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**The Western Economics Forum**
A peer-reviewed publication from the Western Agricultural Economics Association

**Purpose**
One of the consequences of regional associations nationalizing their journals is that professional agricultural economists in each region have lost one of their best forums for exchanging ideas unique to their area of the country. The purpose of this publication is to provide a forum for western issues.

**Audience**
The target audience is professional agricultural economists with a Masters degree, Ph.D. or equivalent understanding of the field that are working on agricultural and resource economic, business or policy issues in the West.

**Subject**
This publication is specifically targeted at informing professionals in the West about issues, methods, data, or other content addressing the following objectives:
- Summarize knowledge about issues of interest to western professionals
- To convey ideas and analysis techniques to non-academic, professional economists working on agricultural or resource issues
- To demonstrate methods and applications that can be adapted across fields in economics
- To facilitate open debate on western issues

**Structure and Distribution**
The *Western Economics Forum* is a peer reviewed publication. It usually contains three to five articles per issue, with approximately 2,500 words each (maximum 3,000), and as much diversity as possible across the following areas:
- Farm/ranch management and production
- Marketing and agribusiness
- Natural resources and the environment
- Institutions and policy
- Regional and community development

There are two issues of the *Western Economics Forum* per year (Spring and Fall).

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Note from the editor

Readers I am pleased to introduce the following three articles:

*What do buyers value when making herd sire purchases? An analysis of the premiums paid for genetic and phenotypic differences at a bull consignment auction* by Jacob N. Brimlow and Stephen P. Doyle. The authors use a sample of western livestock data to demonstrate the genetic attributes that determine sire qualities and performance.

*The impact of chronic wasting disease on the geographic distribution of the US captive cervid industry* by Aaron Anderson and William Haden Chomphosy. This article presents the effects that CWD has on the commercial deer and elk industry.

*Understanding Landowner Decision Drivers Regarding Conservation through Research* by Cheryl J. Wachenheim and William C. Lesch. These researchers provide a framework for pursuing and understanding landowners' land use decisions as pertinent to conservation.

Regards
Don McLeod, editor
Western Economics Forum
What do buyers value when making herd sire purchases? An analysis of the premiums paid for genetic and phenotypic differences at a bull consignment auction

Jacob N. Brimlow and Stephen P. Doyle

Introduction
Understanding how buyers value traits and performance measures when making sire selections is important for bull sale auctions, seedstock producers, extension agents, and other educators. Recognizing the challenge commercial bull buyers face sorting through available genetic and phenotypic information, many small- and mid-sized bull sale auctions attempt to differentiate their sales by consolidating and summarizing relevant information. Because computing summary scores and measuring bull traits is costly, auction owners and managers need to know what traits and information are most valuable to buyers to make their marketing efforts cost effective. Further, the profitability of seedstock producers depends on their ability to supply bulls that meet the needs of the commercial beef cattle industry, and the relative value placed on different traits at auction provides insight into what traits are most desired by buyers. As market conditions change and new measures of performance and performance predictions become available, the prices buyers are willing to pay for traits and performance indicators may change.

This paper uses data from a mid-size Nevada bull test station and sale to estimate how breeding bull buyers value a variety of sire selection criteria made available through a sale catalog and supplemental worksheet. Previous studies have taken similar approaches to analyzing bull sale prices, including Dhuyvetter et al., 1996, Chvosta et al., 2001, Jones et al., 2008, Vanek et al., 2008, McDonald et al., 2010, and Bekkerman et al., 2013, but none place both genetic and phenotypic measures of carcass and growth characteristics in models that include feed efficiency (measured using Residual Feed Intake (RFI)) and summary scores provided by the bull auction. This study provides further evidence of what bull buyer’s value in making sire purchasing decisions and provides new evidence by including genetic measures of carcass traits in a model that includes feed efficiency, phenotypic carcass traits, and seller provided conformation summary values.

Methods

**Hedonic Pricing Model**
We use hedonic regression analysis to estimate the implicit prices paid by buyers at auction for perceived improvements in bull attributes, including lower RFI scores. Modeling a bull sale using the hedonic regression framework assumes that a bull’s sale price is based on buyers’ valuation of its attributes (Ladd and Martin, 1976). The hedonic model can be parameterized so regression estimates represent the present value of the expected future returns to attributes that provide value over time (Wallburger, 2002), a characteristic useful for breeding bulls, whose values are determined largely by the performance of their progeny.

Following previous studies (Dhuyvetter et al., 1996, Chvosta et al., 2001, Jones et al., 2008, Vanek et al., 2008, McDonald et al., 2010, and Bekkerman et al., 2013), we employ a semi-log...
linear hedonic regression model, using a log transformation of Sale Price to adjust for the characteristic positive skewness of price data.\(^2\) Our semi-log linear hedonic regression model is

\[
\ln(\text{Sale Price})_i = \beta_0 + \beta_1 (\text{Total Conformation Score}_i) + \beta_2 (\text{Muscle Structure Score}_i) + \ldots + \beta_n (\text{Year}_2012) + \varepsilon_i,
\]

where \(i\) indexes individual sale records (bulls), \(n\) is the number of independent variables (22), the \(\beta\)'s are the parameters to be estimated and the marginal effect of a change in each variable on \(\ln(\text{Sale Price})\), and \(\varepsilon_i\) is an error term assumed to have constant variance.

**Data**

Data included 426 complete records from bulls sold at a mid-sized consignment auction yard in Nevada in 2007 (\(n=138\)), 2008 (\(n=94\)), 2009 (\(n=78\)), and 2012 (\(n=117\)). Data from 2010 and 2011 were not available. Table 1 lists the explanatory variables (except dummy variables for breed and year) used in the hedonic regressions, including a definition and expected sign of the impact of an increase in each variable on bull sale price at auction.

Gelbvieh, Charolais, and Balancer bull data were deleted because of small samples, and two price outliers (Sale Price > $9000) were removed.\(^3\) Seller provided summary scores for fertility, weaning, test gain, and ultrasound measurements were not included in the analysis because of collinearity with the EPD’s and other genetic measures. As in Vanek et al. (2008), we addressed collinearity between birth, weaning, and yearling EPD’s by replacing weaning and yearling EPD’s with a birth-to-yearling gain measure (\(BYGE\)) calculated by subtracting each bull’s birth EPD from its yearling EPD.

We did not include sale order in our regressions because of its collinearity with other measures of quality. At many bull consignment sales, higher quality bulls are auctioned first. As seen in Dhuyvetter et. al. (1996), Jones et al. (2008) and Vanek et al. (2008), this can lead to a statistically significant relationship between sale order and price that may hold even after controlling for quality characteristics, introducing problematic collinearity that is more pronounced for estimations with relatively low sample sizes. A regression of SaleOrder on the other explanatory variables used in our regression yielded a relatively high adjusted R-square of 0.68, and we chose to omit it from our regressions.

Summary statistics are reported in Table 2.

---

\(^2\) Even after the log transformation, our price variable failed tests for normality (negative skewness). This issue was recognized by McDonald et. al. (2010), and Bekkerman et al. (2013) used a quantile regression approach and found statistically significant differences in estimates of the marginal effects of bull characteristics on price across price quantiles. Because of the sample size and focus of the study, we continue with a linear hedonic regression model, recognizing that our estimates may not capture variation in marginal impacts across different levels of bull prices.

\(^3\) The residuals (scatter plots and Cook’s D statistic) from regressions on an initial data set of 429 observations were analyzed to identify records with large amounts of leverage and/or influence, and 3 records containing data entry errors were identified and dropped, leaving a final set of 426 records.
<table>
<thead>
<tr>
<th>Western Economics Forum, Fall 2014</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Table 1: Comparison of Independent Variables Used in Previous Evaluations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Variable</td>
</tr>
<tr>
<td>---------------------------------------------</td>
</tr>
<tr>
<td>Independent variable</td>
</tr>
<tr>
<td>Earnings</td>
</tr>
<tr>
<td>Education</td>
</tr>
<tr>
<td>Experience</td>
</tr>
<tr>
<td>Age</td>
</tr>
<tr>
<td>Gender</td>
</tr>
<tr>
<td>Race</td>
</tr>
<tr>
<td>Income</td>
</tr>
<tr>
<td>Housing Status</td>
</tr>
<tr>
<td>Employment Status</td>
</tr>
<tr>
<td>Health Status</td>
</tr>
<tr>
<td>Education Level</td>
</tr>
<tr>
<td>Income Level</td>
</tr>
<tr>
<td>Housing Status Level</td>
</tr>
<tr>
<td>Employment Status Level</td>
</tr>
<tr>
<td>Health Status Level</td>
</tr>
<tr>
<td>Education Level Level</td>
</tr>
</tbody>
</table>

Note: The table above compares variables used in previous evaluations with those used in the current evaluation.
Table 2: Summary Statistics

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean</th>
<th>Std. Dev.</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Price</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Price</td>
<td>2717.02</td>
<td>978.86</td>
<td>1200</td>
<td>6500</td>
</tr>
<tr>
<td>Natural Log of Price</td>
<td>7.85</td>
<td>0.34</td>
<td>7.09</td>
<td>8.78</td>
</tr>
<tr>
<td>Seller Provided Summary Scores</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Conformation Score</td>
<td>12.61</td>
<td>1.64</td>
<td>7.55</td>
<td>17.49</td>
</tr>
<tr>
<td>Muscle Structure Score</td>
<td>7.96</td>
<td>1.78</td>
<td>1.5</td>
<td>13.5</td>
</tr>
<tr>
<td>Expected Progeny Differences</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Birth weight EPD</td>
<td>2.31</td>
<td>1.86</td>
<td>-4.5</td>
<td>7.3</td>
</tr>
<tr>
<td>Milk EPD</td>
<td>20.42</td>
<td>5.16</td>
<td>7</td>
<td>38</td>
</tr>
<tr>
<td>Birth to Yearling Gain EPD</td>
<td>76.29</td>
<td>14.91</td>
<td>9.3</td>
<td>112.1</td>
</tr>
<tr>
<td>Ultrasound Intramusc. Fat EPD</td>
<td>0.17</td>
<td>0.21</td>
<td>-0.33</td>
<td>1.07</td>
</tr>
<tr>
<td>Ultrasound Ribeye Area EPD</td>
<td>0.22</td>
<td>0.21</td>
<td>-0.27</td>
<td>0.94</td>
</tr>
<tr>
<td>Ultrasound Rib Fat EPD</td>
<td>0.00</td>
<td>0.02</td>
<td>-0.049</td>
<td>0.062</td>
</tr>
<tr>
<td>Phenotypic Indicators</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Residual Feed Intake</td>
<td>-0.13</td>
<td>1.80</td>
<td>-7.74</td>
<td>5.77</td>
</tr>
<tr>
<td>Final Average Daily Gain</td>
<td>3.66</td>
<td>0.54</td>
<td>1.88</td>
<td>5.63</td>
</tr>
<tr>
<td>Ultrasound Marbling</td>
<td>4.47</td>
<td>1.27</td>
<td>1.74</td>
<td>8.51</td>
</tr>
<tr>
<td>Ultrasound Adjusted Ribeye Area</td>
<td>13.74</td>
<td>1.42</td>
<td>9.68</td>
<td>18.2</td>
</tr>
<tr>
<td>Ultrasound Back Fat</td>
<td>0.31</td>
<td>0.08</td>
<td>0.11</td>
<td>0.52</td>
</tr>
<tr>
<td>Birth Weight</td>
<td>81.71</td>
<td>9.07</td>
<td>50</td>
<td>110</td>
</tr>
<tr>
<td>205-day Adjusted Weight</td>
<td>673.31</td>
<td>71.06</td>
<td>430</td>
<td>861</td>
</tr>
<tr>
<td>Final Weight</td>
<td>1131.34</td>
<td>98.45</td>
<td>860</td>
<td>1410</td>
</tr>
<tr>
<td>Dummy Variables</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spring Born</td>
<td>0.39</td>
<td>0.49</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Red Angus</td>
<td>0.14</td>
<td>0.35</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Hereford</td>
<td>0.14</td>
<td>0.35</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Year_2008</td>
<td>0.22</td>
<td>0.42</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Year_2009</td>
<td>0.18</td>
<td>0.39</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Year_2012</td>
<td>0.27</td>
<td>0.45</td>
<td>0</td>
<td>1</td>
</tr>
</tbody>
</table>

Notes: n = 426
Results
Table 3 reports coefficient estimates, robust standard errors\(^4\) and statistical significance, and two interpretations of the estimated impact of each independent variable on bull sale price. The results of the regression largely conform to expectations, with statistically significant variables all having the expected signs. The R-square of 0.60 indicates the model has significant explanatory power.

In a semi-log linear hedonic regression model, the coefficient estimates can be interpreted as the \(\%\) change in Sale Price associated with a one-unit increase in each independent variable using

\[
\% \Delta y = 100 \cdot (e^{\beta_1} - 1),
\]

where \(y\) is the un-logged dependent variable (Sale Price) and \(\beta_1\) is the coefficient estimate being interpreted. For example, the coefficient estimate for FinalADG is 0.107, indicating that a one-unit increase in FinalADG is associated with an estimated \(100 \cdot (e^{0.107} - 1) = 11\%\) change in Sale Price, on average, holding all other variables in the analysis constant.

Table 3 also reports estimates as changes in price from the mean. For example, a one unit increase in BirthWt (a one pound increase) is associated with a \$16 decrease in price, on average, holding all other variables in the analysis constant.

As expected, our results indicate that buyers value both genetic and phenotypic indicators of low birth weight, high finishing weights, rapid growth, and favorable carcass characteristics. EPD’s for birth weight, birth to yearling gain, and rib eye area were all statistically significantly related to price. Ultrasound measurements indicating bulls with larger rib eye areas and increased marbling were positively related to price. Variables measuring weight and average daily gain were all statistically significant and had the expected signs. Our estimates indicate that buyers are willing to pay a small premium for more feed efficient animals as measured by RFI.\(^5\)

Bulls born in the spring (younger at the time of sale) received less, on average, than those born in the fall. Red Angus bulls received less than Angus, on average, while Hereford bulls received more. Year dummy variables were included to capture differences in cattle market conditions over time (e.g., cost of feed), and show the average difference in bull sale prices for the year indicated versus the omitted year, 2007. On average, bull prices in 2008 and 2009 were lower than in 2007, but higher in 2012.

One-unit increases in each continuous independent variable may represent very small (e.g., BYGEPD) or very large (e.g., FinalADG) changes, making interpretation of the relative importance of each variable difficult. As in Vanek et al. (2008) and McDonald et al. (2010), we estimated a linear regression using independent variables that were standardized using their

\(^4\)The residuals from the final regression model with 426 observations were homoscedastic but not normally distributed; a Shapiro-Wilk Test for normality of the residuals rejected the hypothesis of normally distributed residuals, and the Beusch-Pagan / Cook-Weisburg test failed to reject the hypothesis of homoscedastic residuals. To account for the non-normality of the residuals, we use a robust Huber/White/sandwich estimator to compute the standard errors.

\(^5\)Lower (negative) RFI scores are preferred, so a negative coefficient estimate on RFI indicates buyers are willing to pay a premium for improvements in RFI.
Table 3: Hedonic Regression Coefficient Estimates and Interpretations

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coeff Est.</th>
<th>Std Error</th>
<th>% change</th>
<th>Estimated Price Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seller Provided Summary Scores</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Conformation Score</td>
<td>0.016</td>
<td>* 0.009</td>
<td>2%</td>
<td>$43.46</td>
</tr>
<tr>
<td>Muscle Structure Score</td>
<td>0.011</td>
<td>0.009</td>
<td>1%</td>
<td>$30.35</td>
</tr>
<tr>
<td>Expected Progeny Differences</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Birth weight EPD</td>
<td>-</td>
<td>*** 0.010</td>
<td>-4%</td>
<td>-$117.65</td>
</tr>
<tr>
<td>Milk EPD</td>
<td>0.002</td>
<td>0.003</td>
<td>0%</td>
<td>-$5.45</td>
</tr>
<tr>
<td>Birth to Yearling Gain EPD</td>
<td>0.007</td>
<td>*** 0.001</td>
<td>1%</td>
<td>$18.58</td>
</tr>
<tr>
<td>Ultrasound Intramus. Fat EPD</td>
<td>0.062</td>
<td>0.071</td>
<td>-6%</td>
<td>-$164.40</td>
</tr>
<tr>
<td>Ultrasound Ribeye Area EPD</td>
<td>0.148</td>
<td>* 0.078</td>
<td>16%</td>
<td>$432.23</td>
</tr>
<tr>
<td>Ultrasound Rib Fat EPD</td>
<td>0.475</td>
<td>0.744</td>
<td>-38%</td>
<td>-$1,026.86</td>
</tr>
<tr>
<td>Phenotypic Indicators</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Residual Feed Intake</td>
<td>0.022</td>
<td>*** 0.006</td>
<td>-2%</td>
<td>-$59.49</td>
</tr>
<tr>
<td>Final Average Daily Gain</td>
<td>0.107</td>
<td>*** 0.028</td>
<td>11%</td>
<td>$307.26</td>
</tr>
<tr>
<td>Ultrasound Marbling</td>
<td>0.032</td>
<td>*** 0.013</td>
<td>3%</td>
<td>$87.28</td>
</tr>
<tr>
<td>Ultrasound Adjusted Ribeye Area</td>
<td>0.030</td>
<td>*** 0.011</td>
<td>3%</td>
<td>$83.55</td>
</tr>
<tr>
<td>Ultrasound Back Fat</td>
<td>0.125</td>
<td>0.173</td>
<td>-12%</td>
<td>-$318.59</td>
</tr>
<tr>
<td>Birth Weight</td>
<td>0.006</td>
<td>*** 0.002</td>
<td>-1%</td>
<td>-$16.23</td>
</tr>
<tr>
<td>205-day Adjusted Weight</td>
<td>0.000</td>
<td>** 0.000</td>
<td>0%</td>
<td>$1.20</td>
</tr>
<tr>
<td>Final Weight</td>
<td>0.000</td>
<td>*** 0.000</td>
<td>0%</td>
<td>$1.11</td>
</tr>
<tr>
<td>Dummy Variables</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spring Born</td>
<td>0.075</td>
<td>*** 0.027</td>
<td>-7%</td>
<td>-$196.01</td>
</tr>
<tr>
<td>Red Angus</td>
<td>0.069</td>
<td>** 0.043</td>
<td>-7%</td>
<td>-$179.93</td>
</tr>
<tr>
<td>Hereford</td>
<td>0.262</td>
<td>* 0.056</td>
<td>30%</td>
<td>$813.44</td>
</tr>
<tr>
<td>Year_2008</td>
<td>0.238</td>
<td>*** 0.037</td>
<td>-21%</td>
<td>-$576.49</td>
</tr>
<tr>
<td>Year_2009</td>
<td>0.279</td>
<td>*** 0.036</td>
<td>-24%</td>
<td>-$660.88</td>
</tr>
<tr>
<td>Year_2012</td>
<td>0.206</td>
<td>*** 0.045</td>
<td>23%</td>
<td>$622.11</td>
</tr>
</tbody>
</table>

Notes: n = 426; R-square = .6028; ***, **, and * indicate statistical significance at the 99%, 95%, and 90% level, respectively.

1 Estimated percentage change in bull sale price when the corresponding independent variable goes up by one unit.

2 Estimated impact on a bull's sale price (at the mean) of a one unit increase in the corresponding independent variable.
standard deviations.\textsuperscript{6} Table 4 reports the standardized regression coefficients, which show the relative impact of bull characteristics on sale price, and are interpreted as the effect on price (measured in standard deviations) of a one standard deviation increase in the explanatory variable. For example, a one standard deviation increase in $BYGEPD$ is associated with a 0.297 standard deviation increase in the natural log of sale price. Genetic measures of gain ($BYGEPD$) and birth weight ($BirthEPD$) topped the list of factors influencing bull sale price, while seller-provided $TotalConformationScore$ was the least influential statistically significant variable.

### Table 4: Ranked standardized coefficient estimates

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
</tr>
</thead>
<tbody>
<tr>
<td>Birth to Yearling Gain EPD***</td>
<td>0.297</td>
</tr>
<tr>
<td>Birth Weight EPD***</td>
<td>-0.240</td>
</tr>
<tr>
<td>Final Average Daily Gain***</td>
<td>0.170</td>
</tr>
<tr>
<td>Birth Weight***</td>
<td>-0.159</td>
</tr>
<tr>
<td>US Adjusted Ribeye Area***</td>
<td>0.126</td>
</tr>
<tr>
<td>US Marbling***</td>
<td>0.118</td>
</tr>
<tr>
<td>Final Weight***</td>
<td>0.117</td>
</tr>
<tr>
<td>Residual Feed Intake***</td>
<td>-0.117</td>
</tr>
<tr>
<td>205-day Adjusted Weight**</td>
<td>0.091</td>
</tr>
<tr>
<td>US Ribeye Area EPD*</td>
<td>0.089</td>
</tr>
<tr>
<td>Total Conformation Score*</td>
<td>0.076</td>
</tr>
<tr>
<td>Muscle Structure Score</td>
<td>0.058</td>
</tr>
<tr>
<td>US Percent Intramuscular Fat EPD</td>
<td>-0.038</td>
</tr>
<tr>
<td>US Back Fat</td>
<td>-0.030</td>
</tr>
<tr>
<td>Milk EPD</td>
<td>-0.030</td>
</tr>
<tr>
<td>US Rib Fat EPD</td>
<td>-0.024</td>
</tr>
</tbody>
</table>

Notes: *, **, *** indicate statistical significance at the 90, 95, and 99% level, respectively.

**Discussion and Conclusions**

Our results show that bull buyers base purchase decisions on a combination of genetic and phenotypic measures, focusing primarily on weight and growth indicators. Both genetic and phenotypic measures of birth weight were highly valued, reflecting that buyers place significant emphasis on birth weights. Birth weight EPD ($BirthEPD$) received a higher premium than actual birth weight ($BirthWT$); this may indicate buyer acceptance of $BirthEPD$ as a genetic measure of value in selection programs. Similar findings were reported by Jones et al. (2008). Furthermore, Irsik et al. (2008) and McDonald et al. (2010) found similar trends in phenotypic and genetic birth weight measures, reporting bulls with lighter birth weights and EPD’s received premiums. Lighter birth weight bulls produce lighter calves, reducing dystocia and the need for

\textsuperscript{6} This procedure removes the challenge of comparing variables with different units, but interpretation and validity of the standardized coefficients is sensitive to normality of the distributions of the independent variables.
calving intervention. While birth weight was important, the birth to yearling gain EPD (BYGEPD) topped our list of standardized coefficients (Table 4), indicating bull buyers were willing to pay a premium for bulls with high genetic potential for growth from birth to yearling. Similar findings were reported by Irsik et al. (2008) and McDonald et al. (2010).

Phenotypic ultrasound measures of carcass quality were more highly valued than genetic measures. Ultrasound measurements for ribeye area and marbling (USAdjRibeye and USMarb) followed only genetic and phenotypic measures of gain and birth weight in importance, but the ribeye area EPD (USREAEPD) was at the bottom of the statistically significant list of factors, and intramuscular and rib fat EPD's (USPIMFEPD and USRibFatEPD) were not statistically significant. The preference for phenotypic measures over genetic measures of carcass quality are likely explained by two factors: 1) carcass quality characteristics tend to be highly heritable, so selecting on the phenotypic characteristic of a bull is a simple and reliable indicator of herd impact, and 2) carcass quality EPD's are perceived to be less accurate and unreliable. A similar explanation for the latter was reported for yearling weight EPD by Jones et al. (2008). Buyers may have less confidence in EPD measures for yearling bulls because pedigree estimates used to produce the EPD's have relatively low reported accuracy or are reported as interim values.

A focus on growth and carcass characteristics that ignores feed efficiency may be detrimental to beef cattle production profitability. Feed inputs account for the largest share of beef production costs (Arthur et al., 2001; Herd et al., 2003), estimated to be 50% or higher (Kennedy et al., 1993). While there is evidence to support the significant role of feed inputs on production system profitability, past and current practices in livestock genetic selection to improve beef production have primarily focused on output traits (Herd et al., 2003) such as carcass characteristics.

Advances in feeding technology and data acquisition have allowed for improved phenotypic and genetic measures of feed efficiency. A newer measure that is getting more widespread attention is Residual Feed Intake. Residual feed intake (RFI; Koch et al., 1963), or net feed efficiency (NFI), is popular because of its reported favorable or negligible phenotypic and genetic relationships with feed intake, feed conversion ratio (FCR), and body weight (Arthur et al., 2001; Hoque et al., 2006; Tedeschi et al., 2006; Nkrumah et al., 2004). However, RFI is an expensive phenotype to measure. Bull test stations face decisions of whether or not to incur the necessary costs to provide RFI scores for bulls, and this decision will depend on buyer valuation of the trait.

Ours and previous (McDonald et al., 2010) estimates that buyers pay a premium for improvements in RFI are likely explained by RFI's potential to generate increases in profit for producers by increasing how efficiently animals convert feed energy into gain. A one point improvement (decrease) in RFI indicates that an animal eats one pound less feed per day than would be expected given its size and rate of gain. Our estimates suggest a 2% premium (about $60 at the mean), on average, for a one-point improvement in RFI. Crews et al. (2006) investigated the economic value of RFI at the feedlot, developing a multiple trait selection index, including bull residual feed intake, with the objective of improving the net feedlot revenue of progeny representing bulls with bull test data. The final selection index included bull residual feed intake (kg/day), bull average daily gain (kg), and bull yearling weight (kg); the economic weight of -10.12 for bull residual feed intake (RFI, kg) indicated an increase in net feedlot revenue per unit improvement in RFI. Crews et al.'s (2006) finding that bulls with favorable RFI generate higher net revenues due to reduced feed intake in the feedlot is consistent with our estimate that buyers pay a premium for improvements in RFI at auction.
In an attempt to address the increasing amount of information buyers sort through at a sale, and to differentiate their auctions, sale managers often provide phenotypic summary evaluations to buyers. Our results provide new evidence that buyers place less emphasis on seller provided summary scores than on phenotypic and genetic measures. Total Conformation Score, which summarizes the conformation of a bull relative to its cohort, ranked lowest on the list of statistically significant determinants of sale price, and Muscle Structure Score was not statistically significant. However, if summary scores influence bull buyers’ or seedstock producers’ choice of sale, they may be worth providing regardless of the premium they command at the sale.

Differences in age and breed were valued by buyers. As in Vanek et al., 2008 and McDonald et al., 2010, our results indicate that long yearlings (approx. 18 months) appear to be preferred by buyers. As suggested by Vanek et al. (2008), this result is likely a function of bull buyers having the expectation that an older bull has a greater breeding capacity compared to its younger counterpart due to physiological maturity; however, Irsik et al. (2008) reported that the premium received by seedstock producers for a long yearling bull may not offset the added expenses.

Our results show that bull breed is an important consideration for bull buyers. Unlike previous studies (Dhuyvetter et al. (1996); Irsik et al. (2008)) where Angus bulls received the largest premium, Hereford bulls received a premium over Angus in our study. This result may reflect supply and demand for Hereford bulls in the West. Angus offerings outnumbered Hereford 3:1 in an average year at the sale investigated.

Results of this study indicate that western cattle producers place primary importance on phenotypic and genetic indicators of growth and birth weight when making herd sire selections. Unlike previous studies estimating the impact of improvements in residual feed intake, this study included both phenotypic and genetic predictors of carcass quality, allowing comparisons of the relative importance of each to buyers. Results suggest that phenotypic ultrasound measures were preferred over genetic predictors of carcass quality in this study, providing incentive to bull sale managers to include this information in their catalogs. Feed efficient bulls (favorable RFI) received a premium, but it is undetermined how the premium is related to cost savings. Finally, our study provides new evidence that buyers place less emphasis on auction-provided conformation summary scores relative to other information when making purchase decisions; further research is required to determine whether the cost of generating summary scores is justified by their ability to attract buyers and sellers to one auction over another.

Literature Cited


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

Aaron Anderson¹ and William Haden Chomphosy²

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 20th 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 experienced a continued decline 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:

\[ \Delta s_{ij} = \beta_0 + \beta_1 s_{ij} + \beta_2 \Delta GDP_i + \beta_3 \Delta inc_i + \beta_4 \Delta ctl_i + \beta_5 \Delta shp_i + \beta_6 \Delta got_i + \beta_7 cwd_i + e_i. \]

\( \Delta s_{ij} \) 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); \( s_{ij} \) 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; \( \Delta cttle_i, \Delta shp_i, \) 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

<table>
<thead>
<tr>
<th></th>
<th>Regression A</th>
<th></th>
<th>Regression B</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$R^2 = .38$</td>
<td>Sample Size: 30</td>
<td>$R^2 = .42$</td>
<td>Sample Size: 49</td>
</tr>
<tr>
<td>coefficient</td>
<td>estimate</td>
<td>SE</td>
<td>estimate</td>
<td>SE</td>
</tr>
<tr>
<td>intercept</td>
<td>0.79</td>
<td>27.87</td>
<td>8.37</td>
<td>25.33</td>
</tr>
<tr>
<td>size</td>
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<td>0.00</td>
<td>0.03**</td>
<td>0.01</td>
</tr>
<tr>
<td>Δgdp</td>
<td>0.68</td>
<td>0.60</td>
<td>0.90*</td>
<td>0.53</td>
</tr>
<tr>
<td>Δinc</td>
<td>0.30</td>
<td>0.37</td>
<td>0.27</td>
<td>0.18</td>
</tr>
<tr>
<td>Δcattle</td>
<td>-2.75</td>
<td>2.22</td>
<td>-1.20</td>
<td>1.13</td>
</tr>
<tr>
<td>Δsheep</td>
<td>-0.57</td>
<td>0.69</td>
<td>0.28</td>
<td>0.28</td>
</tr>
<tr>
<td>Δgoats</td>
<td>-0.29</td>
<td>0.25</td>
<td>-0.32**</td>
<td>0.14</td>
</tr>
<tr>
<td>cwkd</td>
<td>-54.10**</td>
<td>23.49</td>
<td>-45.92***</td>
<td>14.15</td>
</tr>
</tbody>
</table>

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

Three other coefficients were significant in regression B: size, Δgdp, and Δgoats. 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 Δgdp 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 Δgoats 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.

References


Understanding Landowner Decision Drivers Regarding Conservation through Research

Cheryl J. Wachenheim and William C. Lesch

High commodity prices and other factors have led to a reduction in land devoted to conservation (Stubbs, 2012; Rashford, Walker and Bastian, 2010). The loss of associated environmental benefits as landowners and operators forgo conservation practices and opt-out of conservation program participation can be especially long-felt due to the cost of land conversion.

Motivated by a desire to understand the decision-making process of landowners and operators regarding these conservation practices and programs, Lesch and Wachenheim (2014) and Wachenheim, Lesch and Dhingra (2014) conducted extensive literature reviews of related literature. They considered research investigating (intended or actual) adoption of conservation practices on working lands and in land retirement programs. Wachenheim, Lesch and Dhingra put special emphasis on identifying factors influencing participation in the Conservation Reserve Program (CRP) and also covered literature related to program effectiveness.

A majority of literature reviewed reported on primary research using producer and landowner input elicited through surveys, interviews, and instruments obtaining their reactions to hypothetical choice sets including conservation practices. Literature using secondary data was also considered. Lesch and Wachenheim considered three meta-analyses. Knowler and Bradshaw (2007) reviewed 31 separate analyses covering 23 published studies from a variety of developed and developing countries. They considered the impact of variables in four categories on adoption of conservation practices: farmer and farm household characteristics; farm biophysical characteristics; farm financial/management characteristics; and exogenous factors. Few variables were identified that generally, across studies, explained adoption of conservation practices. A similar review of factors contributing to the adoption of Best Management Practices was advanced by Prokopy et al. (2008). The primary differences from the meta-analysis by Knowler and Bradshaw were that Prokopy et al. limited their meta-analysis to literature originating from the United States and considered only those conservation practices that affected water quality. Referencing some 25 years and 55 studies, they focused on the influence of variables in the categories of capacity, awareness, attitudes, and farm characteristics on adoption rates. A follow-on meta-analysis by Baumgart-Getz, Prokopy and Floress (2012) considered many of the same studies and added unpublished work to overcome bias associated with its exclusion. They used more sophisticated analysis techniques and broke down previously combined variables into separate factors. They also worked to overcome the limitation that data type can influence the predictive effect of variables on adoption. Results of this later work were more conclusive.

Studies by Lambert et al. (2006a, 2006b, and 2007), Lambert, Sullivan, and Claassen (2007), and Lambert and Sullivan (2006), who used secondary data to investigate use of working land structures among family farms, were considered. Also reviewed were studies related to adoption of tillage practices; riparian buffers and forests, conservation technology and enrollment in the

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Conservation Reserve Enhancement Program and the Environmental Quality Incentives Program. Lesch and Wachenheim also looked at barriers to adoption.

Literature specifically related to CRP was reviewed by Wachenheim, Lesch and Dhingra (2014). Considered were studies that examined the impact of commodity prices on CRP enrollment and modeled CRP extensions under varying levels of rental payments and with and without grazing allowed. Studies which estimated the role of CRP on the disposition of other fallow acres (slippage) and on land values; examined landowner contract bidding; and investigated CRP contract holders’ views on the use of CRP parcels for recreation were also included. In contrast to Lesch and Wachenheim (2014), most of the work reviewed did not attempt to estimate or predict participation in conservation programs or adoption of conservation practices.

The goal of the literature reviews was to identify and better understand the role of factors influencing the decision-making process and decisions of landowners and farm and ranch operators regarding conservation practices and enrollment in conservation programs. The purpose of the current article is to share recommendations regarding research efforts resulting from the extensive consideration of related literature.

Recommendations

Research recommendations are offered to help guide efforts to elicit, analyze and draw conclusions from producer and land-owner attitudes, perceptions and actual or intended behavior regarding conservation. Readers will find some recommendations to be new and others to be useful reminders. The relevance and order of importance of each is left to the investigator, policy maker, or others putting them into practice.

1. Recognize and incorporate the reality that few decisions are made in isolation by paying attention to the influence of others on and role of others in the decision-making process. Most reviewed literature was focused around information as reported by the landowner or producer without explicit input by or consideration of those involved in or influencing their decision. A notable exception was Habron (2004) who found spousal influence significant in explaining use of riparian fencing within the Umpqua River Basin of Southwest Oregon. When the focal point of a study is estimating the likelihood of actual (versus intended) behavior, this dependent variable (participated or did not participate) implicitly includes the influence of others. If this is absent from the associated predicting independent variables, important information may be lost.

Recognition of this limitation associated with using surveys was one driver in the growth in popularity of using experimental auctions to evaluate market potential for products. Incorporating the possibility the participant may be required to purchase the product adds consideration of the influence of others (e.g., family members) into the bid selection. Because experimental auctions with the possibility of a bid being accepted would generally not be appropriate to predict enrollment in conservation programs or adoption of conservation practices, including consideration of familial or other personnel influences otherwise needs to be made more explicit. In one notable exception, Chakrabarti, Swallow and Anderson (2014) used a Lindahl auction framework to elicit financial contributions for payment to farmers in two Vermont counties who agreed to protect the nesting habitat of the Bobolink.

2. Consider that what respondents report may not be what they do, believe or experience, or the specific farm structure and practices they have in place. The internal and/or predictive validity, as well as reliability of extant findings is usually not investigated. There is some evidence from the conservation literature that survey responses may produce data at odds with observed practices (e.g., see Carr and Tait, 1991). Research which examines behavior (what did or did not occur), especially when it is evidenced by supporting secondary data (e.g., USDA program...
enrollment data), may therefore be more predictive of future behavior than respondent-reported intentions. The tradeoff is that secondary data generally does not allow for the same detailed understanding of why.

3. **Consider variables carefully for inclusion in data collection and analysis.** Variables historically shown to be important to explain conservation behavior but which are sometimes absent include some related to farm structure such as land location\(^2\), farm type, and the type of conservation practice considered (Vitale et al., 2011; Camboni and Napier, 1993). Landowner variables sometimes not considered include those related to the planning horizon as it relates to farm transition (e.g., heir transfer, retirement); occupation including farm and non-farm; land ownership; level of interest in what others are doing and thinking; motivations; thoughts on external stakeholders; traditionalism; and attitudes about property rights and the role of the government. Focusing on literature reviewing decision-making by landowners and operators with like circumstances to the target population and conducting in-person surveys or focus groups among the population of current interest as part of instrument development can be useful to identify important variables for inclusion.

Likewise, inclusion of variables that the literature or in-person interviews or focus groups show to be unimportant or, even if important in explaining behavior, managerially insignificant, should be reconsidered to limit instrument length. For example, Baumgart-Getz, Prokopy, and Floress (2012) and Prokopy et al. (2008), contrasting with Gedikoglu and McCann (2012), did not find risk aversion to be significant in explaining conservation behavior and suggested researchers consider carefully whether it is necessary to include. It may be that risk aversion is not important to the decision, but it may also be that the proxy used to represent risk aversion does not adequately do so.

This proxy and that representing any host of other variables the theoretical model supports as potential contributors to specific decisions is worth careful investigation prior to conducting a study. For example, Baumgart-Getz, Prokopy, and Floress (2012) improved on an earlier meta-analysis by breaking the factor education into formal and extension; investigating ordinal versus continuous representation of data; and delineating social networks into four types. The distinctions for education and information venues are likely to become increasingly important as social networks and other learning and sharing venues evolve at an ever-increasing pace.

Other methods of eliciting landowner perceptions should be considered to further refine variables considered. Research reviewed, particularly that related to CRP adoption, concluded that a host of factors are self-reported to be important to most decision-makers; so many that it is difficult to distinguish between those factors more and less important. In this case, the literature likely over-represents the number of influencing factors as well as their importance. Rather than asking landowners to eliminate factors that they do not consider or minimally consider in the decision (few are actually eliminated), it may be valuable to (first) ask them to identify those that are important and to rank or otherwise prioritize them.

Finally, data collected and variables considered must provide the information required to answer the specific research questions posed. A study designed to predict enrollment in a land

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\(^2\) A reviewer made an interesting point regarding the choice of variable designed to represent land location. As the reviewer notes, land location can be measured in any number of ways; for example, distance from a place of importance such as the nearest town or elevator or as being within a specific county. Further complicating representation of location is the reality of fragmented farms. It may be prudent to query operators about the location of the parcel(s) in question to the home farm or other specified location or land feature.
retirement program will differ from one investigating the effect of characteristics of that land retirement program on overall conservation acres; the latter would need to explicitly include intent that may influence slippage.

4. Consider barriers to adoption. Knowing what would prevent / is preventing participation may require that question be explicitly asked. In a conceptual paper, Nowak (1992) argues that the key to increasing adoption of conservation practices is to overcome barriers preventing such. He notes reasons farmers may be unable to adopt including lack of information or that needed information is too expensive to obtain, that the change may be too expensive or the labor requirements too great, that the planning horizon for the decision-maker may be too short to recoup the investment, or that there is a lack of support, managerial skill, or the authority to make the decision. Nowak notes that unwillingness to adopt may stem from conflicting, inadequate, or non-case-specific information, that the structure or practice may not fit with the current production system in place or otherwise is not appropriate for the farm, or increased risk. The importance of barriers to adoption of conservation practices has been confirmed by work by Ervin and Ervin (1982), Brant (2002), Lemke et al. (2010), and McCann and Claassen (2014), among others, but has not received due attention in the literature designed to estimate or predict conservation inclinations.

5. Consider modeling the decision-making process. The literature includes detailed reviews of the challenges associated with different models. Early attempts to predict conservation behavior such as Rahm and Huffman (1984) and Besley and Case (1993) noted problems associated with use of aggregate data such as considerable variability in within-area soil type and weather patterns. Also noted in the literature are problems associated with the use of time series, cross sectional and panel data to predict conservation practice or program adoption. Besley and Case (1993) proposed use of dynamic choice modeling, arguing that focus should be placed on modeling the decision-making process itself as opposed to the resulting static choice. For example, research concluding that landowners refine their bids for enrollment in the CRP in response to results of earlier enrollment periods (i.e., that they learn) supports investigation of the bid determination process used by producers, work notably absent from the literature.

6. Investigate whether differences in landowner or farm structure characteristics call for estimation of separate equations. Multiple authors have concluded that, because of differences in effect of influencing factors, a research question should identify the specific conservation practice under consideration (e.g., Knowler and Bradshaw, 2007; Habron, 2004). Other factors that might justify separate equations include: benefactor of practice (e.g., landowner, downstream resident); farm locale; farm type; irrigation use; and full versus part-time farmer. For example, Ervin and Ervin (1982) modeled only those owning and operating farmland in recognition that the tenant / operator relationship would change the nature of the decision-making process.

Adopting segmentation techniques will also improve the fit of programs and associated education efforts about the same. For example, understanding decision-making regarding use of buffer strips among livestock producers in the Prairie Pothole Region and designing appropriate educational efforts will likely be more fruitful than for general conservation programs among farmers throughout the Midwest.

7. However, recognize that a focus on a particular conservation practice and / or program may be limiting if considered in isolation if choices regarding conservation practices are not independent. Separate estimations or those not inclusive of all conservation options may not then accurately predict conservation behavior, underscoring the importance of understanding the whole of the decision-making process a priori to the use of quantitative survey efforts.
8. Be cognizant of the overarching importance of economic factors over the length of the planning horizon. Understanding and predicting landowner choices can be improved by explicitly including their expectations about future market conditions, but this is sometimes overlooked or underemphasized in the literature. This factor poses measurement challenges conceptual as well as operational but is worthy of investigation when the contract horizon is long. Costs included in adoption of conservation practices or returning land from a conservation-oriented use back into production can be high.

Economic conditions considered should also be relatively wide in range. Results from the literature covering periods with different market conditions cannot be confidently extrapolated to current and future conditions. More complete study of this area may require longitudinal considerations or somewhat extensive use of sensitivity analysis. There does exist literature reporting on the effect of changes in commodity prices without an increase in land-rental payment rates for land retirement programs such as CRP. This work concludes, not surprisingly, that increased commodity prices would result in acres pulled or not re-enrolled. In practice, maximum rental rates are calculated based on soil productivity and existing local cash rents. That is, increases in opportunity cost associated with program enrollment are designed to be reflected in higher rental rates. Changes in the maximum bid rate are an endogenous response to changes in economic conditions rather than the exogenous assumption depicted throughout much the existing literature used to investigate sensitivity of the solution.

A final economic consideration often overlooked in the literature is the effect of changes in practices or program enrollment on farmland prices for the involved and nearby acres, which can be especially important if the landowner also owns adjacent or nearby land. For example, the literature shows that CRP has a positive impact on economic returns to land ownership and that this impact varies by region and by source (e.g., farmland prices, agricultural returns, growth premium, option value) (e.g., see Chamblee et al., 2011; Lin and Wu, 2005; and Wu and Lin, 2010). However, it should be noted that farmers may not be aware of these benefits and therefore they may not be influencing their decisions; the literature reviewed in Wachenheim, Lesch and Dhingra (2014) presents conflicting information about this.

9. Carefully define the model to include the reality from the literature that landowners may not simply maximize net present value. For example, results from Suter, Poe and Bills (2008), Lynch and Brown (2000), and Kingsbury and Boggess (1999), among others, suggest that up-front payments (e.g., establishment payments) are more important than the annual payment for CRP by more than would be explained by economics alone. This may be true even when cash flow is not limiting, perhaps because these payments represent to the landowner the government’s investment (share) in establishing required infrastructure to implement the conservation practice. Further, the literature shows that producers do not always make economic choices that appear to be most economically-efficient, or, maximize economic return; certainly we have more to learn about landowner decision-making.

10. Consider continued, not just initial, adoption. What may motivate participation or conversion initially may differ from what would motivate continued participation or conversion. This is likely particularly true when substantial or costly changes are involved in conversion to or from land-use involving conservation practices and / or enrollment in conservation programs. This distinction has received little attention in the literature.

Even given the steep penalty, early withdrawal from a conservation contract is also an option. It should be considered, particularly under conditions when the opportunity cost of continuing to honor the contract is high. Most literature is based on the implicit assumption that, once enrolled, landowners will complete the contractual period. Our investigation uncovered no
studies of producers who had exercised an early-opt out under penalty. Studies drivers in this
group may reveal insights useful to policy intending to maintain target-levels of conservation-
land or important to specific landscape types or specific producer groups.

11. Explicitly address non-response bias and response distribution which does not reflect the at-
large population under consideration; even for initial or very detailed reporting

Adjusting for bias before reporting is particularly important when results that do not include the appropriate
adjustment are likely to be externally interpreted without full consideration of this bias. As
response rates to traditional mail and/or telephone surveys wane, this rises in importance.

Conclusions

Some common themes emerged from the literature reviews. First, the value of well-defined
study objectives and associated testable hypotheses cannot be overstated; nor can
understanding the theoretical underpinnings defining the model within which to test these
hypotheses. Spending the time understanding the question and the context within which to
answer it is fundamental to meaningful research about decision-making regarding conservation.
One best begins by gaining a thorough understanding of what we already know. Review the
most current literature relevant to your specific research objectives.

Other recommendations are useful reminders and will be helpful for research teams to address
prior to study implementation. One is the importance of recognizing and mitigating self-
reporting bias. What people report to be or about what they did or would do does not always
accurately reflect reality. The familiar lessons of asking the right questions and creating some
redundancy when collecting information may help mitigate the impacts of inaccuracies in self-
reported data. Non-reporting bias also warrants explicit consideration, particularly given the
potential for misuse of reported results. Second, take into account that landowners may not be
aware of some of the financial implications of their decision. Third, use available resources to
well-define variables used to explain perceptions, attitudes, or choices. Carefully consider the
literature and conduct focus groups, face-to-face interviews, or other means of qualitative
research prior to undertaking a more extensive study. Do not overlook barriers to adoption.
Fourth, in model development and analysis keep in mind there may be a lag between factors
influencing the decision and the decision and its implementation. Fifth, carefully consider the
trade-off between adopting a narrow focus on a particular conservation practice and a more
general look at the many conservation options available to landowners; sometimes a trade-off
between a good fit to the model and a relevant fit. Sixth, consider not only the adoption
decision, but the decision to continue an existing conservation practice or program, as well as
any decision to opt-out. Measure twice, cut once.

References

(CRP) Participants On Environmental Effects, Wildlife Issues, And Vegetation Management

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3 A reviewer noted that this is common sense. As fewer responses speak for the agricultural sector and
response rates are low and continue to decline, adjusting for non-response bias grows in importance.
Organizations are sophisticated and can mine data for an answer that, once the data is corrected for bias,
is not in evidence. The recommendation is that scientists must more carefully than ever consider how
data can be used to tell a different story than that resulting when data is adjusted for non-response and
other bias that make it unrepresentative of the population to which it is attributed.


Stubbs, M (2012), Conservation Reserve Program (CRP): Status and Issues, Congressional Research Service (October 18), R42783, 16 pages.


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