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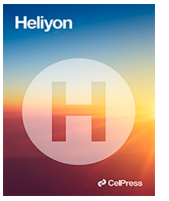

Economic benefit of co-regulation to manage aflatoxin risk in maize

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ABSTRACT

Aflatoxins are toxic fungal metabolites that occur naturally in the field among cereals, oilseeds, and nuts that may increase during storage. Texas grown maize, commonly referred as corn, has some of the highest aflatoxin levels in the US. In 2011, the Office of the Texas State Chemist (OTSC) collaborated with the Risk Management Agency (RMA) of the United States Department of Agriculture (USDA) and the Texas grain industry to implement the state's first co-regulation governance option to manage aflatoxin risk. Co-regulation is a form of risk management that relies upon a government-private partnership in regulation; utilizing government-backed codes of practice that result in a more connected and transparent marketplace. To measure the economic benefit of co-regulation to manage aflatoxin risk, interviews were conducted among twenty-seven participants in the OTSC aflatoxin co-regulation program who represented 31% of the grain companies that handled maize contaminated by aflatoxin according to Texas Commercial Feed Rules. A comparative approach was used by gathering evidence from 2010 to 2018, in order to evaluate the results before and after the OTSC implemented its co-regulation strategy. The results were evaluated by using the data gathered from the interviews to measure the specific costs and benefits incurred by producers and grain handlers. The findings were modeled in the form of an income statement. From the income statement, the total economic benefit of the One Sample Strategy in 2018 was $14,572,180. This study provides a more realistic characterization of cost drivers associated with aflatoxin risk management and counters exaggerated economic losses associated with aflatoxin in maize from prior studies.

1. Introduction

Mycotoxins are toxic fungal metabolites that occur in agricultural goods [1]. Aflatoxins are produced primarily by strains of *Aspergillus flavus* and *Aspergillus parasiticus* [2]. These species are soil borne organisms that can produce aflatoxins as they attach and build on a food source [3]. Since their discovery in the early 1960s, consumption of aflatoxin contaminated feeds and foods are known to have detrimental health effects on humans and animals [1]. Depending upon the level of toxicity in the foods or feed, there have been known injuries to both humans and animals that are hepatic, gastrointestinal, immunosuppressive, teratogenic, oncogenic, liver damaging, and fatal [1]. In the United States (US), crops grown in hotter climates located in the Southeast and the Southwest are more susceptible to aflatoxin. The level of aflatoxin in Texas has been the subject of numerous scientific papers [4,5] and government reports

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[6,7]. These papers and reports also demonstrate the paucity of research and extension success involving pre-harvest aflatoxin risk management. One notable exception involves the adoption of atoxigenic fungi (product names Afla-Guard® GR) as a biocontrol. The amount of Afla-Guard® GR use in the US is not publicly available nor was it available from OSS firms.

In the US, there are no regulatory limits prescribed by the Food and Drug Administration (FDA) [8]. Rather, in 1969, the FDA set an action level for aflatoxins at 20 μg/kg for all foods, including animal food, based on FDA's analytical capability and the agency's aim of limiting aflatoxin exposure to the lowest possible level [9]. Based on the progression of scientific research over time, the FDA revised its action levels for aflatoxins to vary among crops and uses for those crops through a Compliance Policy Guide (Sec. 683.100). The FDA Compliance Policy Guide contains action levels for aflatoxins in animal food first issued in 1979 with multiple revisions [9]. The FDA policy is non-binding and not legally enforceable, but reflects the Agency's current thinking. Many research and extension personnel who publish peer reviewed journal articles and bulletins on aflatoxin incorrectly refer to FDA regulatory limits. However, several states in the US have set aflatoxin rules that include regulatory maximum levels (MLs). In Texas, aflatoxin regulations were promulgated by the Texas Feed and Fertilizer Control Service (FFCS) of OTSC, which is the regulatory risk manager for aflatoxin contamination in cereals, oilseeds, and animal feeds. The FFCS rules contain MLs for aflatoxin by animal species and growth states that are similar to FDA action levels. OTSC guidance for managing aflatoxin risk was first issued in February 1991 with subsequent revisions since [10].

In 2011, OTSC collaborated with RMA of the USDA and the Texas grain industry to implement OTSC's first co-regulation governance option, known as the One Sample Strategy (OSS) [11]. Specifically, the OSS standardizes maize sampling and testing procedures to reduce variability of aflatoxin test results following USDA procedures provided by the Federal Grain Inspection Service (FGIS) including the use of FGIS validated aflatoxin test kits. Co-regulation, relies upon a government-private partnership in regulation using government-backed codes of practice or action plans [5,12]. This strategy established five pillars to connect the government-backed codes of practice to the public-private partnership with the end goal being a more connected and transparent marketplace. The five pillars included crop insurance, inventory tracking and reporting, laboratory quality systems, surveillance and monitoring, and communication and outreach.

Prior research examining the economic consequences of aflatoxin contamination reported potential losses in the US associated with aflatoxin range between $52 million and $1.68 billion dollars based on aflatoxin data from Illinois, Iowa and Texas from 2011, 2012, and 2013 [13]. The authors did not reference the Texas One Sample Strategy aflatoxin risk management program which was initiated in 2011 [5]. Other shortcomings in the Mitchell article included an underrepresentation of the Texas aflatoxin data and a limited characterization of grain elevator discounts. These omissions are addressed through this study.

In 2011, RMA entered into an agreement with OTSC to advance the OSS co-regulation program [11]. Through this program, OTSC verified testing accuracy of OSS participants by analyzing 612, 693, and 482 retained samples in 2013, 2014, and 2015, respectively [5]. These results were augmented by the agency's regulatory program, which collected and analyzed 927, 709, and 547 samples in 2013, 2014, and 2015, respectively [14]. A need exists to provide a comprehensive review of aflatoxin risk management techniques in addition to the impact a co-regulation strategy has on potential losses and gains associated with aflatoxin risk management.

Collaboration between OTSC and RMA was announced in a Manager's Bulletin on July 26, 2011 [11]. The RMA issued Manager's Bulletin MGR-12-004 on April 12, 2012, authorizing the OSS for aflatoxin testing in approved Texas elevator facilities for the 2012 and succeeding crop years [15]. The OSS was further expanded to include all mycotoxins via Managers Bulleting: MGR-17-2015 in 2017 [16]. FFCS verifies testing accuracy of OSS participants retained samples. Further, OTSC provides an annual report to RMA that includes crop insurance certificates issued under FFCS authority.

'The implementation of the OSS built upon a quality system–based code of practice successfully managed aflatoxin risk in Texas by using co-regulation as a governance option' [5]. Toward this end, the purpose of this study was to examine the costs and benefits of a co-regulation strategy to manage aflatoxin risk.

2. Materials and methods

Procedures for the OSS were first presented in a white paper written for the OTSC Advisory Committee, Texas legislators and the USDA RMA [17]. A handbook describing the USDA-FGIS protocol and their application to the OSS via a food safety plan was first published in 2011 and is currently in its 12th version [7]. The Texas Commercial Feed Control Act §141.072 requires firms to report their official inventory results, which includes mycotoxin contaminated maize to the OTSC per Feed Industry Memorandum No. 5–12 Herrman [18]. The purpose of the feed industry memorandum is to ensure that mycotoxin contaminated maize is directed to the proper end-user to protect consumers and the marketplace. The memorandum was first published in 1991 and includes provisions for blending to minimize the economic impact of aflatoxin and ensure an adequate supply of maize for the Texas livestock and poultry industry.

2.1. Lab quality systems

The OSS ensures the accuracy of testing methods by having participants utilize a laboratory quality systems approach. The fundamentals in this approach include development of a food safety plan by participating firms, description of sampling and testing methodology following USDA protocol outlined in the OSS handbook, analyst qualification, and use of working controls (reference material) to ensure testing accuracy. Verification of official sample testing accuracy is done through the OTSC's Agricultural Analytical Service (AAS) using high performance liquid chromatography with photochemical reactor for enhanced detection (HPLC-PHRED), with fluorescence detection as described by Dai et al. [19].

2.2. Surveillance & monitoring

The FFCS field staff inspects firms participating in the OSS to ensure accurate sampling and testing methods are practiced. Verification samples from firms are collected by investigators and have them analyzed within five working days. The results of these samples are sent back to the participating firms to provide them with objective feedback for their continuous improvement to measure accurately. The OSS firms that are unable to accurately sample and test are removed from the program and are not permitted to issue certificates of analysis on behalf of the OTSC for crop insurance purposes. A correlation analysis of OTSC-OSS results is performed annually using Excel and is reported through the USDA National Institute of Food and Agriculture (NIFA) System [20].

The years 2010 and 2018 were selected to provide a representation of the presence of aflatoxin in Texas before and after the One Sample Strategy. The economic benefit of co-regulation in managing aflatoxin risk was quantified and qualified by conducting a census of interviews with current firms participating in the One Sample Strategy. It was then evaluated by using the data gathered from the interviews to determine the value of specific costs and benefits to program participants. Costs incurred by OTSC to implement OSS did not significantly increase the agency's regulatory budget.

Each participant interviewed was initially contacted via email to explain the research that was being conducted, the importance of their involvement, and to request their participation. After the initial email, each participant was called to evaluate their willingness to participate. Those that consented to giving an interview were asked a series of fifteen strategic questions to determine the costs and benefits of the OSS. The following costs and benefits used as specific measures of value can be observed in Table 1. The interview questions were requesting information from the years 2010 and 2018 in order to provide an objective comparison of the costs and benefits of the OSS before and after its implementation. The quantitative information received from the interviews was modeled as an income statement for 2018. Each interview participant was asked the same series of fifteen questions. No incentives were given to interview participants for their involvement in this research. Each interview participant and their responses are anonymous.

3. Results

3.1. Before the One Sample Strategy (2010)

In 2010, there were approximately 248,500 farm operations performing on 131,600,000 acres in Texas. Only 1.6% of total production acres or 2,080,000 acres were harvested in Texas for maize with total production resulting in 299,520,000 bushels. The economic unit for feed in the United States (US) is typically a short ton which is 907.18 kg and one bushel of maize in the US is equivalent to 25.401 kg. The total estimated market value of the Texas maize crop in 2010 was $1,398,758,000 [21].

In 2010, the Office of the Texas State Chemist sampled maize originating from sixty-seven counties in Texas, twenty-six of which experienced aflatoxin levels greater than 20 μg/kg. The highest level of contamination occurred in Williamson County and was 1340 μg/kg. The samples that were collected revealed that only 39% of the harvested maize was below 20 μg/kg, the lowest regulatory limit. The samples also revealed that 39% of the harvested maize was between 20 μg/kg and 300 μg/kg, which at that level maize may be discounted or even rejected at the grain elevator.

3.2. After the One Sample Strategy (2018)

In 2018, there were approximately 247,000 farm operations performing on 127,000,000 acres in Texas. Only 1.4% of total production acres or 1,750,000 acres were harvested in Texas for maize with total production resulting in 189,000,000 bushels. The total estimated market value of the 2018 Texas maize crop was $774,900,000 [22].

In 2018, OTSC sampled maize originating from fifty-eight counties in Texas. Twenty-two of those counties experienced aflatoxin greater than 20 μg/kg with the highest level of contamination occurring in Wharton County at 1169 μg/kg [10]. The samples that were collected reveal that 41% of the harvested maize was below 20 μg/kg, the lowest regulatory limit. The samples also revealed that 38% of the harvested maize was between 20 μg/kg and 300 μg/kg, a level that risks being discounted or even rejected at the grain elevator.

Table 1
The costs and benefits that were used as specific measures of value to determine the economic benefit of shared governance.

Specific Value Measures	
Costs	Benefits
Startup Equipment	Premium Pricing Received
Sampling and Testing	Crop Insurance Indemnification Payments
Blending	Resolved Testing Conflicts Savings Value
Discount Pricing	Difference in Maize Markets
Rejected Loads Freight	Profit from Aflatoxin Testing
Inspection Fees	Basis

3.3. Study scope and scale

As a result of the co-regulation program, participants in the OSS consist of grain elevators and feed mills. In 2018, there were thirty-four participants in OSS. These 34 participants represented approximately 31% of the grain handling establishments in the 22 counties that experienced maize containing greater than 20 μg/kg aflatoxin in 2018. Twenty-nine participants from nineteen counties were selected to be contacted for an interview. A total of twenty-seven participants from eighteen counties (93%) successfully completed an interview. Out of the twenty-seven participants who completed an interview, eighteen (66.7%) were grain elevators and nine (33.3%) were feed mills.

These data were used to determine and evaluate the costs and benefits before and after the implementation of the OSS using an income statement.

The benefits that are specific measures of value to the OSS include: premium pricing received, crop insurance indemnification payments, savings associated with resolved testing conflicts and improved market from profit associated with aflatoxin testing and basis. Potential limitations in data gathered during the research include: (i) the interview participant not understanding the question; (ii) the interview participant providing estimations rather than concrete evidence as their responses; (iii) the dilemma of omission and commission with interview participants; (iv) the interviewer poorly communicating, understanding, or recording.

3.4. Premium pricing

Grain elevators and feed mills in the OSS have received premium prices on their grain because of the guarantee the OSS provides. Grain elevators receive premium prices from feed mills and feed mills receive premium prices for maize targeted to produce deer feed which is sold as whole maize (deer corn) to attract deer during hunting season. Premiums received have ranged from $0.05 - $0.30/bu. All of the premiums that have been received have been since OSS implementation in 2011, therefore no premiums were received in 2010. Participants that have not received premiums for their grain still believe that the OSS has provided them value as stated below

Even though I have never received a premium for the OSS, it improves relationships and makes grain easier to sell.

I haven't received any premiums, but I believe there is potential.

The OSS has made our company a preferred vendor.

Six of the participants reported they received premiums and 21 indicated they did not receive premiums. Out of the six participants who did receive premiums, four were grain elevators and two were feed mills.

3.5. Crop insurance indemnification payments

Crop insurance is one of the five pillars of the OSS public-private partnership. Firms participating in the program whose employees are qualified may issue official aflatoxin results on OTSC certificates of analysis, which approved insurance providers can use to issue timely crop insurance indemnification payments [11]. The value of the payment producers receive is based on their insurance policy (coverage) and level of aflatoxin contamination. The value of crop insurance indemnification payments from aflatoxin contamination that was collected during the interviews averaged $220,000/farm. That crop insurance benefit was calculated using an average indemnification of $220/acre with the average size farm being 1,000 acres and the assuming 100% of the crop was affected. The number of participants who know of producers who received crop insurance payments in 2010 and 2018 was 4 and 23, respectively. This indicates a significant increase in accessibility to crop insurance, providing Texas farmers with improved financial risk management. Four interview participants made it known that they chose not to issue official OTSC analysis results for crop insurance indemnification.

3.6. Resolved testing conflicts

A grain elevator or feed mill is responsible for delivering the appropriate quality of grain at the correct amount to their buyer. The cost of transporting the grain is accounted for in the price the grain elevator or feed mill charges the buyer. According to the OSS Handbook, grain tested at an OSS firm is exempt from regulatory sampling. Participating firms may affix an OTSC seal as evidence that the maize has been tested according to the code of practice. Buyers can test and retest a load and can refuse it for any reason. A rejected load is a cost to the grain elevator or feed mill that is not accounted for. Participants credited the OSS for giving their grain credibility to buyers, which results in a savings value in resolved testing conflicts. Below are several comments by OSS participants involving dispute resolution:

The OSS does help minimize risk of rejected loads, which reduces potential for increased freight costs.

Before the OSS, mycotoxin testing was a black box that few farmers, vendors or truckers understood. We had many arguments about whether we knew what we were doing. It's still a black box, but the OSS has given us more credibility.

The savings is in the prevention of conflict later on.

It has saved us from conflicts and given us credibility.

The consistency of the OSS equals savings. It saves us from sending out loads that may cost us later on.

Although, other participants indicated frustrations of having buyers retest their grain, despite participating in the OSS as follows: *Most buyers retest anyways (this was said by five different participants).*

Only 30% of buyers know what the OSS means. It helps manage aflatoxin, but does not solve the issue.

One of the most frustrating things is when a truck has been tested and segregated at our location as under 20 μg/kg, but then goes to its final destination and is re-tested and rejected because it might test 21 or 22 μg/kg. Usually they will not retest and I incur additional freight costs because the end users method of testing found the corn to be 1 or 2 μg/kg higher than the under 20 μg/kg we tested.

The other issue this year (2018) was that because there was so much aflatoxin corn many places began testing more frequently and places that normally accept our test were now also retesting our corn. This resulted in many more rejected loads and increased freight costs for loads that were 'border line' 21 μg/kg 22 μg/kg. VERY FRUSTRATING!!! Especially when they get rejected at one place and the get freighted 50 miles to another and the load passes at the 2nd place. Still got the grain sold and unloaded, but lost an additional 0.35/bu because of freight.

The values associated with resolved testing conflicts include: a prevention of a $0.30/bu discount, cost savings of 30% because a third party no longer conducting testing, load costs ranging from $0.35/bu and $200 - $1,000/load. Sixty percent of the participants credit the OSS for helping them resolve testing conflicts for their firm since the 2011 implementation. By resolving these testing conflicts, participants received a substantial cost saving.

3.7. Difference in maize markets

OSS participants were questioned on whether or not they saw a positive, negative, or no difference at all between 2010 and 2018 in their maize markets. The difference in their maize markets is defined by multiple factors including: number of buyers, who their buyers are, relationship strength between their buyers, and the future outlook on the market. The number of participants who indicated that there has either been a positive, negative, or no difference at all in their maize markets between 2010 and 2018 was 12, 4, and 11, respectively. A difference in maize markets can occur for a variety of reasons mainly relating to supply and demand. Examples of factors that influence the supply and demand of maize in Texas include: market consolidation, droughts, floods, hurricanes, mycotoxins, prices of other commodities, and other geographical areas buying or selling maize in Texas at certain price points. With aflatoxin being an influencer in the supply and demand of maize in Texas, participants revealed how the OSS has made a difference in their maize markets as follows:

It has increased our market opportunities.
Tractor supply wanted to sell our bagged corn because of the OSS.
We are now selling more to feed stores.
We have the same buyers, but the OSS has strengthened relationships.
Buyers love the OSS. It just makes it easier to sell.
The Mars Pet Food Plant bought from us because of the OSS.

Buyers are more confident in what they are getting because corn quality has improved with the OSS and Afla-Guard® GR.

It has helped in our relationship with our biggest customer, H-E-B.

The OSS led to a great relationship with Mummies because they needed grain for deer corn.

Deer corn sales have doubled every year for the last three years.

Before the OSS, producers would drive to local elevators to see who would accept their grain with the aflatoxin levels that it contained. Now after the OSS, there is higher quality grain because now elevators won't accept grain if it is a certain level.

I'm not sure how many buyers we have because of the OSS.

The difference in corn markets has come from a shift in market share. There is more consolidation, which leads to less sellers and buyers. (Three participants said this.)

The qualitative evidence above, the results of 44.4% of interview participants seeing a positive difference in their maize markets between 2010 and 2018, and the results of only 14.8% of interview participants seeing a negative difference in their maize markets between 2010 and 2018 are indicators that the OSS has played a role in improving maize markets in Texas.

3.8. Profit from aflatoxin testing

Interviews of all possible OSS firms revealed that multiple participants were able to form a new business enterprise from the services they provide. Participants were able to profit from the OSS by charging a price higher than the cost to producers for the accurate, defensible, and timely test results they could deliver. The number of participants that profited from charging for their aflatoxin testing capabilities was 5, with 22 reporting that they did not charge for testing. Out of the five participants that charged for

aflatoxin testing four of them utilized the Romer Labs FluoroQuant Afla Test and charged prices of $10/test, $20/test and $25/test, while the other utilized the Vicam AflaTest and charged a price of $0.02/bu."One participant stated that they planned to raise their price from $25/test to $35/test beginning in 2019 to increase their profits even more.

3.9. Basis

Basis is the difference between the futures price and the local cash price [23]. Basis if often referred to as 'the voice of the market' because it communicates whether the market wants one's grain or not. There are multiple factors that affect basis such as supply and demand, transportation costs, storage availability, geographical location, and quality. Due to having multiple factors influence it, there is a limitation in using basis as a means to measure the economic value of co-regulation as an option to manage aflatoxin risk. Despite the limitation basis has in this scenario, it does contribute to the transparent communication in the marketplace. Dr. J. Mark Welch, Extension Economist and Assistant Professor in Agricultural Economics specializing in grain marketing at Texas A&M University, stated in an interview, 'There is a positive difference in reliability in what we have with testing results before and after the One Sample Strategy. This has helped us understand the quality of Texas corn. Overall, OSS is a tool that has enhanced and improved our capabilities in marketing our grain' (2019 interview with Texas A&M professor, Dr. Welch; unreferenced, see 'Notes'). An example of the positive difference in basis between 2010 and 2018 that was provided by an interview participant is presented in Table 2. This positive $1.50 difference demonstrates that the OSS is partially related to marketing maize at a higher price.

3.10. Costs

The costs that are specific measures of value to the OSS that have been identified are: startup equipment, sampling and testing, blending, discount pricing, inspection fees, rejected loads freight, and the loss of maize markets.

3.11. Startup equipment

The OSS Handbook states that in order for firms to be eligible for participation in the OSS, they need qualified employees with knowledge of official USDA sampling and grinding procedures and that aflatoxin tests are performed using FGIS verified mycotoxin test kits. These requirements are included in the OSS Handbook, which is updated annually [7]. Firms incur a cost associated with purchasing testing equipment and additional labor as employees are trained and qualify to perform sampling, sample preparation and testing under OTSC supervision. The size of an operation, their experience level with aflatoxin testing, and their existing infrastructure are all factors for a firm in determining the cost value of the necessary equipment they need to obtain in order to comply with OSS standards. Twenty participants reported that they incurred a startup cost when joining the OSS to comply with equipment standards. The cost values for startup equipment for interview participants ranged between $600 and $16,200. Seven participants stated that it was *"hard to value."* The total cost value for startup equipment for all twenty-seven interview participants was $80,800 with the average cost value per firm being $7,345.

3.12. Sampling & testing

Each OSS participant is required to submit a specialized Sampling and Testing Plan describing how the standard operating procedures will be carried out [7]. If firms were testing for aflatoxin prior to joining the OSS, they were required to change their prior methods of testing to match the USDA standards contained in the OSS handbook [7]. Taking all of those individual factors into account, the total cost to sample and test for aflatoxin was quantified by the number of tests that were performed and the cost of each test. The number of interview participants that provided information for the number of aflatoxin tests preformed in 2010 and in 2018 was 9 and 23, respectively. The number of tests that were conducted in 2010 and 2018 were 2,233 and 17,511, respectively.

From the interviews, there were nine pairs of data for the number of aflatoxin tests conducted in both 2010 and 2018. Out of the nine pairs of data, five of those conducted 0 tests in 2010, eight of those increased the number of tests given from 2010 to 2018, and one of those stayed the same in number of tests given from 2010 to 2018. The number of interview participants that provided information for the cost of each aflatoxin test conducted in 2010 and in 2018 was 9 and 21, respectively. The cost of each aflatoxin test, factoring with and without labor, in 2010 and 2018 are presented in Table 3.

From the census of interviews, there were nine pairs of data for the cost of aflatoxin tests conducted in both 2010 and 2018. Out of the nine pairs of data, five of those did not have costs for 2010. Still, out of the nine pairs of data from 2010 to 2018, one cost decreased by $5 (including labor), one cost increased by $1 (not including labor), one cost increased by $4 (by the truckload), and one cost stayed the same.

From the data given from interview participants that is outlined in Table 2, the average cost of conducting an aflatoxin test was

Table 2
Basis levels observed in 2010 and 2018 within the same Texas County.

2010	2018
-$0.60	$0.90

Table 3
The cost of each aflatoxin test conducted in 2010 and 2018 by One Sample Strategy participants.

2010		2018	
With Labor	$16.36 - $21.50	With Labor	$11.63 - $25
Average (With Labor)	$18.93	Average (With Labor)	$17.06
Without Labor	$9.08	Without Labor	$6 - $10.50
Average (Without Labor)	$9.08	Average (Without Labor)	$7.70
By Truck	$8	By Truck	$12

cheaper in 2018 than it was in 2010, regardless of labor costs. The cost of an aflatoxin test conducted by the truckload is more expensive in 2018 than in 2010. On average, the uniform sampling and testing methods of OSS has decreased the cost to conduct an aflatoxin test.

3.13. Blending

OSS firms that have maize with aflatoxin contamination exceeding 300 μg/kg have the option to blend with other maize to an acceptable level [18]. Firms may submit a preseason aflatoxin blending plan as a supplement to their annual Sampling and Testing Plan. Firms with an approved blending plan receive an aflatoxin blending permit from OTSC. A blending permit allows the facility to distribute unprocessed whole maize originally containing not more than 500 μg/kg aflatoxin after blending it with similar corn containing no less than 20 μg/kg. The final blended product, which must be below 200 μg/kg, can be labeled for intrastate distribution to finishing cattle in confinement, as allowed under Texas Commercial Feed Rules Title 4 Chapter §61.66.

Four participants reported an associated a cost to blending their contaminated maize, while 10 reported not cost and 13 participants indicated they did not blend. The only two values received from interview participants on the cost of blending were $0.05 - $0.10/test and $8/test. The other two interview participants reported that an associated cost to blending is *'hard to value.'* Blended maize under the authority of the OTSC for distribution in Texas is not a violation of the Food Drug and Cosmetic Act (FDCA) 402(a) (a). Specifically, the FDCA states that "A food shall be deemed to be adulterated if it bears or contains any poisonous or deleterious substance which may render it injurious to health; but in case the substance is not an added substance such food shall not be considered adulterated under this clause if the quantity of such substance in such food does not ordinarily render it injurious to health" [24]. Thus, under FDA definition the blending of maize containing 20 μg/kg of aflatoxin with maize containing >20 μg/kg of aflatoxin for intrastate commerce is not adulteration.

3.14. Discount pricing

Discount schedules detail price reductions based on aflatoxin contamination levels. They are implemented to make up for the economic losses that are incurred from aflatoxin-related quality deductions. Discount schedules are published by the grain elevators and feed mills at harvest along with other quality factors. These discounts may change in accordance with market conditions and level of contamination during harvest. Discounts can apply to both the suppliers and the buyers of grain connected to a grain elevator or feed mill. The number of interview participants that always posted a discount schedule was 2, while 6 responded that they posted a discount schedule before harvest and one reported positing a discount schedule after harvest.

The grain elevator or feed mill is responsible for: determining if they want to post a discount schedule or not, determining the timing of posting their discount schedule, determining if the discount applies to both suppliers and buyers of grain, and determining their discount schedule values. Qualitative evidence was gathered from interview participants on how they determine each of these responsibilities are described below:

Buyers determine the discount based on the maize's end use.
Discount schedule changes every year depending on the market.
No discount schedule was necessary because we went by contract specifications.
There is no discount schedule because we do not accept anything over 50 μg/kg.
We discounted based on our ability to sell it. We usually discounted 25 cents/bu, but did not post a schedule because anything over 21 μg/kg is subject to rejection.
No discount schedule is needed because we determine discounts on an individual basis.

Table 4
Example 1 of a discount schedule posted by a One Sample Strategy participant in 2010.

2010 Aflatoxin Discount Schedule Example 1	
0–20 μg/kg	$0
21–100 μg/kg	$0.10
101–300 μg/kg	$0.20

Aflatoxin over 300 μg/kg will not be accepted.

Three out of the nine participants that posted a discount schedule had posted one in both 2010 and 2018. Only one out of the three participants that had a discount schedule in 2010 and 2018 could recall the values for both years. Values for discount schedules posted in 2010 and 2018 can be observed in Tables 4–7 below. Discounts are accounted for on a per bushel basis.

Other examples of 2018 discount schedule values include: $1.50 off anything over 50 μg/kg; $0.25 cents off anything over 21 μg/kg; $0.25 cents off anything 21–100 μg/kg and $0.50 cents off anything over 101 μg/kg.

3.15. Inspection fees

The Texas Commercial Feed Act §141.071 states, 'For each fiscal year, a person who manufactures or distributes commercial feed or a component of commercial feed in this state, including a person who mixes, mills, or processes customer-formula feed, shall pay to the Service an inspection fee prescribed by this section' [25]. Every lot of aflatoxin contaminated maize (>20 μg/kg) meeting the definition of 'commercial feed' is subject, in addition to other requirements of the law, to the payment of the inspection fee [18]. Facilities with licenses to distribute commercial feeds, including customer formula feeds, pay a minimum annual fee of $100 due with the first quarterly report (ending November 30) of each year (except as described in the succeeding paragraph). This minimum annual fee will be credited toward the tonnage fee owed during the fiscal year. The minimum fee presently covers the first 526.32 tons of feed (19 cents/ton). Once this annual fee credit is depleted, a remittance of 19 cents per ton sold shall be submitted during the remainder of the fiscal year [18]. Inspection fee values for aflatoxin contamination were collected from the OTSC. For the purpose of this research, inspection fee values were totaled up only for aflatoxin contaminated maize subject to the inspection fee from the OSS participants who had completed an interview. All inspection fee values were unavailable for 2010. The total inspection fee values for OSS participants in 2018 totaled $5,060.10.

3.16. Rejected loads freight

A cost is incurred for grain elevators or feed mills when a load of maize they have shipped to a buyer is rejected due to unacceptable levels of aflatoxin contamination. Interview participants indicated in the 'Resolving Testing Conflicts' section outlined above that the OSS has a savings value in resolving testing conflicts, but there is still an issue with buyers retesting the grain, even with the OSS seal of approval. With buyers retesting grain using different sampling and testing standards than that of the OSS, there is potential for them to find different results and reject the load. A few interview participants indicated the even with buyers retesting grain, it is not very common for loads to be rejected as stated below:

It is not very often that a load is rejected.
Out of hundreds of loads, only two or three have ever been rejected.

Based on data that interview participants provided, which included cost per load and the number of rejected loads, an estimation of $98,450 was found to be the cost value of freight from rejected loads in 2018 for OSS participants.

3.17. Income statement

Quantitative information was gathered from the USDA 2018 State Agricultural Overview of Texas, from OSS interview participants, and from the OTSC Tonnage Reporting Systems to model the estimated total economic value of the OSS in 2018. The income statement displaying the comparison of the cost and benefit specific value measures can be observed in Table 8. There was not enough completed data from 2010 to provide an objective total economic value comparison between 2010 and 2018, but there was enough completed data from 2010 to provide an objective comparison in specific cost and benefit value measures such as sampling and testing costs, and premium prices received.

Revenue was calculated as follows:

- Maize sales by OSS participants were calculated using 3,000,000 bushels times the average price of $3.75 per bushel.
- Maize insurance payments were calculated using an estimate value of policy per farm of $220,000 with 16% estimated damage of 2,779,096 bushes of contaminated maize handled by 26 farms receiving indemnification.
- The estimated premiums were $1,012,000 based on 5,060,000 bushels receiving an average $0.20 per bushel.

Table 5
Example 1 of a discount schedule posted by a One Sample Strategy participant in 2018.

2018 Aflatoxin Discount Schedule Example 1	
0–20 μg/kg	$0
21–100 μg/kg	$0.10
101–300 μg/kg	$0.20

Aflatoxin over 300 μg/kg will not be accepted.

Table 6
Example 2 of a discount schedule posted by a One Sample Strategy participant in 2018.

2018 Aflatoxin Discount Schedule Example 2	
0–20 μg/kg	$0
21–50 μg/kg	$0.25
51–300 μg/kg	$0.45

Aflatoxin over 300 μg/kg will not be accepted.

Table 7
Example 3 of a discount schedule posted by a One Sample Strategy participant in 2018.

2018 Aflatoxin Discount Schedule Example 3	
0–20 μg/kg	$0
21–100 μg/kg	$0.50
101–200 μg/kg	$0.75
201–300 μg/kg	$1.00

Aflatoxin over 300 μg/kg will not be accepted.

Table 8
2018 one sample strategy aflatoxin income statement.

Revenue:		Value In USD
	Maize Sales	$69,235,560
	Crop Insurance Payments	$5,661,121
	Premiums	$1,012,000
	Resolving of Testing Conflicts (savings)	$9,844,959
	Aflatoxin Testing Kit Profit	$9,246
	Total Benefits:	**$16,527,326**
	Gross Profit:	**$85,762,887**
Expenses:		
	Inspection Fees	$5,060
	Aflatoxin Discounts	$1,462,499
	Test Startup Costs	$80,800
	Sampling and Testing Costs	$298,738
	Blending Costs	$9,600
	Rejected Loads Freight Costs	$98,450
	Total Expenses:	**$1,955,147**
Net Operating Income:		**$83,807,740**
Estimated Total Economic Value:		**$14,572,180**

Sources: USDA 2018 State Agriculture Overview: Texas, One Sample Strategy Participant Interviews, OTSC Tonnage Reporting Data

- Revenue ($9,844,959) from resolving conflicts based on $583 per load time 16,887 loads reported to have benefited from the OSS program.
- The testing profit was calculated using $1.69 estimate profit per analysis times 5,471 tests performed at a fee.

The Expenses were calculated as follows:

- Total inspection fees payed to OTSC were $5060 based on $0.19 per ton for 26,632 tons.
- Aflatoxin discounts were based on the difference discount schedules based on aflatoxin contamination time and the percent of crops in the contamination categories. Startup costs were $80,000, sampling and testing costs of $298,783 based on 17,511 loads at $17.06 per test.
- Blending costs based on number of loads tested in conformance with the firm's blending plan.
- Loss associated with freight of rejected loads ($98,640) was calculated using an estimate of $583 additional freight cost for 16,887 with 1% of loads rejected or a total of 169 loads for participants in the OSS program.

The estimated total economic value of participants in OSS was calculated at $14,572,180 by subtracting the total expenses from the gross profit. This added value of over $14 million only extends to the OSS participants in 2018.

4. Discussion

To date, the OSS has not expanded beyond Texas. Currently, only Texas and Oklahoma have promulgated rules for aflatoxin. However, the RMA has not restricted the adoption of the OSS program by other states. Rather, the infrequent occurrence of aflatoxin in the US maize-belt and limited engagement of states and universities in assisting the grain and feed industry manage aflatoxin risk likely contributes to limited adoption of OSS and co-regulation. There are many cost drivers and benefits with OSS in Texas that could be realized in the US and abroad. For example, discount schedules for aflatoxin are published by most grain elevators, multi-peril crop insurance includes quality indemnification for mycotoxin contamination, and mycotoxin testing accuracy by firms through the adoption of a quality systems approach using USDA approved sampling, grinding, and testing protocol and access to reference material and proficiency testing programs to ensure testing accuracy are available to all, though adopted by few. Economic drivers and past economic loss estimates, while exaggerated [13], appear sufficient to warrant adoption of co-regulation beyond Texas. OTSC is working with developing countries through the Aflatoxin Proficiency Testing and Control in Africa (APTECA) program and collaborations with international organizations including those in Eastern and Southern Africa, the World Food Program, faculty in Kenya, Malawi, and Rwanda and trade associations [26–28].

5. Conclusion

5.1. Implications

We have concluded that there is an economic benefit of co-regulation to manage aflatoxin risk. In our economic analysis of comparing the cost and benefit specific value measures before and after the OSS implementation, it was concluded that the estimated total economic value of OSS in 2018 was $14,572,180. The quantitative model incorporated the findings of the specific cost and benefit value measures from 27 companies representing 31% of the grain elevators in counties with aflatoxin exceeding the 20 μg/kg regulatory limit in Texas.

Specific conclusions of the OSS that are encompassed in the total economic value include: it has validated producers ability to receive crop insurance indemnification payments; it has resulted in a savings value for participants from the resolution of testing conflicts, despite buyers frequently retesting loads; it has improved marketing maize at a higher price; it has installed profitable new business enterprises for its participants; it has, on average, lowered the cost of testing; it has created an average cost of $7,345 for participants to get the necessary equipment to join; and it has formed a blending cost for participants.

Overall, the confidence, certainty, credibility, accuracy, assurance, trust, and peace of mind that OSSS participants discussed having has been measured as a valuable and tangible asset. In other words, the increased conformance to official methods has increased confidence, resulting in increased economic benefits. We have concluded that successfully implementing the five pillars of co-regulated mycotoxin risk management in Texas has created a more connected and transparent marketplace; and by implementing the standards, policies, and practices as outlined above, generated an economic benefit for participants of the OSS.

5.2. Future work

One key to a more connected and transparent marketplace through the OSS is broad and unending communication. This research revealed that many buyers are retesting grain that already has been confirmed with the OSS seal. This is in part due to only an estimated 30% of buyers understanding what having the OSS seal means. Therefore, the weight of the economic benefit of the OSS to participants is limited to the buyer's level of understanding of risk.

Additional work includes performing the same type of analysis examining the economic impact of the OSS on managing fumonisin risk in 2017. FFCS now distributes reference material to all grain elevators testing for aflatoxin and fumonisin and all industry personnel receives technical support by FFCS field investigators to help firms improve sampling, sample preparation and testing accuracy for aflatoxin and fumonisin.

Author contribution statement

Kelsey Postma: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Timothy J. Herrman; Mary Sasser: Conceived and designed the experiments; Performed the experiments; Wrote the paper.

Data availability statement

Data included in article/supplementary material/referenced in article.

Additional information

No additional information is available for this paper.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Timothy Herrman, Kelsey Postma, and Mary Sasser are employed, or have been employed, by the Office of the Texas State Chemist, which oversaw the implementation and administration of the Feed and Fertilizer Control Service's One Sample Strategy, the primary subject of this paper. As authors, we are reporting on our work regulating aflatoxin contamination. This statement serves as a disclosure of any possible conflicts of interests resulting from such employment.

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Appendix

Notes

1. On April 9th, 2019 Kelsey Postma interviewed Dr. D.J. Welsch to discuss the One Sample Strategy. Dr. Welsch is a professor of Agricultural Economics that specializes in Grain Marketing.

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