgroup Consumer Behavior Responses to Information and Food Safety Technology Treatments." *Environmental and Resource Economics* 54(4): 593-611.

Morgan, O. Ashton, J.C. Whitehead, W. Huth, G. Martin, and R. Sjolander. 2016. "Measuring the Impact of the BP Deepwater Horizon Oil Spill on Consumer Behavior." *Land Economics*, 92(1): 82-95.

Morgan, O.A., J.C. Whitehead and W. Huth. 2016. "Accounting for Heterogeneity in Behavioral Responses to Health Risk Information Treatments." *Journal of Environmental Economics and Policy*, forthcoming.

Parsons, G.R., O.A. Morgan, J.C. Whitehead, and T.C. Haab. 2006. "The Welfare Effects of Pfiesteria-Related Fish Kills in Seafood Markets: A Contingent Behavior Analysis." *Agricultural and Resource Economic Review* 35: 1-9.

Shulstad, R.N. and H.H. Stoevener. 1978. "The Effects of Mercury Contamination in Pheasants on the Value of Pheasant Hunting on Oregon." *Land Economics* 54(1): 39-49.

Smith, E., E.O. van Ravenswaay, and S.R. Thompson. 1988. “Sales Loss Determination in Food Contamination Incidents: An Application to Milk Bans in Hawaii.” *American Journal of Agricultural Economics* 70:513-520.

Swartz, D.G., and I.E. Strand. 1981. “Avoidance Costs Associated with Imperfect Information: The Case of Kepone.” *Land Economics* 57: 139-150.

Wessells, C.R., and J.G. Anderson. 1995.“Consumer Willingness to Pay for Seafood Safety Assurances.” *Journal of Consumer Affairs* 29: 85-107.

Wessells, Cathy, Jeffrey Kline & Joan Gray Anderson. 1996. “Seafood safety perceptions and their effects on anticipated consumption under varying information treatments”. *Agricultural and Resource Economics Review* April: 12-21.

Table 1 Seven SP Questions with Varying Informational Treatments

SP Question	Text
SP1: Expected meals consumed next year	Please think about the number of oyster meals you expect to eat over the next 12 months starting from today. Starting with the [NUMBER] oyster meals you told us that you typically eat in a year, if the average price of your oyster meals stays the same do you think you will eat more, less, or the same number of oyster meals over the next year? *Then*, about how many more or less oyster meals do you expect to eat over the next year?
SP2 and SP3: Expected meals consumed next year with a price increase (decrease)	Oyster prices change over time. For example, if oyster harvests are large, prices go down. When oyster harvests are smaller, prices go up. Suppose the price of your portion of your typical oyster meal goes up (down) by [DOLLAR_UP] [(DOLLAR_DOWN)] but the prices of all other food products stay the same. Compared to the [NUMBER_SP1] oyster meals you said that you expect to eat over the next year, do you think you would eat more, less, or the same number of oyster meals over the next year with the higher (lower) price for each meal? *Then*, about how many more or less oyster meals do you expect to eat over the next year?
SP4: Ban	Imagine that the ban on harvesting oysters from affected areas lasts for about another [NUMBER]. Suppose that the average price of your oyster meals stays the same, compared to the [NUMBER_SP1] oyster meals you previously told us you expect to eat next year, do you think you will eat more, less, or about the same number of oyster meals next year?? *Then*, about how many more or less oyster meals do you expect to eat over the next year?
SP5: Ban plus Traceability System	Again assume that the Louisiana ban on harvesting oysters from affected areas lasts for another [NUMBER] but now a seafood traceability system is in place making the labeling of the location of catch for all oyster products mandatory such that the state of harvest is always known to the consumer. Suppose that the average price of your oyster meals stays the same, compared to the [NUMBER_SP4] oyster meals you previously told us you expect to eat next year, do you think you will eat more, less, or about the same number of oyster meals next year? *Then*, about how many more or less oyster meals do you expect to eat over the next year?
SP6: Ban Lifted plus Traceability System	Suppose now that the Louisiana ban on oyster harvesting from all affected areas is lifted right now and a seafood traceability system is in place making the labeling of the location of catch for all oyster products mandatory such that the state of harvest is always known to the consumer. If the average price of your oyster meals stays the same, compared to the [NUMBER_SP5] oyster meals you previously told us you expect to eat next year, do you think you will eat more, less, or about the same number of oyster meals next year? *Then*, about how many more or less oyster meals do you expect to eat over the next year?
SP7: Ban Lifted plus Traceability System, plus Price Increase	If the Louisiana ban on oyster harvesting from all affected areas is lifted right now and a seafood traceability system is in place making the labeling of the location of catch for all oyster products mandatory such that the state of harvest is always known to the consumer. However, because of the additional costs incurred by oyster producers to label their product, the program will result in an increase in the price of an average oyster meal for all consumers. Suppose that the price of your portion of your average oyster meal goes up by [DOLLAR_UP] but the prices of all other food products stay the same, compared to the [OYSTER_SP4] oyster meals you previously told us you expect to eat next year, do you think you will eat more, less, or about the same number of oyster meals next year? *Then*, about how many more or less oyster meals do you expect to eat over the next year?

Table 2 Descriptive Statistics

Variable	Description	Mean	Std. Dev.	Min	Max
PRICE	Price change in oyster meals	1.47	2.19	-5.00	6.00
QUANTITY	Average annual oyster meals consumed	19.32	43.4	0.00	380.00
INC	Household income of respondent ($thousands)	73.51	38.39	8.00	150.00
MALE	Respondent is male (=1)	0.47	0.50	0.00	1.00
AGE	Respondent age in years	47.5	17.8	18.00	89.00
RACE	Respondent is Caucasian (=1)	0.78	0.41	0.00	1.00
RP2	Post-Spill Revealed Preference Elicitation (=1)	0.08	0.28	0.00	1.00
SP1	Pre-Spill Stated Preference Elicitation (=1)	0.25	0.43	0.00	1.00
SP2	Post-Spill Stated Preference Elicitation (=1)	0.58	0.49	0.00	1.00
SICK	Chance of getting sick (Five-point scale from "Not Likely at all" to "Very Likely")	0.73	1.01	0.00	4.00
MISSICK	Inputed missing chance of getting sick	0.02	0.15	0.00	1.00
RAW	Respondent consumes raw oyster meals (=1)	0.68	0.47	0.00	1.00
BAN	Months until ban on harvesting Louisiana oysters is lifted	1.15	2.52	1.00	9.00
AT-RISK	Respondent is at-risk from consuming raw Gulf oysters (=1)	0.17	0.38	0.00	1.00
TRACE	New traceability system in place (=1)	0.25	0.43	0.00	1.00
TRACE PREM	Price premium associated with new traceability system	0.20	0.75	0.00	7.00
GULF	Respondent knows their consumed oysters are harvested from Gulf (=1)	0.45	0.50	0.00	1.00

Sample size = 382 respondents

Table 3 Respondent Expectations Regarding Length of Remaining Ban (Percent Responses)

Question	Not Much Longer	About a Month	About 3 Months	About 6 Months	About 9 Months	About a Year	More Than a Year
How long do you expect the Gulf oyster harvest ban will last?	15.8	1.5	6.1	16.8	4.1	32.4	23.2

Table 4 Random Effects Poisson Model Results

Variable	Coefficient	Standard Error		
Constant	2.712***	0.264	2.716***	0.272
PRICE	-0.052***	0.001	-0.052***	0.001
INC	-0.003***	0.001	-0.003***	0.001
MALE	0.414***	0.104	0.413***	0.108
AGE	-0.005	0.004	-0.005	0.004
RACE	0.228*	0.126	0.226*	0.128
RP2	-0.118***	0.011	-0.118***	0.011
SP1	-0.019*	0.011	-0.019*	0.011
SP2	-0.046***	0.008	-0.046***	0.008
SICK	-0.023***	0.001	-0.022***	0.001
MISSICK	-0.336***	0.006	-0.343***	0.006
RAW	0.640***	0.125	0.641***	0.127
AT_RISK	-0.419***	0.158	-0.416**	0.168
BAN	0.001	0.012	0.001	0.006
TRACE	0.030***	0.006	-0.002	0.006
TRACE GULF			0.069***	0.005
TRACE PREM	-0.072***	0.003	-0.062***	0.005
PREM GULF			-0.022***	0.007
Alpha	1.191***	0.103	1.188***	0.104
Sample Size	382		382	
Periods	12		12	
Log Likelihood	-26648.4		-26641.0	

Table 5 Baseline Annual Per-Person Consumer Surplus Estimates

Treatment	Annual CS	95% Lower Bound	95% Upper Bound
Pre-Spill RP1	$419.4	$406.5	$432.3
Pre-Spill SP1	$389.3	$377.3	$401.2
Post-Spill RP1	$336.0	$325.7	$346.3
Post-Spill SP1	$351.5	$340.7	$362.3