A STOCHASTIC ANALYSIS OF TRACTOR OVERTURN COSTS ON CATFISH FARMS

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Abstract

An area of health and safety risk in agriculture that can be especially dangerous is aquaculture farming. One of the main sources of injuries on aquaculture farms is tractor overturns which often results in crushing injuries. There is likely a higher probability of tractor overturns on an aquaculture farm than a traditional row crop farm due to the type of conditions that prevail on aquaculture farms. An aquaculture farm requires tractor movement near pond levees and water and these levees themselves are often quite steep. Many of the activities on an aquaculture farm such as mowing, feeding, and pond maintenance require a tractor to be operated near a pond levee.

Rollover protection systems (ROPS) on tractors can help to minimize injuries caused by tractor rollovers. ROPS systems do not lessen the probability of rollover but ROPS systems do help to lower the expected injury cost and the severity of a rollover. Despite the benefits of ROPS, not every tractor is so equipped. Some earlier work indicated that the cost to retrofit these older tractors to ROPS might outweigh the expected benefits.

This paper uses stochastic (i.e., randomly determined) analysis to determine if risk averse farmers are more likely to retrofit tractors with ROPS. A distribution function of injury costs should a rollover occur is developed for both ROPS and non-ROPS tractors. Risk aversion is modelled by assuming a negative exponential utility function for the farmer. A simulation is run where first a draw from a binomial distribution is taken to determine if a rollover occurs during a given hour of tractor operation. If a rollover does occur then a draw from the injury cost distribution is taken. For each point, the utility is calculated. At the simulation end, the average utility is converted back to a certainty equivalent.

Results indicate that many risk averse producers will be willing to retrofit older tractors with ROPS. However, producers who are risk neutral probably will not retrofit. These results might explain why not all tractors have been retrofitted despite the long-term availability of retrofit kits.

Keywords: aquaculture, safety, simulation, risk aversion, stochastic

Introduction

Farming is in general a risky occupation. Farmers face production and marketing risks that are largely weather driven and somewhat unique to agriculture. In addition, farmers face the standard financial risks that are common to all business. Health and safety risk is also another risk category that farmers have to confront. This risk category alone is enough to make farming very risky. Farmers have to work in conditions where weather can be a factor and their job includes operating complicated heavy machinery and handling unpredictable animals.

An area of health and safety risk in agriculture that is especially dangerous is aquaculture farming. One of the main sources of injuries on aquaculture farms is tractor overturns which often results in crushing injuries (Claussen). There is likely a higher probability of tractor overturns on an aquaculture farm than a traditional row crop farm due to the type of conditions that prevail on aquaculture farms. An aquaculture farm requires tractor movement near pond levees and water and these levees themselves are often quite steep. Many of the activities on an aquaculture farm such as mowing, feeding, and pond maintenance require a tractor to be operated near a pond levee.

Rollover protection systems (ROPS) on tractors can help to minimize injuries caused by tractor rollovers. ROPS systems do not lessen the probability of rollover but ROPS systems do help to lower the expected injury cost and the severity of a rollover. Some studies have estimated that ROPS could save $684,729 per overturn (Center for Disease Control 1993). Thus, there exists some incentive for farmers to retrofit older tractors with ROPS.

Since 1986, tractor manufactures began a voluntary program of adding ROPS to 20 horsepower and above tractors sold in the U.S. However, almost all tractors manufactured since 1967 can be retrofitted with ROPS. Still, many tractors operating on aquaculture farms do not have this protection.

An earlier paper by Stephens (2010) examined whether the net benefits outweighed the costs when considering a retrofit of ROPS on older tractors. They found that the small number of reported rollovers in their study only equated to a net benefit of $14 per year. As all the ROPS retrofit packages cost over $147, the number of years required before benefits outweighed the costs would be longer than the remaining expected lives of most tractors. However, this study only examined risk neutral decision makers. In reality, most farmers are risk averse and would be willing to pay something extra to minimize risk.

This paper re-examines the study by Stephens (2010) to include risk averse farmers. Instead of just comparing the expected dollars of benefits and costs, this paper will use a negative exponential distribution function to represent the utility of farmers and then convert this utility back to a certainty equivalent. Therefore, this paper will examine the retrofit to ROPS on older tractor decision for farmers who are risk averse.

Background

A study by Myers (2008) of tractor overturns in the U.S. for 1997 estimated 2,412 overturns occurred resulting in 125 and 573 fatalities and non-fatalities, respectively. Of these injuries, over 95% occurred on non-ROPS tractors. Even though the percentage of non-ROPS tractor is decreasing, there are still many of these tractors on the job. According to Myers (2009), the percentage of ROPS equipped tractors during the years 2001 to 2004 was estimated to be 48.8%. The situation on aquaculture farms is better with 77.8% having ROPS protection according to this same study.

The study by Stephens (2010) used a net present value cost analysis where the benefits of ROPS over non-ROPS tractors was calculated each year and then summed together by discounting benefits in future years. The median cost of a ROPS retrofit was found to be $949 with the minimum price for a retrofit at $147. Thus, the entire future benefits of added ROPS protection had to exceed this retrofit cost to make the conversion worthwhile for a risk averse farmer.

This study calculated the benefits of ROPS for each hour of tractor operation and then multiplied the benefit per hour by the number of hours of tractor use in a year. The expected accident cost per hour of operation was calculated by multiplying the probability of an accident occurring per hour by the cost should an accident actually occur. Because the probability of a rollover was determined to be the same for both ROPS and non-ROPS equipped tractors, the calculation really amounted to comparing the cost should a rollover occur.

The overturn rate used by Stephens (2010) was based on a survey administered by the National Agricultural Statistical Service of 120 Mississippi aquaculture farmers. This survey had 98 responses representing 1020 tractors. Of these tractors, 88% were equipped with ROPS. From the survey, there were only two overturns from the 10-year time frame that was used in the questionnaire. Thus, the response rate was very small (i.e., 2 overturns per 2,852,427 hours of tractor operation).

As shown in Stephens (2010), the benefit calculation also needed the injury cost should a rollover occur for both ROPS and non-ROPS tractors. Here, a study by Myers (2004) was used. This study estimated the probability of either no injury, non-fatal injury, or death for both ROPS and non-ROPS tractors. These results are shown in Table 1. As noted in the table, direct costs and indirect costs are the same for ROPS vs non-ROPS tractors. The difference between ROPS and non-ROPS tractors is in the probabilities of either an injury or death occurring. As one would imagine, the probably of death or injury is lower when a ROPS tractor is used.

Table 1. National Data on Costs of Tractor Overturns Adjusted for 2010 Dollars

	ROPS-equipped		non-ROPS-equipped	
Parameter	Fatal	Nonfatal	Fatal	Nonfatal
Direct Cost*	$45,715	$2,335	$45,715	$2,335
Indirect Cost*	$518,142	$14,248	$518,142	$14,248
Cost per Overturn	$563,857	$16,583	$563,857	$16,583
Total Overturns**	59	888	2,581	11,398
Probability of fatal or nonfatal if rollover	0.00115	0..17	0.0959	0.69
Expected Cost	$648	$2819	$54,901	$11,442
Total Expected Cost	$3,467		$65,553	
Expected benefit of ROPS	$65,553-$3,467=$62,066			

* Leigh et al. 2001
**Myers et al. 2008

As shown in the above table, the expected benefits to ROPS should a rollover actually occur, amounts to $62,066. However, since the probability of a rollover is so small, the expected net benefits for a typical sized catfish farm only amounts to $14 per year. Here, the average sized catfish farm used a tractor 325 hours per year. The $14 benefit is obtained by multiplying the probability of a rollover per hour of tractor operation (2 per 2,852,427), the benefit if a rollover occurs ($62,066) and the tractor hours per year (325) together.
The study by Stephens (2010) also looked at dividing the catfish farms into small and large farms. The small farms used their tractors 589 hours per year while the larger farms used their tractors 293 hours. Even for the smaller farms, the net expected benefits were only $26 per year from retrofitting ROPS. Given the cheapest conversion to ROPS of $147, it would take at a minimum 5.74 years to pay for the retrofit. Given the age of many of these tractors, a retrofit seems unlikely under these conditions.

Analysis with risk averse farmers

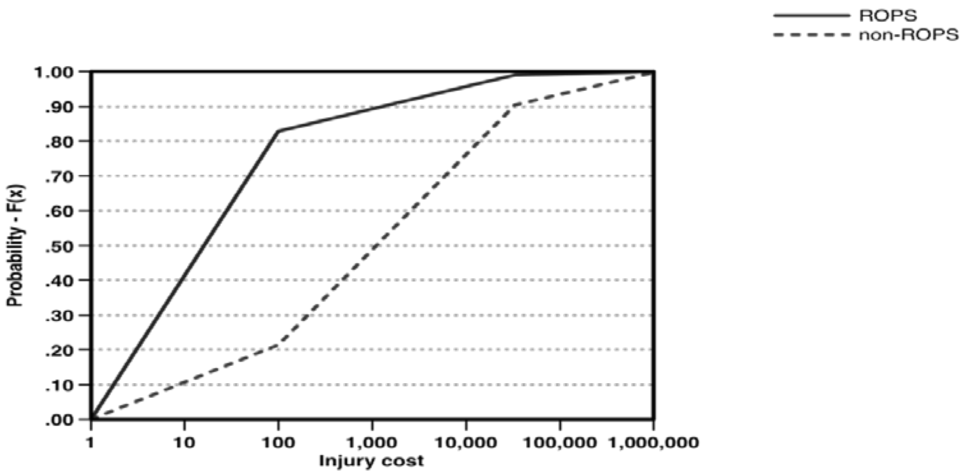
All of the above analysis used in Stephens (2010) assumed risk neutral producers so that only expected costs and benefits needed to be examined. A more realistic analysis should include risk averse producers. For this paper, a negative exponential utility function was used for the producers. This type of utility function means that producers would be willing to pay to reduce risk. A certainty equivalent was then used to convert the average utility back to a dollar amount.

To start the risk averse analysis, the point estimates of costs and probability of costs for both ROPS and non-ROPS tractors should an accident occur had to be converted into a cumulative distribution function (CDF distribution). This CDF was needed so that a Monte Carlo simulation could pull draws for accident costs should a rollover occur. Thus, a Monte Carlo process produces the stochastic analysis of random sampling from a distribution. Sampling from the distribution will give the same average value as before. The difference is a stochastic sampling process of the distribution will allow an analysis of points where a risk averse producer might behave differently than a non-risk averse producer.

In Table 1, there are only 3 states for a rollover, no injury, injury but no fatality, and fatality. There are costs associated with these three states. To develop a CDF that keeps the same expected costs, two extra points are needed so that the costs shown in Table 1 are actually at the midpoint of a segment of a CDF. For example, the first state in Table 1 is for no injury to occur which has a zero cost. In the CDF conversion, a zero cost accident actually had potential costs from $0 to $100. It was felt that "no injury" actually meant that a rollover required no visit to the doctor. There were likely some costs for bandages, ice packs, etc.

The second state from Table 1 was for nonfatal injuries. These had an expected cost of $16,583. Given that the top end of the no injury range was $100, the potential costs should an injury occur could range from $100 to some higher limit. Because an expected cost of $16,583 is needed, the top end of the injury but no death state had to be almost twice $16,583 (i.e., $33,166 less $100). The expected cost for a fatality was $563,857. However in the CDF, a fatality could range from $33,166 to $1,094,548. This range would give an average of $563,857. Figure 1 below shows what the CDFs look like for the ROPS tractors and the non-ROPS tractors.

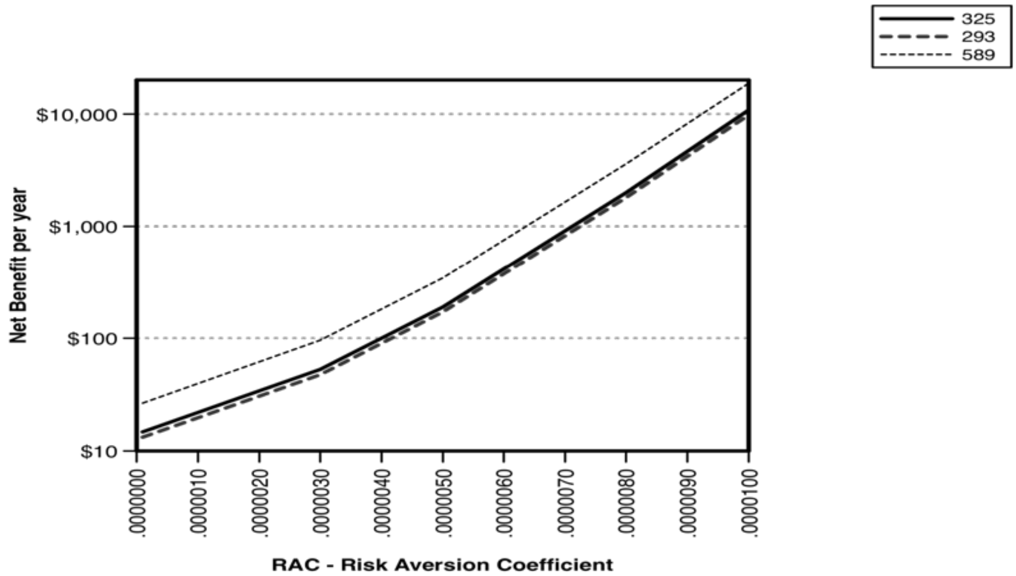
Figure 1. CDF of Injury Costs from ROPS Tractors and non-ROPS Tractors



The next step is to simulate whether a rollover occurs and then, if a rollover occurs, a draw is taken from the CDF of injury costs. Because so few rollovers occur, a very large simulation is needed to ensure enough points are pulled from the rollover CDF of costs. Remember that a draw from the injury CDF is only taken when a rollover occurs.

For each point in the simulation, an expected cost is calculated by multiplying the zero or one draw to determine if a rollover actually occurs by the injury cost draw from the CDF of costs. For each of these injury costs, the utility is calculated by using a negative exponential distribution. Finally these utilities are averaged together to get the mean utility. This mean utility is then converted back to a certainty equivalent.
Results will vary depending upon the risk aversion coefficient used. As the risk aversion coefficient becomes larger, the benefits from retrofitting ROPS should increase. Figure 2 below shows the certainty equivalents or net benefits to a risk averse farmer for different levels of the risk aversion coefficient.

Figure 2. Certainty Equivalents (Net Benefits) to a Risk Averse Farmer



Results

As Figure 2 shows, making farmers risk averse greatly affects the retrofit to ROPS decision. Instead of only a benefit of $14 per year, benefits can easily be between $100 and $1,000 per year. Figure 2 shows these results for three farm sizes, the 325 tractor hours per year average farm, the 589 tractor hours per year small farm, and the 293 hours per year large farm.

When benefits start to approach $100 per year, the retrofit decision becomes much easier as the conversion comes close to paying for itself after only one year. Thus at least some farmers should be interested in the retrofit conversion.

Discussion

Given that many of these ROPS conversions have been available for awhile the question becomes why have not all farmers converted. It could be because for these farmers, they are not risk averse enough to make the ROPS retrofit worthwhile. Additionally, some farmers may not fully appreciate the costs associated with a rollover.

Another issue to consider is who is using the tractors. Risk averse farmers may well be making the conversion on tractors they themselves drive. However, for tractors likely to be driven by hired help, farmers may be examining those decisions as risk neutral owners. That is, if farmers know they personally won't be on a tractor then they may analyze a ROPS retrofit decision purely in terms of expected net returns and net costs (i.e., they make the decision as risk neutral when they themselves may still be risk averse).

Remaining life of the tractor will certainly have some influence on whether to adopt ROPS protection. The longer the remaining tractor life, the more likely farmers are to add ROPS. Also, the ability to retrofit ROPS on a tractor is important. Given the range of retrofit costs, some tractors are more suited to adding ROPS than others.

Conclusions

For aquaculture farmers who are truly risk neutral, adding ROPS will likely not add enough benefits to outweigh the costs. However, as farmers become more and more risk averse, then adding ROPS becomes much more likely. Given the range of possible outcomes, a small change in the risk aversion coefficient can lead to a big change in the certainty equivalent of benefits. For many risk averse producers, ROPS retrofits can be justified within a year.

Those older tractors not yet converted to ROPS either have risk neutral producers or may have risk averse owners but are being driven by hired employees. Tractor age and retrofit costs could also have some influence on why not all tractors have been retrofitted. Finally, the possibility exists that producers are not fully aware of the potential costs that could occur from a rollover accident.

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