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# VALUE OF LIFE AND INJURY: EVIDENCE FROM A U.S. FISHERY

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*Here, revealed trade-offs between monetary rewards and safety risk for shrimp fishermen in the Gulf of Mexico are investigated. Shrimp harvesting is one of the most dangerous occupations in the United States with an occupational fatality rate significantly above the average. The instrumental variables method is employed for estimation of the injuries and fatalities. My estimates of the value of a statistical life and the value of statistical injury, using the sample selection model, are in line with the estimates from other industries and provide useful information for public policy.* (*JEL* J17, Q2, K2, D2)

## I. INTRODUCTION

This paper aims to estimate the value of a statistical life (VSL) and the value of a statistical injury (VSI) using data on the daily decisions of commercial fishermen in the Gulf of Mexico (GOM) shrimp fishery. When deciding whether or not to make a trip, commercial fishermen must evaluate expected benefits, namely revenues, and costs, which include the risk of fatality or injury. Variation in daily revenues and the risk of fatality or injury provide the opportunity to examine how individuals trade-off more money for greater physical risk.

The VSL is a common method for assessing the benefit of social regulation by government agencies in dealing with issues such as the environmental and product safety. There is a great deal of variations in the estimates of the VSL for public policy purposes. A survey of the trade-offs between money and fatality risk by U.S. government agencies to establish a market reference point for spending resources and to improve safety produced a range between \$1 million and \$6 million (Viscusi and Aldy 2003). More recent estimates of the VSL remain rather wide: \$0.6–\$0.9 million for transportation choices in Sierra Leone (LeÓn and Miguel 2017), \$9–\$11 million for using air bags (Rohlfs, Ryan, and Kniesner 2015), and \$1.03–\$1.64 million for speed limit regulation in the United States (Ashenfelter and Greenstone 2004). Also, analysis of a panel data by Kniesner, et al. (2012), yields VSL estimates of \$4 million to \$10 million. There are only a few estimates of the VSI. These estimates are typically much lower than the VSL estimates and, in some cases, they are negative (Kuhn and Oliver 2013; Parada-Contzen, Andres, and Felipe 2013; Viscusi 2004; Viscusi and Gentry 2015). Elsewhere, Hersch and Viscusi (2010) address the perception that immigrants are concentrated in dangerous jobs and often they do not receive compensating wages, which suggests that they face a lower wage curve than the U.S. natives. Their analysis of a U.S. data concludes that Mexican workers, particularly those with poor English communication skills, receive lower wage premium for

**ABBREVIATIONS**

BLS: Bureau of Labor Statistics
CDC: Centers for Disease Control
DWH: Deepwater Horizon
EEZ: Exclusive Economic Zone
FTE: full-time equivalent
GSS: Gulf Shrimp System
IFQ: individual fishing quota
IV: Instrumental Variable
MRS: Marginal Rate of Substitution
NMFS: National Marine Fisheries Service
NOAA: National Oceanic and Atmospheric Administration
TXC: Texas Closure
USCG: U.S. Coast Guard
VSI: Value of Statistical Injury
VSL: Value of a Statistical Life

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risky jobs than the U.S. natives. The VSI for the U.S. natives ranges between \$6.52 and \$8.80 million, while the figure for the Mexican immigrants ranges between \$2.28 and \$5.24 million. Heterogeneity in the VSL and VSI likely exists in fisheries as well, since immigrants make a significant portion of the crews.

While commercial fishing is identified as one of the most dangerous occupations, few studies have attempted to estimate the VSL in individual fisheries. In one study, Schnier, Horrace, and Felthoven (2009) have estimated the VSL for the Alaskan red king crab and snow crab fishermen, using a revenue sharing remuneration system, at \$4–\$5 million. In another study, Lavetti (2015) applies a hedonic wage model to data from a survey of commercial fishing deckhands in Alaska Bering Sea red king crab fishery. His value of statistical life estimates ranges between \$2.6 and \$11.9 million.

My approach in this study is to apply a two-stage Heckman model to the captain's decision to fish and estimate the marginal rate of substitution (MRS) between risk of fatality (injury) from commercial shrimp fishing and economic reward, which is used to estimate the VSL and VSI. This approach is similar to the method used by Ashenfelter and Greenstone (2004), Alvarez and Schmidt (2006), and Schnier, Horrace, and Felthoven (2009). I use the instrumental variable (IV) method to control for the endogeneity of risk by employing weather condition as instrument for daily fatality (injury) risk. I also account for heterogeneity in the decision agents by dividing the sample based on the ethnicity of the captain.

The remainder of the paper is organized as follows. I first provide a description of the shrimp fishery, followed by a review of the commercial fishing safety literature. Next, I describe the data used in this study. Then, the empirical modeling strategy presents the IV method for estimation of the fatality and injury rates, the model for estimating the upper bound for the VSL and VSI, and the sample-selection model. This is followed by the discussion of the statistical results and concluding remarks.

## II. U.S. SHRIMP FISHERY

Shrimp is one of the most popular seafood in the United States accounting for approximately 25% of the total seafood consumption in the country. In fact since 1980 the per capita consumption of shrimp has nearly tripled, while the per capita consumption of fresh and frozen seafood has increased by approximately half (National Marine Fisheries Service 2010). The growth in shrimp demand over the last few decades has been met with rising imports from developing countries such as China. In fact, the low cost imports of shrimp have increased by more than sixfold since 1980, capturing approximately 94% of the U.S. market. However, rising imports have adversely affected prices. Responding to the industry concerns about shrimp imports, the U.S. International Trade Commission initially introduced adjustment assistance programs in the form of loan guarantees for shrimp-boat operators in mid-1970s. Discovering the ineffectiveness of the adjustment programs in early 1980s, anti-dumping duties have been imposed on many importers since 2005. However, the anti-dumping duties have been ineffectual in curtailing imports produced by exploitation of natural shrimp biomass in developing countries and by technological advancements in aquaculture production (Marvasti and Carter 2016).

Despite this pressure, domestic shrimp landings have been stable in recent decades, because of the limited shrimp biomass and lack of a viable shrimp aquaculture sector. The GOM region dominates shrimp landings domestically, producing nearly 80% of the total U.S. harvest (National Marine Fisheries Service 2010). In general, in spite of the government attempts to predict shrimp abundance, the size of the population is largely unknown before each shrimping season (Matthews 2008). Since the life cycle of the GOM shrimp is limited to 1 year, the annual fluctuations in the stock are due to environmental conditions rather than the previous year's landings (Anderson 2004). The domestic landings are highly seasonal, peaking during the spring and fall, which overlaps with the typical tropical weather patterns when the risk of accidents is higher than other seasons. Shrimp vessels typically do not target other fish species because of vessel specialization and gear characteristics. In 2012, 1,150 federally permitted vessels operated in the GOM shrimp fishery landing 88 million pounds of shrimp valued at \$296 million (Liese 2014). The spawning, growth, and migration patterns of shrimp are the major determinants of the abundance of shrimp during the year, which in turn determines trip decisions and hence landings patterns. Other natural factors such as tropical storm activity also influence trip decisions and patterns.

Several government regulations have an impact on captain's trip decisions. For example, in addition to voluntary refraining by captains to take a fishing trip during low abundance periods, some states have imposed regulatory closures which prohibit harvesting during the shrimp maturation period. The most notable seasonal shrimp closure in the GOM is in Texas. Since 1981, to increase the yield of brown shrimp by protecting them during the rapid growth period in their life cycle, the GOM Shrimp Fishery Management Plan has prohibited shrimp fishing in the Exclusive Economic Zone (EEZ) off the coast of Texas from mid-May to mid-July. As a result, brown shrimp harvested are larger and older than other species of shrimp, comprising more than half of the total harvest in the GOM (Nance 2011). Unpredictable closures are also a factor. For example, the GOM was closed to fishing because of the Deepwater Horizon (DWH) oil spill, which was the largest marine oil spill in history lasting for 3 months. As a result, on average, 15.83% of the EEZ in the GOM was closed to fishing between May and December 2010.

In addition to the Texas closure (TXC) and the DWH incident, other State and Federal government regulations are also likely to have affected the shrimp vessel captain's fishing decision during the study period here. One regulatory change to consider is the introduction of the individual fishing quota (IFQ) programs in 2007 for red snapper and in 2010 for grouper-tile fish designed to promote efficiency and to eliminate the fishing derby in these fisheries in the GOM. The IFQ program increased the commercial fishing season length for red snapper from approximately 85 days a year to year round. These IFQ programs have reduced commercial fishing accidents and fatalities (Marvasti and Dakhlia 2017). The red snapper IFQ program has also led to consolidation in the reef fish fishery reducing the demand for the crew, which is likely to make qualified crew members available to other fisheries in the region and facilitate the decision to take a commercial shrimp fishing trip.

Also, a few commercial fishing vessel safety acts have been introduced since 1988. These regulations do not affect the trip decision, but are likely to influence the frequency of injury incidents. A more recent legislation, known as the Coast Guard Authorization Act of 2010, imposes stronger regulations than previous legislations requiring training for commercial fishing vessel operators as well as design, construction, and maintenance standards for new vessels. The U.S. Coast Guard (USCG) uses several strategies to mitigate safety risks of commercial fisheries, including training, vessel structural considerations, operational factors, and equipment issues.[1] The Occupational Safety and Health Administration recognizes that commercial fishing safety or risk varies by vessel type, fishing gear, targeted species, and geographic region (Hughes and Woodley 2010–2011). A study of the commercial fishing industry in Maine, for example, shows that more than 40% of the vessels studied did not comply with vessel safety regulations and that lack of safety training was common. Furthermore, interviews with the vessel captains with respect to their risk preference suggested that they were risk-loving (Backus and Davis 2011).

Furthermore, National Oceanic and Atmospheric Administration (NOAA) observer programs are likely to affect risk-taking behavior among fishermen. The shrimp observer program has been in existence since the 2003, selecting randomly from the trip hulls. Before each trip, observers inspect the vessel to make sure that it meets USCG regulations; if it does not meet the safety standards, they will not travel with the vessel and will report it for violation. Furthermore, observers will not take the trip if the vessel does not have a valid Commercial Fishing Vessel Safety Examination certificate, a voluntary examination that can be taken each year. Observers cannot, however, stop a vessel from taking the fishing trip without them. While the safety measures in the observer programs are designed to protect the observers, their presence is likely to improve fishermen's safety as well. Since a small fraction of the shrimp commercial vessels is observed each year, the effect of the program on safety in the fishery is unclear.

The level of self-employment in the commercial fishing industry in the GOM is significantly above the national average, which may help us understand attitudes towards risk in the industry. The Bureau of Labor Statistic (BLS) Current Population Survey indicates that the percentage of self-employed workers in the U.S. economy as a whole was less than 10% in 2011. The BLS data also shows that the percentage of self-employed in the U.S. commercial fishery was 48% in the same year, while 76% of the employees in the GOM commercial fisheries were self-employed. In fact, self-employed workers tend to have a

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[1] Both the Coast Guard Authorization Act of 2010 and the Coast Guard and Maritime Transportation Act of 2012 require all vessels operating beyond 3 nautical miles the U.S. territorial sea baseline to undergo a safety examination by October 2015 (U.S. Coast Guard, 2014).

higher rate of occupational fatalities than salaried workers, perhaps due to the smaller size of their business and a higher likelihood of ignoring safety regulations. Pegula (2004), for instance, shows that in 2001, although the self-employed made up only 7.4% of the U.S. civilian workforce, they suffered approximately 20% of the occupational fatalities. The disproportionate rate of occupational fatalities among the self-employed occurs even within the same industry or occupation (Pegula 2004).

Another demographic aspect of the shrimp fishery in the GOM is the role of owner-operated commercial vessels and high participation of the Vietnamese in its labor force. Approximately 59% of the shrimp vessels are owner operated and 22% of the owners appear to be of Vietnamese origin.[2] However, 0.5% of the labor employed in agriculture, forestry, fishing, and hunting in the United States is Vietnamese, similar to the fraction of Vietnamese in the U.S. economy (Allard 2011).

## III. LITERATURE ON OCCUPATIONAL INJURIES IN COMMERCIAL FISHERIES

Because of harsh weather, long hours, laborious work, and dangerous work conditions, commercial fishing is one of the most dangerous occupations in the United States (BLS 2011). To illustrate, the U.S. rate of occupational fatalities is 3.5 per 100,000 full-time equivalent (FTE) for all industries nationwide, but it is 116.0 for commercial fishery industry (Centers for Disease Control 2010). According to the Centers for Disease Control (CDC), during the period from 1992 to 2008, 23% of the U.S. commercial fisheries-related deaths occurred in the GOM, where harvesters of shrimp, oyster, and snapper/grouper had the highest number of fatalities (Dickey 2011). Interestingly, 62% of fatalities occurred while the vessel was engaged in nonfishing operations such as transiting, mooring, moving inbound and outbound, and towing. The CDC range of the fatal occupational injury rates per 100,000 FTE for selected Northeast fisheries is 141.7–200 and for Alaska is 43–56.7 (Centers for Disease Control 2010). In the GOM, the shrimp fishery has the highest number of occupational injuries in the GOM, and the states of Louisiana and Texas have the highest number of fatalities because of the nature of shrimp fishery and its fleet size. Based on the 2006–2013 USCG data, my calculations show that the occupational fatality rate per 100,000 FTE in the GOM shrimp fishery is 99.01, while the injury rate is 149.18. Using the CDC fatality data, the rate for the same period for the GOM shrimp fishery is 157.52 per 100,000 FTE. Clearly there are variations between the two government agencies in reporting commercial fishing accidents.

A few studies have addressed the issue of commercial fishing safety. For example, Bergland and Pedersen (1997), focusing on a theoretical model, examine the interaction between safety and fishery regulations and explored the moral hazard effects of public safety measures. The authors argued that owners, captains, and crew can influence the probability of accidents through decisions about both investment (shape and size of vessels) and operations (when and where to fish, what kind of and how much fishing tackle, number of crew and hours on duty). Jin and Thunberg (2005) analyzed the 1981–2000 northeastern U.S. coast commercial fleet data and found that weather conditions, vessel location, time of year, and vessel characteristics affect the likelihood of accidents. However, the authors did not find evidence suggesting that changes in either fishery management or revenues influence accident rates.

Some studies of the commercial fisheries accidents have addressed fishermen's attitude towards risk. A study of commercial fishing in Maine showed that 40% of the vessels were noncompliant with vessel safety regulations and lack of safety training was common. Also, captain interviews revealed risk loving attitudes (Backus and Davis 2011). Elsewhere, in a survey of perception of occupational risk among Maine commercial fishing vessel captains and fishermen, Davis showed that they tend to downgrade the level of their occupational risk, and as a result, they are less likely to comply with safety regulations (Davis 2012). Davis also pointed to the high level of self-employment in the industry and the consequence that fishermen are economically vulnerable as the variation in the price of catches causes significant financial uncertainty. Expectedly, Davis discovered that risk-averse fishermen earn significantly less than the risk takers.

Smith and Wilen (2005) address the perceived notion that, because commercial fishermen face both high financial and physical risk, the risk preference among commercial fishermen must be inherently high. The authors use panel data

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[2] This estimate is based on the name of the owners in the NOAA vessel registration. Also, Vietnamese origin of the fishermen is the only available ethnicity variable.

from the California sea urchin dive fishery to test the risk-loving attitude among fishermen. Weather conditions and prevalence of great white sharks in the area are used as proxies for physical risk. Their findings do not support the idea that commercial fishermen are inherently risk-loving. Some earlier studies have also concluded that fishermen, in spite of their chosen occupation, are risk-averse (e.g., Bockstael and Opaluch 1983; Eggert and Martinsson 2004; Mistiaen and Strand 2000). These results are surprising, because if fishermen are both rational and risk-averse, one would expect significantly higher earnings for fishermen than in other industries. It is thus conceivable that fishermen do not fully take into account the level of risk that they are facing. Risk preferences can clearly affect VSL and VSI. Leigh (1995), however, believes that compensating wages and VSL estimates for risk differentials across industries are not credible due to inaccuracy of the CDC and BLS fatality data. Here, I explore the effect of the high participation of the Vietnamese on the VSL and VSI.

## IV. DATA

I use multiple public (some confidential) data sources in this study. First, I construct a panel of daily trip profile for the GOM active federally registered commercial shrimp vessels for the 2006–2013 period. For this purpose, I use the U.S. commercial food shrimp landings data from a survey of dealers and port agents conducted by the Gulf Shrimp System (GSS) of the National Marine Fisheries Service (NMFS) in Galveston, TX. The data consists of 1,452 vessels taking a total number of 76,619 trips, with an average trip length of approximately 23 days. This data is used to construct the daily trip profile for each vessel. Since price data are not reported in the GSS data, I computed the values based on the GSS revenue and landing data, with no distinction among different species of shrimp. Vessel characteristics, such as age, length, horse power, and capacity are from the NMFS Survey the Federal Permit Shrimp Holders.[3] After dropping the missing vessel characteristics data, the number of completed observations is 899,813. Therefore, the average number of trips per vessel during the study period is 620 (77.5, annual).

The source of data for the fatal and nonfatal injuries for federally registered commercial shrimp vessels in the GOM are CDC and USCG reports, respectively.[4] The reports contain information on several variables including time of the accident and fishery type. Since the nature and the duration of commercial fishing trips do not follow the 40-hour-per-week standard, to build the daily rate of fatal and nonfatal injuries, I construct the daily fleet-wide FTE similar to the U.S. BLS hourly-based approach (Northwood 2010). The hourly based approach has been used in some current estimates of the rate of injuries and fatalities (Gentry and Viscusi 2016; Viscusi 2013; Viscusi and Gentry 2015). Here, I first use the number of days at sea and number of crew to construct the number of crew days for each trip. However, the number of days at sea is not collected in the GSS. Therefore, the average number of days at sea is calculated using the total number of days at sea and the number of trips from an annual survey of federally registered shrimp vessels. Then, daily crew days for the fishery are calculated by adding the crew days for all vessels, which happen to be on the fishing trip on each particular day. Next, the aggregate daily crew days is multiplied by 3 (24 hours divided by 8) to arrive at the total number of FTE per trip, based on the assumption that fishermen are exposed to injury risk throughout the entire trip. The rate of fatality (injury) is calculated by dividing the daily 1 year moving average of USCG fatality (injury) figures by the daily 1 year moving average of FTE in the fishery, which helps dealing with zero values when vessels are docked.[5]

Other sources of data include National Center for Atmospheric Research reports for the historical weather information, BLS for the regional unemployment and self-employment data, and NMFS Shrimp Observer Program for the number of commercial shrimp vessels with observers on the board per day. Since most measures of weather conditions, such as wind speed and wave height, are correlated, I use only wind speed, and show that it is a valid instrument for fatality (injury) risk variable. TXC data are from NMFS. I construct the TXC variable as a weighted average of number of days Texas waters were closed to shrimpers by geographic areas by multiplying the number of closure days in each month by the fraction of the EEZ in the GOM which was

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[3] NMFS did not collect any information on the demographic characteristics of the crew or captain during the study period.

[4] Data received through author's personal communications with the USCG and CDC.

[5] It is notable that there were no fatalities in 2013, therefore, to calculate the rate of injuries zero values for number of fatalities are replace with 0.001 to avoid infinity values in the rates.

subject to closure. Texas and the federal government coordinate the closure.

Another challenging task is finding an accurate measure of compensation for labor in the fishery sector, because of a lack of fishery-specific data, lack of standard working hours, and the large percentage of the self-employed in some fisheries. Furthermore, the use of a lay system based on a predefined share of net revenues (revenues net of most variable costs) to compensate crews is rather common in commercial fisheries (McConnell and Price 2006). Therefore, I created a proxy for wages, based on data availability. I first calculated the average ratio of pay to crew and captain over the gross shrimp revenues, which turn out to be 0.23.[6] Then, this ratio is multiplied by the daily gross real revenues per vessel from shrimp landing. To arrive at the daily revenues for captain and crew, the result is divided by the number of days at sea, assuming that the daily revenues are constant during the trip, but vary across trips.

The list of variables considered in the empirical analysis and their descriptive statistics are presented in Table 1. While some variables, such as vessel characteristics, are time-invariant, others, such as injury rates and wind speed are time-variant.

## V. EMPIRICAL MODELING STRATEGY

Because of the difficulty of estimating the VSL, indirect methods are commonly used. Three indirect methods include survey methods, risk trade-off inside of the labor market (hedonic wage decomposition models), and risk trade-offs outside of labor market (Viscusi 1993). I use the wage-risk trade-offs outside the labor market to estimate VSL and VSI. Accordingly, my empirical strategy aims at extracting information regarding the fishermen's trade-offs between earnings and risk of fatality or injuries from commercial shrimp fishing. For this purpose, I develop a model taking the selection bias and endogeneity into account. To recover the captain's MRS between the return to the shrimp fishing trip and the risk of injury, I regress the vessel revenues against the expected fatality (injury) rate. First, Hausman test is applied to examine the endogeneity in the rate of fatality (injury). The test statistics for the fatality and injury estimates are 17,179 ($df = 12$) and 28,377 ($df = 12$), respectively, suggesting that the two-stage least squares is preferred to least squares at the 1% level.

### A. *Fatality Rate Instrument*

I use IV method to implement the two-stage least squares and control for the endogeneity of risk in estimating the MRS. The IV method uses weather condition as instrument for daily fatality (injury) risk. Wind speed is likely to be highly correlated with fatal and nonfatal injuries and uncorrelated with the revenue. A group of control variables are also added to the IV equation. Thus, as the first-stage regression, I estimate the natural log of daily 1 year moving average of fatality (injury) rate for the vessel ($i$) on a fishing expedition on a given day ($t$) as:

$$\begin{aligned} (1)\quad LnF_{it} = \mu_0 + \mu_1 LnW_t + \mu_2 Ln(NC/VLEN)_{it} \\ + \mu_3 Ln(W - VLEN)_{it} + \mu_4 LnDAYS_{it} + \\ \mu_5 LnAGE_{it} + \mu_6 HMS_i + \mu_7 LnOBS_t + \\ + \mu_8 SLAW_t + \mu_9 TCDAYS_t + \mu_{10} DWH_t + \nu_{it}, \end{aligned}$$

where $\nu_{it}$ is the random error term. The independent variables, which are defined in Table 1, capture regulatory, economic, environmental, and technological factors. High winds increase the chances that an accident will occur, therefore, its coefficient is expected to be positive. If crowding contributes to the likelihood of an accident, the coefficient of the ratio of the number of crew to vessel length would be positive. Also, if large vessels sustain strong winds better than small vessels, the coefficient of the interaction between wind speed and vessel length would be negative. Long trips are likely to cause fatigue making accidents more likely, therefore, the coefficient of number of days at sea is expected to be positive. Since wear and tear of the aging vessel and higher likelihood of the vessel not being equipped with safety features increase the chances of injuries, the coefficient of age would be expected to be positive. Make of vessels is likely to influence the likelihood of accidents and the direction of the effect may vary between fatal and nonfatal injuries. If the presence of the observers on shrimp vessels and associated vessel safety inspection are effective in improving safety, the coefficient of the daily number of shrimp observers would be negative. The coefficient of the DWH oil spill is expected to

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[6] Financial data for active shrimp fleet from various available annual NOAA shrimp reports are used to calculate the ratio of pay to crew and captain over gross shrimp revenues (Liese, various years).

**TABLE 1**
Descriptive Statistics (2006–2013)

| Variable | Description | Mean (Standard Deviation) |
|---|---|---|
| F | Fatality rate per 100,000 FTE—CDC | 250.74 (274.42) |
| INJ | Injury rate per 100,000 FTE—USCG | 266.10 (228.59) |
| P | Real ex-vessel price per pound (using CPI index, not seasonally adjusted, 1982 base year) | 1.55 (0.57) |
| R | Per crew real net revenue share (using CPI index, not seasonally adjusted, 1982 base year) | 193.58 (202.11) |
| DAYS | Number of days at Sea | 22.90 (10.18) |
| W | Wind speed measured as meter per second (m/s) averaged over an 8-minute period for buoys | 5.99 (1.82) |
| SE | Percentage of GOM self-employed commercial fishermen | 0.68 (0.04) |
| UN | Monthly rate of unemployment in the region | 6.99 (1.94) |
| DWH | Percentage of the GOM closed due to the DWH oil spill | 1.32 (5.55) |
| TCDAYS | Texas closures dummy (close = 1, open = 0) | 0.17 (0.37) |
| CNY | Dummy variable for the Christmas and Gregorian calendar New Year holidays (December 25 and January 1 = 1, otherwise = 0) | 0.005 (0.070) |
| OBS | Number of commercial shrimp vessels in observer program per day | 0.45 (0.77) |
| SLAW | Coast Guard Authorization Act of 2010 (after 2010 = 1, prior to 2010 = 0) | 0.50 (0.50) |
| NC | Number of crew on a vessel per trip | 3.31 (0.08) |
| VLEN | Length of the commercial reef fish vessels in feet | 69.95 (13.26) |
| DEP | Fishing area depth | 10.06 (2.63) |
| AGE | Vessel age | 22.47 (10.92) |
| HMS | Vessel hull made of steel (yes = 1, no = 0) | 0.73 (0.45) |
| OWNER | Owner-operated vessel (yes = 1, no = 0) | 0.59 (0.49) |
| CUMFD | Cumulative days fished in the year | 40.14 (57.98) |
| VIET | Vietnamese origin of vessel owner (yes = 1, no = 0) | 0.22 (0.41) |

be positive due to accidents associated with this event. Finally, if the training and vessel safety standards of the Coast Guard Authorization Act of 2010 have had any effects in reducing accidents by 2013, I would expect a negative sign for the coefficient of the dummy variable for this law.

### *B. Upper Bounds of VSL and VSI*

Next, to recover the captain's MRS between the return to the shrimp fishing trip and the risk of injury, I regress the vessel revenues against the expected fatality (injury) rate from the first-stage. The second-stage regression then estimates the following vessel revenue model in natural log form to obtain the expected daily revenues for captain and crew per vessel:

$$(2)\quad Ln\mathrm{R}_{it} = \alpha_0 + \alpha_1 Ln\widehat{F}_{it} + \alpha_2 Ln\mathrm{P}_{it} + \alpha_3 LnVLEN_i + \alpha_4 LnDEP_i + \alpha_5 HMS_i + \alpha_6 IFQ_t + \alpha_7 TCDAYS_t + \alpha_8 DWH_t + \varepsilon_{it},$$

where is $\widehat{F}_{it}$ the predicted value of the fatality (injury) rate and $\varepsilon_{it}$ is the random error term. The independent variables include regulatory, economic, and technological factors as described in Table 1. The predicted value of the fatality (injury) rate per crew or captain is calculated by scaling up the predicted values from Equation (1) by the number of crew. The value of $\alpha_1$ represents the upper bound for the MRS between risk of fatality or injury from commercial shrimp fishing and captain and crew revenue share. The captain is assumed to value his crew members' lives as much as his own, otherwise a separate MRS needs to be estimated for each. Other variables in the equation are essentially control variables.

### *C. Sample Selection Model and VSL/VSI Estimation*

Since the nonrandomness in the selection process to take a commercial fishing trip can create a selection bias disturbing the estimation of VSL, I apply the Heckman two-step procedure. Therefore, my methodology divides the processes into two, "selection" equation and the "substantial" or "main" equation. The trip decision by vessel *i* captain on each day (*t*) is captured by a binary variable determining whether a vessel is on a fishing trip, and the model is specified as:

$$(3)\quad \mathrm{Prob}(Fish = 1)_{it} = \beta_0 + \beta_1 E(R_{it}) + \beta_2 W_t + \beta_3 SE_t + \beta_3 UN_t + \beta_4 DWH_t + \beta_5 TCDAYS_t + \beta_6 IFQ_t + \beta_7 CNY_t + \beta_8 CUMFD_t + \tau_{it},$$

where $E(R_{it})$ is the annual daily backward-moving average of the predicted value of the captain and crew share of the revenues from Equation (2), and $\tau_{it}$ is the random error term. The backward moving average reflects the revenue expectations based on of the past performance of the vessel and its coefficient is expected to be positive. High wind speed discourages trips as it increases the likelihood of an accident. Therefore, a negative sign is expected for the coefficient of wind speed. If the self-employed captain is less motivated to take a trip, the coefficient of this variable would be negative. A high rate of unemployment in the economy signals difficulty of getting jobs elsewhere and more available labor force, making it more likely to take a trip. The coefficient of the DWH oil spill closures of the GOM is expected to be negative as during the closure period parts of the GOM were not available for fishing. The coefficient of the Christmas and New Year dummy variable is expected to be negative as people are likely to take holidays on these days. Finally, if the likelihood of taking a trip rises as fishermen get closer to the end of the fishing season, perhaps due to the larger size of the shrimp, the coefficient of the cumulative fishing days would be positive.

I want to know the effect of unmeasured characteristics of the vessel on the trip decision, and the residuals of the trip decision equation carries the information on these unknown factors. Therefore, these residuals are used to construct a selection bias control factor, ρ, in the second equation. Rho is equivalent to the Inverse Mill's ratio, capturing all unmeasured (unobserved) characteristics related the trip decision. The dependent variable in the main equation is developed using the MRS and ratio of the revenues to fatality rate as $\widehat{V}_{it} = \alpha_1(R_{it}/F_t)$. The main equation in natural log form is then specifies as:

$$\text{(4)} \quad LnV_{it} = \lambda_0 + \lambda_1 LnE(R_{it}) + \lambda_2 LnW_t + \lambda_3 LnOBS_t + \lambda_4 OWNER_{it} + \rho\varphi_{it} + e_{it}.$$

All variables in this equation, except the owner-operated vessels, $OWNER_{it}$, and the random error term, $e_{it}$ are predefined.

## VI. RESULTS AND DISCUSSION

The IV regression is exactly identified as the number of instruments is exactly equal to the number of endogenous variables. Also, the IV method applied here needs to satisfy both relevance and exogeneity requirements. The relevance requirement implies that the endogenous regressor must be correlated with the instrument; that is, $Cov(LnF_{it}, LnW_t) \neq 0$. An $F$-test results for $LnW_t$ in Equation (1) validates the relevance of wind speed as an instrument as the $F$-statistic for the log of wind speed is 566 ($df = \infty$) for the fatal risk and 238 ($df = \infty$) for the injury risk. To address the exogeneity of the wind speed in Equation (2), first covariance of the residuals from Equation (2) is estimated using the actual rate of fatality and injury alternatively to produce the residuals. Then the covariance of the residuals between the log of wind speed and the residuals from estimate of Equation (2) is calculated to show that it meet the requirement that $Cov(LnW_t, \varepsilon_{it}) = 0$. The covariance for the fatality and injury models turn out $-0.0022$ ($df = \infty$) and $-0.0017$ ($df = \infty$), respectively, confirming exogeneity of wind speed in Equation (2).[7]

Regression results for Equation (1) for the rate of fatality and injury are reported in Table 2. The results suggest that high wind speed clearly contributes to the chance of both fatalities and injuries, while the impact appears to be much larger in fatality cases than nonfatal injuries. The sign of the coefficient of the ratio of crew to vessel length shows that crowding on the vessel could increase the risk of nonfatal accidents on the boat. In fatal accident case, the supporting aspect of the presence of crews on the board seems to outweigh the crowding aspect. Aging vessels also have a higher risk of nonfatal accidents, but seem to reduce fatal accidents. The coefficients of the number of days at sea suggest that longer trips are safer. However, this result is sensitive to model specification. The effects of the observer program and the Coast Guard Authorization Act of 2010 have been surprisingly positive. Vessels made of steel turn out to be safer in terms of fatal injuries than vessel made of wood or fiberglass, but the chance of nonfatal injuries appears to increase when the vessel is made of steel.

Table 3 reports the results for the captain and crew revenue share per vessel model using $Ln\widehat{F}_{it}$ for the fatality (injury) risk variable. The result with respect to other variables is as expected. For example, revenues rise with the increase in price, suggesting an inelastic demand for shrimp. Large vessels, which also tend to fish in deep waters, generate more revenues than small vessels. The closure due to DWH resulted in a

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[7] The effect of wind speed on landing is unclear, because empirical analysis does not show a consistent and/or robust relation between wind speed and the level of output (Alvarez and Schmidt 2006; Dakhlia and Marvasti forthcoming and Solís et al. 2014).

**TABLE 2**
Fatality and Injury Rates, First-Stage Estimates

| | Fatalities | | Injuries | |
|---|---|---|---|---|
| **Variables** | **Coefficients** | **(Standard Errors)** | **Coefficients** | **(Standard Errors)** |
| $LnW_t$ | $0.6526^{a}$ | 0.0274 | $0.2184^{a}$ | 0.0014 |
| $Ln(NC/VLEN)_{it}$ | $-0.1542^{a}$ | 0.0078 | $0.0144^{a}$ | 0.0040 |
| $Ln(W\text{-}VLEN)_{it}$ | $-0.1466^{a}$ | 0.0064 | $-0.0210^{a}$ | 0.0033 |
| $LnDAYS_{it}$ | $-0.0054^{b}$ | 0.0023 | −0.0003 | 0.0012 |
| $LnAGE_{it}$ | $-0.0833^{a}$ | 0.0024 | $0.0023^{c}$ | 0.0012 |
| $HMS_i$ | $-0.0878^{a}$ | 0.0036 | $0.0022^{c}$ | 0.0019 |
| $LnOBS_t$ | $0.0162^{a}$ | 0.0005 | $0.0112^{a}$ | 0.0002 |
| $SLAW_t$ | $0.8476^{a}$ | 0.0022 | $0.9632^{a}$ | 0.0012 |
| $TCDAYS_t$ | $0.0944^{a}$ | 0.0027 | $0.1347^{a}$ | 0.0014 |
| $DWH_t$ | $0.0030^{a}$ | 0.0002 | $0.0104^{a}$ | 0.0001 |
| *Intercept* | $-11.9430^{a}$ | 0.0279 | $-11.6977^{a}$ | 0.0144 |
| *Adj.* $R^2$ | 0.15 | | 0.47 | |
| $F$-statistic | 16,756 | | 85,670 | |

a, b, and c denote statistical significance at the 99%, 955, and 90% levels, respectively.

**TABLE 3**
Vessel Trip Revenue, Second-Stage Estimates

| | Fatalities | | Injuries | |
|---|---|---|---|---|
| **Variables** | **Coefficients** | **(Standard Errors)** | **Coefficients** | **(Standard Errors)** |
| $LnF_{it}$ | $0.2667^{a}$ | 0.0016 | $0.2300^{a}$ | 0.0013 |
| $LnP_{it}$ | $0.2560^{a}$ | 0.0025 | $0.2303^{a}$ | 0.0022 |
| $lnVLEN_i$ | $1.800^{a}$ | 0.0061 | $1.8635^{a}$ | 0.0054 |
| $LnDEP_i$ | $0.2071^{a}$ | 0.0041 | $0.1571^{a}$ | 0.0037 |
| $HMS_i$ | $0.1964^{a}$ | 0.0021 | $0.1699^{a}$ | 0.0018 |
| $IFQ_t$ | $0.0039^{a}$ | 0.0019 | $0.0418^{a}$ | 0.0017 |
| $TCDAYS_t$ | −0.0090 | 0.0019 | $0.0688^{a}$ | 0.0014 |
| $DWH_t$ | $-0.0087^{a}$ | 0.0001 | $-0.0104^{a}$ | 0.0001 |
| *Intercept* | $-0.3685^{a}$ | 0.0279 | $-1.0172^{a}$ | 0.0226 |
| *Adj.* $R^2$ | 0.31 | | 0.36 | |
| $F$-statistic | 54,918 | | 68,756 | |
| $\overline{V}_F$ | \$6.14 million | | | |
| $\overline{V}_I$ | | | \$1.26 million | |

a, b, and c denote statistical significance at the 99%, 95%, and 90% levels, respectively.

drop in revenues. However, the focus here is on the fatality (injury) coefficient, which captures the fishermen's trade-offs between earnings and risk of fatality or injury from commercial shrimp fishing. Since the estimated parameters in Equation (2) include vessels that did not fish on some days, to obtain the upper bound per vessel, estimated $\alpha_1$ is multiplied by the ratio of vessel specific daily return to vessel specific daily fatality or injury rate. The result is then divided by the average number of crews per vessel to arrive at the upper bound per worker (crew or captain). Thus, the values of the upper-bound estimates of the VSL ($\overline{V}_F$) and the VSI ($\overline{V}_I$) per worker in the fishery are \$6.14 million and \$1.26 million in real terms, respectively.

Next, I estimated Equations (3) and (4) in sequence to take into account the nonrandomness in the decision to take a commercial fishing trip by the captain. Equation (3) is estimated with a Probit model, assuming that the error term is normally distributed. In the second stage, least squares method is applied for estimation. Estimated parameters of the Heckman model are presented in Table 4. Introduction of the red snapper IFQ program appears to have reduced participation in the shrimp fishery. The selection equation results also show that the expected share of the revenues for the captain and crew increases the likelihood of taking the trip, while poor weather understandably discourages it. The self-employed are less likely to take a fishing trip

**TABLE 4**
Sample Selection Estimates of VSL and VSI

| | **Fatalities** | | **Injuries** | |
|---|---|---|---|---|
| **Variables** | **Coefficients** | **(Standard Errors)** | **Coefficients** | **(Standard Errors)** |
| Selection equation | | | | |
| $LnE(R_{it})$ | $0.3037^{a}$ | 0.0017 | $0.2853^{a}$ | 0.0018 |
| $LnW_t$ | $-0.0613^{a}$ | 0.0005 | $-0.0569^{a}$ | 0.0005 |
| $LnSE_t$ | $1.1715^{a}$ | 0.0766 | $-2.6362^{a}$ | 0.0750 |
| $lnUN_t$ | $-0.0447^{a}$ | 0.0012 | $0.0253^{a}$ | 0.0012 |
| $LnDWH_t$ | $-0.0056^{a}$ | 0.0002 | $-0.0046^{a}$ | 0.0002 |
| $LnTCDAYS_t$ | $0.3658^{a}$ | 0.0022 | $0.3936^{a}$ | 0.0022 |
| $IFQ_t$ | $-0.2282^{a}$ | 0.0036 | $-0.1980^{a}$ | 0.0037 |
| $LnCNY_i$ | $-0.4792^{a}$ | 0.0130 | $-0.4670^{a}$ | 0.0132 |
| $LnCUMFD_{it}$ | $0.0092^{a}$ | 0.0000 | $0.0091^{a}$ | 0.0000 |
| *Intercept* | $-2.5175^{a}$ | 0.0044 | $-0.3697^{a}$ | 0.0427 |
| Main equation | | | | |
| $LnE(R_{it})$ | $0.1121^{a}$ | 0.0031 | $0.3275^{a}$ | 0.0024 |
| $LnW_t$ | $0.0938^{a}$ | 0.0044 | $-0.1692^{a}$ | 0.0032 |
| $LnOBS_t$ | $-0.0320^{a}$ | 0.0006 | $-0.0237^{a}$ | 0.0004 |
| $OWNER_{it}$ | $0.0020^{a}$ | 0.0026 | $0.0302^{a}$ | 0.0019 |
| *Intercept* | $14.7707^{a}$ | 0.0180 | $13.3967^{a}$ | 0.0138 |
| $\rho$ | $-0.3862^{a}$ | 0.0021 | $-0.1788^{a}$ | 0.0030 |
| *Log Likelihood* | −3,238,639 | | −2,917,396 | |
| $V_F^*$ | \$1.86 | | | |
| $V_I^*$ | | | \$0.36 | |

a, b, and c denote statistical significance at the 99%, 95%, and 90% levels, respectively.

on any given day. On the other hand, increases in the rate of unemployment in the region, signals diminished job opportunities elsewhere and improve the likelihood of taking a fishing trip. The coefficient of the DWH shows an adverse effect of the oil spill on the commercial fishing trip decisions in the GOM. The captain is also less likely to opt for a fishing trip on the Christmas and New Year holidays. The coefficient of the cumulative number of days of fishing in a season indicates that as the season progresses the chance of taking a fishing trip rises. This reaction might be a proxy for the growth in the expected size of the shrimp, not captured by the expected revenues.

In the main equation, positive correlations between the captain and crew revenue share and both the VSL and VSI are observed. This suggests that, for a given a rate of fatality (or injury), the VSL (or VSI) increase, if the revenues rise. The sample selection corrected VSL ($V_F^*$) is approximately \$1.86 million in real terms, which is less than half of the upper bound. This figure is much consistent with the estimates by Schnier, Horrace, and Felthoven (2009) for the Alaskan fisheries, but is much smaller than recent VSL estimates for Chilian industries (Parada-Contzen, Andres, and Felipe 2013) and for the use of airbags by U.S. consumers (Rohlfs, Ryan, and Kniesner 2015). The sample selection corrected VSI ($V_I^*$) is approximately \$0.36 million in real terms, which is one-third of the upper bound amount. The statistical significance of ρ suggests that the sample (captain's trip decision) selection is not random. Furthermore, the negative values of ρ indicate that the unobserved variables in the decision model have a negative impact on the share of captain and crew revenues.

As a part of the sensitivity analysis, I considered the effect of ethnicity of the fishermen on the VSL and VSI estimates. The results are reported in Table 5. An observed heterogeneity of fishermen is taken into account by dividing the data set into two subsample of Vietnamese and all other ethnicities. The estimated values of the sample selection corrected VSL ($V_F^*$) and VSI ($V_I^*$) for the Vietnamese group are 29% and 41% lower, respectively, than the values for the rest of the fishermen, suggesting a smaller tradeoff between safety and income and less risk-aversion than the rest of the shrimp fishermen in the area. On average, Vietnamese vessels tend to be smaller (10%) and use fewer crews (9%) than other shrimp commercial vessels. Assuming that there is no discrimination as most of the Vietnamese fishermen are self-employed, these low estimates are consistent with the low estimates of VSL typically observed in developing countries

**TABLE 5**
Sensitivity Analysis of the Estimates of VSL and VSI Based on Ethnicity

| Parameters | Log-Full Sample | Log-Vietnamese | Log-All Others |
|---|---|---|---|
| $\overline{V}_F$ | 6.14 | 5.18 | 6.34 |
| $\overline{V}_I$ | 1.26 | 0.90 | 1.33 |
| $V_F^*$ | 1.86 | 1.41 | 1.99 |
| $V_I^*$ | 0.36 | 0.23 | 0.39 |

and the estimated VSL reported for the U.S. Mexican immigrants by Hersch and Viscusi (2010).

## VII. CONCLUSIONS

The shrimp fishery is the largest in terms of revenues and the number of crew in the GOM. While shrimp fishing is one of the most dangerous occupations in the country, the safety issues in this fishery have not been the subject of any studies in the past. My analysis of the trade-offs between safety risk in the GOM shrimp fishery and monetary rewards suggests that the upper-bound of the VSL for fatality is $6.14 million, compared with $1.26 million for the VSI, in 1982 dollars. Correcting for the sample selection bias, my estimated VSL is $1.86 million and VSI is $0.36 million, in real terms. These estimates are consistent with recent estimates of occupational injuries in other fisheries as well as in other industries, and the VSL for consumer air bags. Therefore, the result indicates that shrimp fishermen are not risk-lovers as some have argued.

This study also concludes that the VSL and VSI estimates for the Vietnamese group are significantly lower than the rest of the population, which can be considered in policy evaluations. The source of this heterogeneity may reflect inadequate English proficiency skills among the Vietnamese population. As a result, one may extrapolate that the ethnic populations, such as the Vietnamese, face a different market opportunities than the rest of the working population. On the other hand, if the risk valuation differentials are attributed to discrimination, it is considered a market failure and the risk differential valuations have no policy implications.

The results here could be beneficial in making other policy decisions. For example, I discovered that the shrimp observer program has not been effective so far in reducing either the fatalities or injuries in the fishery. Perhaps the new USCG safety examination requirement for all vessels operating beyond 3 nautical miles the U.S. territorial sea baseline by the end of 2015 would be more effective in reducing accidents at sea than the observer program. Of course, safety has not been the primary purpose of the observer program. Also, as NOAA is contemplating instituting an IFQ program for the GOM shrimp fishery, its effect on safety might guide the direction of the program.

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