# The impact of chronic wasting disease on the geographic distribution of the US captive cervid industry

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## Introduction

In 2007 there were approximately 7,600 captive cervid (e.g. elk and deer) operations in the US with a total inventory of 338,000 animals (USDA NASS 2007). Production occurs in all regions of the country, but is concentrated in Texas, Pennsylvania, and the north-central part of the US. Texas alone has more than 1,600 deer farms and 350 elk farms (USDA NASS 2007). Production systems are diverse and many operations market multiple products. Breeding operations focus on producing breeding stock that is marketed to trophy hunting preserves and other breeding stock producers. Other operations focus on venison production and will buy weaned stock and sell finished animals. Finally, some producers focus on velvet production or scent products (Burden 2012). Anderson et al. (2007) provide estimates of the size and composition of an average cervid farm in the United States that are useful in describing the industry. A typical operation has 82 animals and is split roughly evenly between females, males, and fawns or calves. Farm size appears to be related to the product being marketed with hunting preserves requiring more acreage than operations strictly intended for breeding. Breeding operations were 25 acres on average, operations that exclusively offered hunting had an average area of approximately 1,000 acres, and operations that featured hunting and breeding had an average area of 1,700 acres.

The industry is difficult to characterize from an economic standpoint due to the diversity of products and variety of operation types. Products are not standardized as in other livestock sectors, and little price or production data is available. The North American Elk Breeders Association (NAEBA) has estimated that captive elk are worth an average of $2,000 and some animals may be worth as much as $5,000. The North American Deer Farmer's Association (NADeFA) has estimated that typical captive deer values range from $375 for fallow deer to $4,000 for elk. Additionally, NADeFA estimated the total value of its members' herds to be $111.6 million (Seidl et al. 2003). There have also been several attempts to characterize the broader regional and national economic impacts of the industry. Eades (undated) used an IMPLAN model of the West Virginia economy to estimate the contribution of the captive cervid industry to the state's economic activity. He reported that the 37 farms in the state at that time contributed $784,000 to annual personal income and supported 66 jobs in the state. A more comprehensive study by Anderson et al. (2007) used a similar model to estimate the impacts of the entire US captive cervid industry on the national economy. They estimated that the industry (excluding spending by hunters) contributes almost $1.3 billion to US GDP.

Chronic wasting disease (CWD) may be a substantial threat to the continued economic viability of the captive cervid industry in the US. CWD is a transmissible spongiform encephalopathy that affects deer and elk and is always fatal. The disease was first identified in captive mule deer in Colorado in 1967, and captive elk were first diagnosed in 1979 (Bies undated). The geographic distribution of CWD suggests that the transportation of live cervids played a role in the spread of the disease to new states (Bies undated), and the disease had been found in 22 states as of 2012 (Federal Register 2012). Miller et al. (1998) examined two outbreaks of CWD in captive

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elk to analyze the epidemiology of the disease in captive populations. Results of the study suggested that the disease had an incubation period of 18-36 months in elk and that lateral transmission (i.e. not mother to offspring) was the primary method of transmission. Miller and Conner (2005) found that the prevalence of CWD was more common in males than females, and the risk of developing the disease was greatest as the animals reached sexual maturity. These epidemiological characteristics of CWD may identify contributing factors to the spread of the disease. In particular, transportation of males at or near the age of sexual maturity to hunting preserves may be a common cause of disease spread to naïve wild populations due to the long incubation period, relatively greater prevalence of the disease in males, and risk of lateral disease transmission.

CWD has a variety of potential negative economic consequences, and much previous research has focused on the disease's impact on hunting and the economic sectors that benefit from hunting (e.g. Bishop 2004, Heberlein 2004). However, the captive cervid industry may also be harmed by direct and indirect factors related to CWD. Impacts from CWD can be realized directly as a result of animal mortality and morbidity. Alternatively, indirect impacts arise as a result of CWD regulations that may require depopulation or quarantine and that reduce marketing opportunities. Collectively, the potential for direct losses and the impact of CWD-related regulations may create a disincentive for captive cervid production which has affected the size and distribution of the industry.

Animal mortality, the most obvious threat to the producers, has had relatively little impact because CWD had only been found in 39 captive elk herds and 15 captive deer herds as of 2012 (Federal Register 2012). Despite the small number of verified cases of CWD, the programs in place for its detection and management are thorough, and the consequences of a positive test can be severe for cervid producers. The federal program for managing CWD names immunohistochemistry (IHC) tests, enzyme-linked immunosorbent assay (ELISA), and Western blot tests as the official assessments of CWD presence in an animal. All suspect positive tests are subject to confirmatory testing by the National Veterinary Services Laboratory (NVSL). In the case of a positive test, whole-herd depopulation is the preferred solution, although long-term quarantine of the herd can be an accepted alternative. Quarantining the herd may include the euthanasia of selected animals followed by additional testing.

Since in 2002, federal regulations have required that animals transported interstate be certified CWD-negative as part of the federal CWD Herd Certification Program, which is a cooperative effort between APHIS, state animal health and wildlife agencies, and cervid owners (USDA 2002, Federal Register 2012). It takes five years for a CWD-free herd to become certified CWD-negative. If a producer loses certified status, they are prohibited from transporting animals interstate and may lose access to important markets. Since the Herd Certification Program was implemented, there have been no substantial changes in federal regulations (CWD Alliance 2015). In addition to the federal rules, some states have more strict regulations that prohibit imports from CWD-endemic areas, and fifteen states have banned all cervid imports (Cosgrove 2012). Access to international markets has also been effected (Seidl and Koontz, 2004). For example, after CWD was detected in captive elk in Alberta in 2002, the value of velvet exports fell by more than one-third (Arnot et al. 2009, Alberta Agriculture 2006).

CWD may have also had a negative impact on consumer demand. Despite a lack of evidence that the disease is transmissible to humans, anecdotal evidence suggests some consumers will avoid venison and other cervid-derived products once aware of CWD. For example, Wisconsin experienced the largest decline in deer license sales in the 20$^{th}$ century after CWD was detected in the state (Heberlein 2004). If hunters respond to CWD, it is reasonable to expect consumers to respond in a similar fashion.

Although the economic impacts of CWD are easy to characterize in a qualitative sense, precise quantitative estimation is difficult for a number of reasons. As stated previously, the products of the captive cervid industry are not standardized and, in any case, little data on product prices is available. This makes it difficult to accurately value animal mortality or any change in industry size that results from CWD. Furthermore, little work has been done to quantify relationships between price and quantity supplied by the domestic industry or quantity of products demanded by US consumers. Without an appropriate model of supply and demand in the industry, it is impossible to correctly model transport and export restriction or changes in consumer demand that result from CWD. Finally, the fact that much of the testing, surveillance, regulatory, and management efforts associated with the disease occur at the state level makes it difficult to account for the costs associated with these activities.

Despite these problems, there have been several previous studies that investigated the economics of CWD in the captive cervid industry. In their mostly qualitative assessment of the economics of CWD in Colorado, Seidl and Koontz (2004) note that preliminary findings indicate that the direct economic impact of CWD in the state is in the tens of millions of dollars. Bishop (2004) presented an analysis that focused on the impact of CWD on hunters in Wisconsin, but it was also reported that management of CWD cost the Wisconsin Department of Natural Resources $14.7 million in the 2002-2003 fiscal year. Unfortunately, it is unknown what percentage of this is attributable to the captive cervid industry.

In addition to US studies, Petigara et al. (2011) presents an economic assessment of CWD in Canada, but only multipliers of potential impacts are provided. Multipliers are a measure of how a certain decline in one industry affects total economic activity within a region. The study did not estimate the actual decline in the industry in Canada that resulted from CWD, and no estimate of the economic impact of the disease was provided. Finally, Arnot et al. (2009) assessed the economic viability of more extensive fencing on cervid farms and indemnity payments for herd depopulation in Alberta. It was estimated that proper fencing on all farms in Alberta would cost US$12 million to $17 million and is unlikely to be a viable option given the small profit margins of most cervid farms. The study also concluded that Canadian federal government's liability for indemnity payments could range from $47 million to $341 million if all herds in Alberta were depopulated.

Our objective was to measure the impact of CWD and CWD-related regulations on the size and geographic distribution of the US captive cervid industry. Understanding these types of impacts from CWD is important for several reasons. First, agencies directly involved in testing, surveillance, or other field activities may benefit because the intensity and scale of their activities can be planned more appropriately when the impacts of disease and disease-related regulations are better understood. Second, an understanding of some of the current impacts of the disease establishes a baseline against which successful policies and management efforts can be measured. Finally, a substantial portion of the current impacts of CWD may not result from the threat of the disease itself, but instead from disincentives created by regulations. If this is true, a better understanding of those impacts could motivate and guide the implementation of regulations that better balance tradeoffs between protecting wild cervid populations and protecting producers.

## Methods

The USDA Census of Agriculture provides the only publicly available data on the size and distribution of the captive cervid industry. The two most recent censuses (2002 and 2007) at the time of our analysis were the only censuses that collected information on deer and elk farming. We examined the impact of CWD on the geographic distribution of the captive cervid industry in terms of two state-level measures: inventory (Figures 1 and 2) and the number of operations

with inventory (Figures 3 and 4). Inventory reflects the total number of captive deer and elk as of the end of the year of the census. The number of operations with inventory was calculated by adding the number of operations with deer inventory and the number of operations with elk inventory. Thus, operations with both deer and elk inventory are counted twice. This is a reasonable approach because an operation that produces both deer and elk may change production practices differently across the two groups in response to the threat of CWD. Additionally, deer production is relatively more prevalent in the Southeast, while elk production is relatively more prevalent in West. These differences indicate that there may be little double counting of operations that have both deer and elk in those regions.

Figure 1. Distribution of CWD (gray areas) as of 2002 and 2002 inventory (100's head)

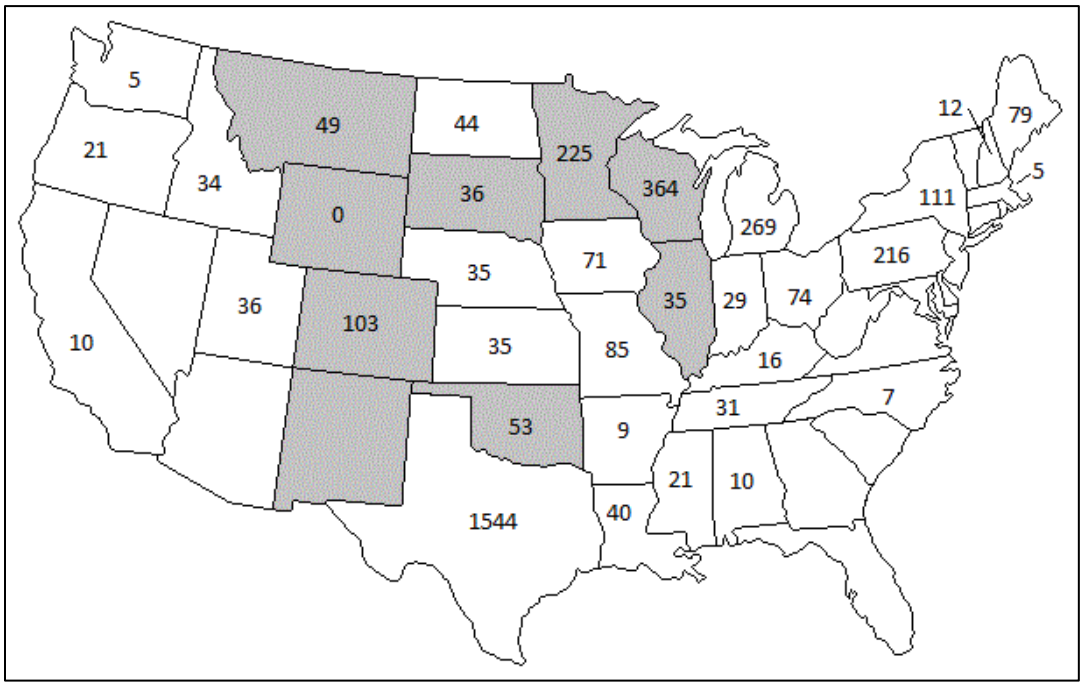


Figure 2. Distribution of CWD (gray areas) as of 2007 and percent changes in inventory between 2002 and 2007

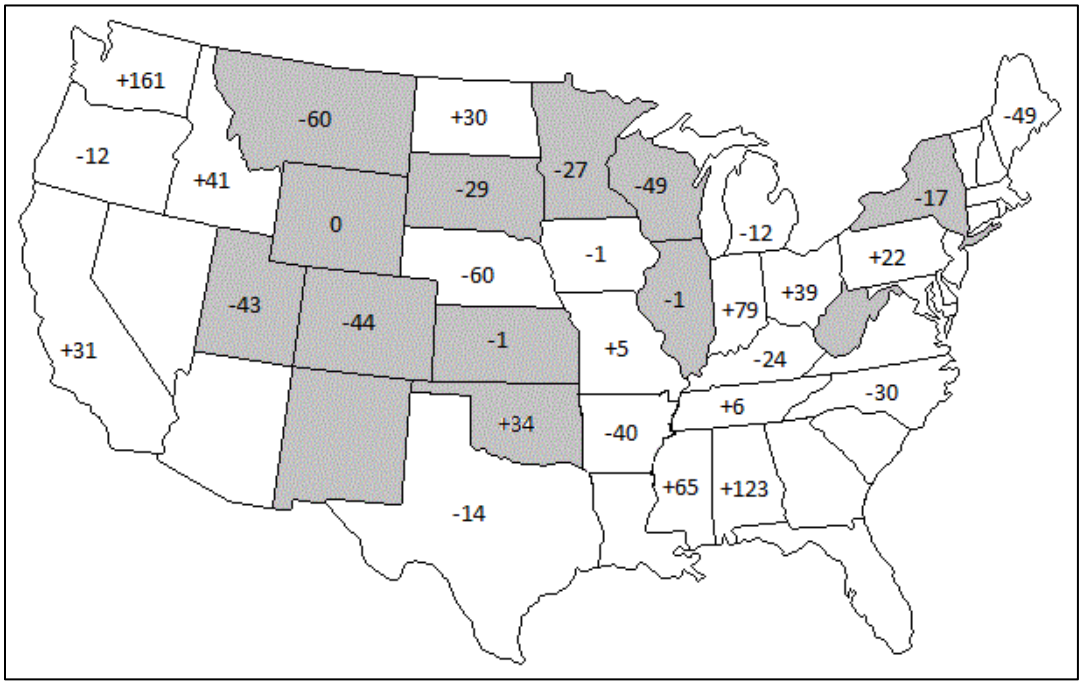



Figure 3. Distribution of CWD (gray areas) as of 2002 and the number of operations

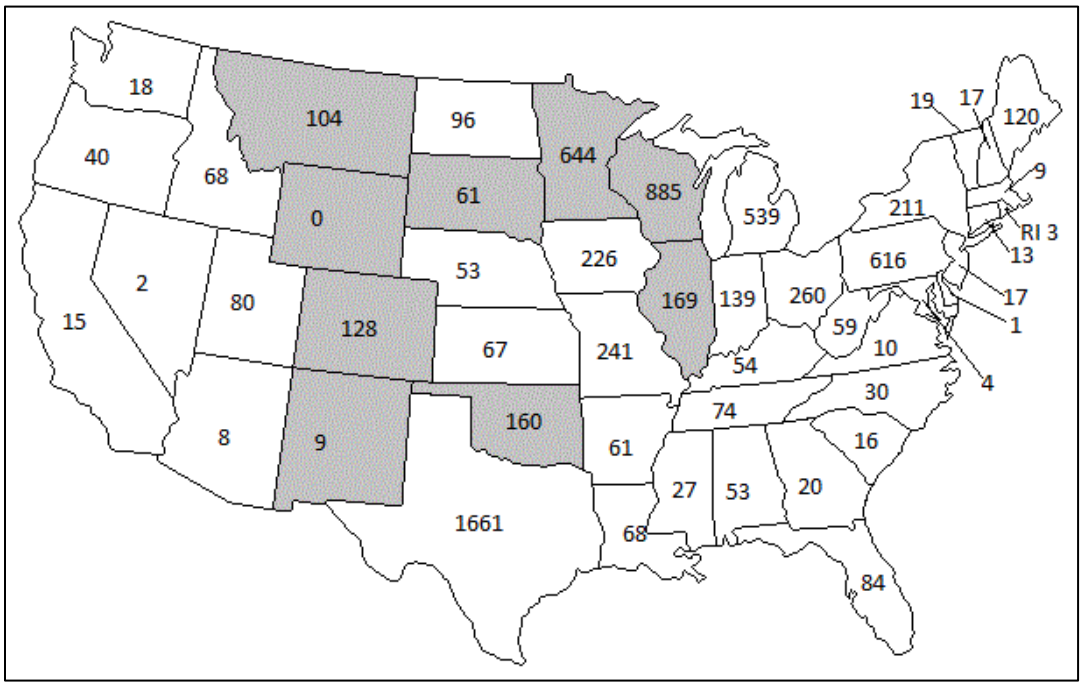
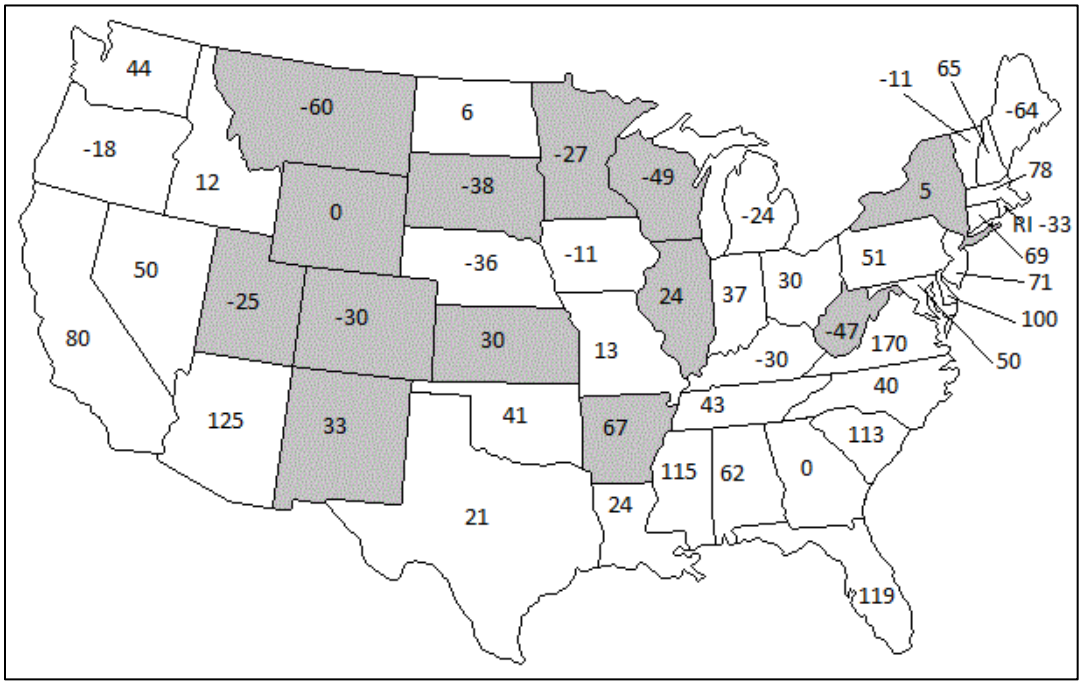


Figure 4. Distribution of CWD as of 2007 (gray areas) and percent change in operations between 2002 and 2007




For states in which there were a small number of producers, inventory data may be withheld by NASS to avoid disclosing information that could be traced back to individual producers. In Figures 1 and 2, states without numbers reflect a state for which deer and/or elk inventories were withheld. Wyoming has a ban on cervid production and thus has a zero in all maps. Figures 2 and 4 indicate that inventories and the number of operations experienced broadly similar changes in many states between 2002 and 2007. This implies that changes were predominately caused by producers leaving the industry, rather than existing producers reducing the sizes of their herds. Furthermore, many of the states that had CWD before 2002 experience a continued declined after 2002. We suspect that there are several reasons for the continued decline. First, the industry in those states may still be adjusting to higher production costs and decreased marketing opportunities driven by the threat of CWD and state-level regulations. Second, the federal-level rules that were implemented in 2002 probably increased the disincentive to produce deer or elk and contributed to the decline experienced after 2002. There are also several states within the CWD and CWD-free regions that experienced industry changes that were opposite of the general trends in those regions. We are unable to offer any explanation for these anomalies, except that producers in CWD-free states may be responding to experiences in surrounding states.

We estimated the following linear model to further explore the impact of CWD:

$$\Delta s_{ij} = \beta_0 + \beta_1 size_{ij} + \beta_2 \Delta gdp_i + \beta_3 \Delta inc_i + \beta_4 \Delta ctl_i + \beta_5 \Delta shp_i + \beta_6 \Delta got_i + \beta_7 cwd_i + e_i \ .$$

$\Delta s_{ij}$ is the percent change in the size of the captive cervid industry from 2002 to 2007 in state $i$ based on data series $j$ (inventory or operations with inventory); $size_{ij}$ is the size of the captive cervid industry in 2002 based on data series $j$; $\Delta gdp_i$ is the percentage change in state gross domestic product; $\Delta inc_i$ is a measure of the change in farm income; $\Delta ctle_i$, $\Delta shp_i$, and $\Delta got_i$ are the percentage changes in cattle, sheep, and goat inventories in the state, and $cwd_i$ is a

dummy variable that indicates the presence of CWD in the state by 2007 (Figure 2 and Figure 4), and $e_i$ is a zero-mean, normally distributed disturbance.

The size of the captive cervid industry in each state was included in the model because the dependent variable is measured in percentage terms. It was hypothesized that state GDP may have affected the size of the captive cervid industry because it may be indicative of local and regional marketing opportunities. State-wide farm income is also included because it might serve as a proxy for underlying trends in agricultural production that are also reflected by the size and distribution of the captive cervid industry. Inventories of other livestock animals are controlled for in the model because in some cases it may be possible to shift production between conventional livestock and captive cervids. Goat and sheep are raised on small farms with specialized markets much like in the cervid industry and it may be relatively easy for cervid farmers in some regions to shift production to these other products. We also included cattle as a control despite several notable differences between cervid production and cattle production. Cattle need more acreage, require more labor-intensive work, and have a much different product market. Despite these differences it may be possible for very large cervid operations (such as those that offer both breeding and hunting) to make the transition into cattle production. If the relative rewards of producing conventional livestock change, the inventories of those animals and the size of the captive cervid industry may change as well.

The presence of CWD is suspected to cause changes in the distribution and size of the captive cervid industry for three reasons. First, the presence of CWD increases relative production costs because it requires producers to take more extensive precautions to prevent contact between wild and domestic cervids. Second, the presence of CWD is a substantial risk for current or prospective cervid producers. If an animal in a producer's herd tests positive for CWD, that producer's marketing opportunities are severely limited. Finally, even if a producer's herd is CWD-free, marketing opportunities may be limited if CWD is known to exist in the area.

## Results

Regression A was specified with the percent change in inventory as the dependent variable. Other than the inventory in 2002 (*size*), the only explanatory variable that had a significant coefficient was *cwd*. The sign and magnitude of the coefficient on *cwd* implies that the presence of CWD within a state by 2007 was associated with a 54 percentage point decrease in inventory from 2002 to 2007, relative to a state that did not have CWD.

Results in regression B, which was specified with the percent change in the number of operations with inventory as the dependent variable, were broadly similar. Importantly, the coefficient on *cwd* was significant and its magnitude was very similar to the estimate from regression A. This similarity reinforces the observation that the decline in industry size is being driven by producers exiting the industry rather than by broad reductions in individual herds. The similarity of the *cwd* coefficients may also imply something about the size of the producers that leave the industry. For example, if only the smallest or largest producers were leaving, a substantial difference in the changes in inventories and number of operations would be expected. The similarity implies that either a representative cross-section of producers were leaving or that medium-sized producers were leaving the industry in relatively larger numbers. If this actually occurred, a possible explanation is that small producers face less risk because they have other revenue sources and that large producers are more reluctant to substitute to other products.

Table 1. Results from regression A with percent change in inventory as the dependent variable and regression B with percent change in the number of operations as the dependent variable

| | Regression A | | Regression B | |
|---|---|---|---|---|
| | $R^2 = .38$ | Sample Size: 30 | $R^2 = .42$ | Sample Size: 49 |
| coefficient | estimate | SE | estimate | SE |
| intercept | 0.79 | 27.87 | 8.37 | 25.33 |
| $size$ | -0.00* | 0.00 | 0.03** | 0.01 |
| $\Delta gdp$ | 0.68 | 0.60 | 0.90* | 0.53 |
| $\Delta inc$ | 0.30 | 0.37 | 0.27 | 0.18 |
| $\Delta cattle$ | -2.75 | 2.22 | -1.20 | 1.13 |
| $\Delta sheep$ | -0.57 | 0.69 | 0.28 | 0.28 |
| $\Delta goats$ | -0.29 | 0.25 | -0.32** | 0.14 |
| $cwd$ | -54.10** | 23.49 | -45.92*** | 14.15 |

note: ***, **, and * indicate significance at 1%, 5% and 10% levels, respectively
note: reported standard errors based on a heteroskedasticy-consistent covariance matrix

Three other coefficients were significant in regression B: *size,* Δ*gdp,* and Δ*goats.* In regression A, the estimates of these coefficients were similar, although only *size* was significant. We suspect that lack of many significant coefficients in regression A resulted from the relatively small sample size. The estimate of the coefficient on *size* was near zero in both regressions, indicating the size of the industry in 2002 had little impact on the change over the following five years. The estimated coefficient on Δ*gdp* was positive in both regressions, indicating that increasing industry size was associated with increasing income. This is an unsurprising result given the products in question. Hunts for trophy deer and elk are typically quite expensive, and much of the meat products are sold to high-end restaurants. Finally, the coefficient on Δ*goats* was also significant and negative in regression B, implying that perhaps there is some substitutability between goat and cervid production.

The coefficients on changes in farm income and changes in cattle and sheep inventories were not significant in either regression. Thus, it appears that changes in cervid industry are not associated with changes in farm income or any underlying trends in the agricultural sector that income changes may reflect. The lack of a relationship between cattle and sheep inventories and the cervid industry indicates that there is little substitution among these animals by producers.

## Conclusion

Our analysis is an important contribution to the understanding of the impacts of CWD because it provides a quantitative assessment of how the disease may be affecting the distribution and size of the captive cervid industry in the US. The regression results suggest that the presence of CWD in a state by 2007 was associated with an approximately negative fifty percentage point change in industry size within those states. The average percent change in inventory between 2002 and 2007 in CWD-free states was about +22%. Thus, if we assume inventories in states with CWD would have grown at a similar rate, our results imply inventories in the CWD states instead contracted by about 28%. Based on the data presented in Figures 1 and 2, if inventories in all states grew at 22%, total inventory in the US would have been about 17.4% higher. This represents a substantial negative impact from CWD in an industry that many analyses and the market share of imports suggest has considerable growth potential in the US (Burden 2012).

Although a lack of data prevents precise monetization of this impact, we can base a rough calculation on the Anderson et al. (2007) estimate of a $1.3 billion contribution to US GDP annually. Assuming a linear relationship between this contribution and inventory, we estimate the industry's annual contribution to GDP would have been about $230 million higher without CWD-related impacts.

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