QUANTIFYING THE RELATIONSHIP BETWEEN U.S. CATTLE HIDE PRICES/VALUE AND U.S. CATTLE PRODUCTION

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Executive Summary

A quantitative economic analysis of the potential impact of hide price/value on U.S. cattle production was conducted. Although cattle are produced for the purpose of providing consumers with beef products, hides are one of many byproducts that result from processing cattle. Consequently, the potential exists for *direct* and *indirect* effects of hide price/values on cattle production. Granger causality tests were used to investigate the possibility of a *direct* effect. The statistical procedure is used to determine if the value of cattle hides is causally linked to fed cattle production quantities. These tests were conducted using quarterly and annual USDA-AMS data for steer hide prices and USDA-ERS data for quantities of steers produced. The Granger causality tests do not provide any evidence that steer hide prices directly influence steer production quantities.

Several studies indicate that cattle hide values (as well as other cattle processing byproducts) influence cattle prices. Because cattle prices influence cattle production, cattle hide values may have an *indirect* effect on cattle production. To investigate the potential size of this *indirect* impact, a reduced form linear regression model is estimated to quantify the effect of steer hide prices on fed steer prices. The model estimates this relationship to be highly inelastic (0.13). This elasticity is combined with a recently published estimate of the own-price elasticity of supply of fed cattle to quantify the *indirect* effect of cattle hide values on cattle production. The results indicate that a 10% increase in hide prices is expected to cause a 0.31% (i.e., less than one-third of 1%) increase in the production of fed cattle. Because this small increase in fed cattle production would necessitate an increase in breeding cattle numbers, the total *indirect* effect of a 10% increase in cattle hide prices would be an increase of 163,400 head of cattle (breeding cows plus steers and heifers). This represents about a 0.17% increase in U.S. cattle inventories. Given that steer hides are more valuable than most other hide types, the 0.17% increase is likely an upper bound on the effect of hide values on cattle production.

In summary, we find that cattle hide prices *do not directly affect* cattle production and have only a *small indirect effect*.

Quantifying the Relationship Between U.S. Cattle Hide Prices/Value and U.S. Cattle Production

Introduction

This report presents a quantitative economic analysis of the relationship between cattle hide prices/value and their potential impact on U.S. cattle production. Cattle are produced to meet consumer demands for beef products. Consumers spend more on beef products than on any other meat species. Cattle hides and edible/inedible byproducts result from the production of consumer beef products. Nonetheless, economic theory suggests that byproduct values may have an indirect impact on cattle production. Specifically, as byproduct values increase (decrease), the price of cattle increase (decrease). The indirect effect occurs because cattle prices influence cattle production. Although the direction of this impact is well known and has been shown in published research to be statistically significant, the relative size of the impact has historically been shown to be small.

Two distinct research approaches are used to fully investigate this issue. The first uses Granger (1969) causality testing to determine if hide prices have a direct effect on cattle production. We use quarterly and annual data from 1995-2019 for the number of fed steers slaughtered as a measure of cattle production. The prices of butt branded steer hides are used as a measure of hide prices because they were more consistently reported than heifer, cow, bull, or calf hide prices. Hence, we use steer quantity and price data for the analyses and note that the use of other cattle production and price data (if available) would likely generate similar results.

The second approach recognizes that cattle hide prices may have an *indirect* effect on cattle production. Hides (and edible/inedible offal) are byproducts of cattle processing. Byproduct values, however, have been shown to have a positive relationship with cattle prices. That is, increases in byproduct values increase the profitability of cattle processing. Hence, cattle processors increase (decrease) cattle price bids as the price of byproducts increase (decrease). Because changes in cattle prices are positively related to cattle production numbers, changes in byproduct values (including hides) are likely indirectly related to cattle production. Based on previously published research, however, this impact is likely to be small. We use linear regression techniques to quantify this relationship.

The Structure of the U.S. Cattle and Beef Industry

The cattle and beef industry is the largest U.S. food sector (in terms of gross revenue) with total annual revenues exceeding $70 billion. The sector is multi-faceted and vertically connected among the cattle production and beef consumption sectors. In 2017, the U.S. beef cow inventory totaled over 32 million head (USDA NASS). The 2017 Census of Agriculture reports that

729,046 ranch operations manage beef cow herds with an average herd size of 44 head (USDA NASS, 2017). Ranchers maintain cattle herds using grazing and supplemental feeding practices. These herds are used for the sole purpose of producing calves. Ranchers source genetics from seedstock producers, and cows are impregnated annually. Cows have a useful productive life between 8-12 years; and bulls, between 4-6 years. When cows and bulls reach the end of their useful breeding life, they are culled and processed. Beef obtained from culled animals is generally used to produce ground beef products.

After birth, calves are kept with their mothers and nursed until the age of 7-9 months, when they are weaned. Weaned calves weigh between 500 and 700 pounds. Between 10-15% of female calves are retained by ranchers each year to replace cull cows. Once weaned, remaining female (heifer) and male (steer) calves are often further "backgrounded" on wheat and grass pastures to add weight. Upon reaching 750-900 pounds, these "feeder" calves are then fed high-energy grain and forage rations. After another 5-6 months, these animals reach weights of 1,300-1,500 pounds and are processed. Approximately 50% of finished beef products obtained from fed cattle are table cuts (e.g., steaks and roasts) with the remainder being ground beef.

Four beef packing companies process approximately 80-85% of all fed steers and heifers. However, hundreds of smaller beef packing and processing companies exist as well (USDA GIPSA). The primary output of packing companies is the production of beef products which are sold to other food manufacturers, retailers, and the hotel, restaurant, and institution (HRI) sector.

Approximately 8% of U.S. beef production is exported. Lower quality middle meats (primarily chuck and round portions) are generally exported to lower-income countries (primarily Mexico), while premium cuts (e.g., steaks and roasts) are generally exported to Pacific Rim countries (especially Japan and South Korea) as well as Canada.

In addition, U.S. companies import about 12% of the total U.S. beef supply. Most beef imports are sourced from Oceania and Canada. Beef obtained from Australia and New Zealand is in the form of trimmings obtained from cattle that are grass fed. These lean trimmings are used to reduce the fat content of U.S. trimmings so that resulting ground beef products are palatable.

The processing of fed cattle, cull cows, and cull bulls produces substantial amounts of byproducts. That is, only about 40% of the live weight of cattle become edible beef products. The remaining 60% consists of various edible (e.g., hearts, kidneys, etc.) and inedible (e.g., hides, tallow, bone meal, etc.) byproducts. Over the past 20 years, the live weight of fed steers has averaged 1,318 pounds per head. Therefore, an average-sized fed steer produces about 527 pounds of beef products. The remaining 791 pounds consist of edible and inedible byproducts. The total value of byproducts typically represents about 10% of the value of a live animal (Peel, 2019).

Figure 1 presents quarterly byproduct values as a percentage of the value of fed steers per head. For this time period, the value of all steer byproducts averaged 11% of the value of fed steers. Historically, hides have represented about one-half of total byproduct values. It appears, however, that changes have occurred over time. For example, prior to 2000, hides were a larger percentage of total byproduct value than non-hide byproducts. The two byproduct categories each represented about 50% of total byproduct values between 2008 and 2016. Between 2017 and 2019, hide values became a smaller percentage of the total relative to non-hide byproducts.

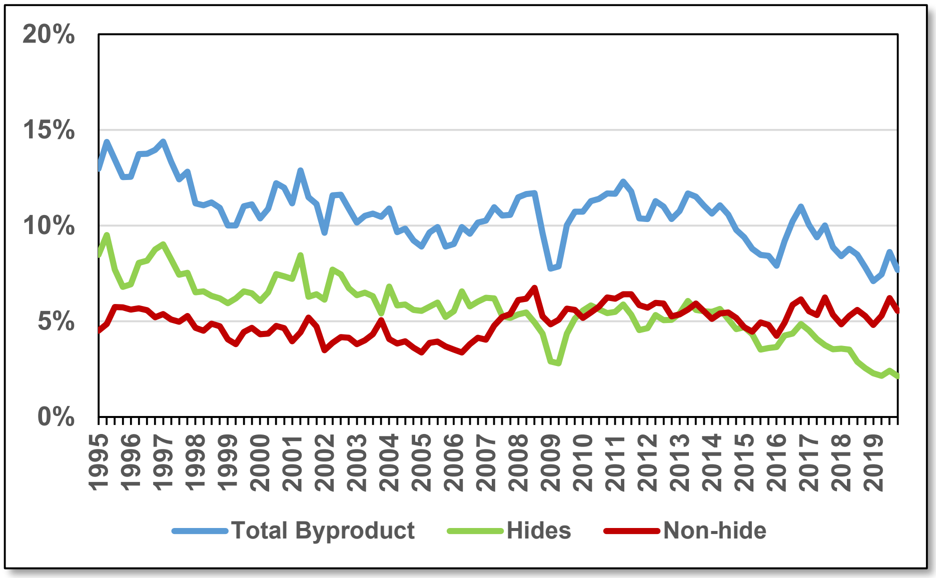

Figure 1. Quarterly Total, Hide, and Non-hide Steer Byproducts as a Percent of Fed Steer Value, 1995-2019.

Hides are generally used by leather product manufacturing companies. Many smaller packing companies, however, find that the value of cattle processing byproducts, including hides, does not offset the additional costs of byproduct processing and marketing. Hence, smaller companies often incinerate byproducts or dispose of them in landfills. In 2019, almost 16% of U.S. cattle hides were discarded in landfills (Kay, 2020). Of course, many smaller companies only process a few animals each week. Large packing plants, however, may process as many as 5,000 head per day. Consequently, the disposal of hides and other byproducts into landfills may not be practical for larger cattle processors.

Major packing companies have the scale, resources, and expertise to profitably process and market byproducts. Almost all hides and most non-hide byproducts are exported. Some non-hide inedible byproducts are used domestically to produce pet food, fertilizers, and industrial lubricants. Edible byproducts, however, are generally exported and represent protein sources for consumers in many developing countries. However, if the value of byproduct processing and marketing becomes less than the cost of incineration or landfill disposal, then processing companies will use alternative disposal methods.

Granger Causality Testing for Direct Impacts of Hide Prices/Value on Cattle Production

We first explore the potential direct effect of hide prices on cattle production using a statistical procedure introduced by Granger (1969). Granger causality tests are used to determine whether changes in one variable cause changes in another. These tests have been routinely applied by economists to explore relationships between many different types of agricultural (and non-agricultural) variables, including production quantities and commodity prices. For example, Thurman and Fisher (1988) used U.S. annual data for egg production and chicken inventories to determine that eggs Granger-cause chickens, but chickens do not Granger-cause eggs. As noted by the authors, the test results more accurately indicate statistical evidence of a "temporal ordering" of the two variables. Granger causality tests have been used in hundreds of studies in which causal relationships between two or more variables are of interest.

Granger causality testing involves estimating two linear regression models (a restricted and an unrestricted model) to assess whether past (lagged) values of one variable are jointly significant in predicting the values of another. Following Pindyck and Rubenfeld (1998), a Granger causality test for the null hypothesis that "*X* does not cause *Y*" is conducted by estimating the following two equations:

Unrestricted Model: $$Y_t = \sum_{i=1}^{m} \alpha_i Y_{t-i} + \sum_{i=1}^{m} \beta_i X_{t-i} + \varepsilon_i$$

Restricted Model: $$Y_t = \sum_{i=1}^{m} \alpha_i Y_{t-i} + \varepsilon_i$$

The Granger test statistic is the *F*-statistic for the joint significance of the β_i coefficients on lagged values of *X*. If the *F*-test statistic exceeds the critical *F*-value, the null hypothesis is rejected, and *X* is said to "Granger-cause" *Y*.

We are interested in whether changes in hide prices lead to changes in cattle production. Thus, the null hypothesis is that hide prices do not cause changes in cattle production. Hide prices are the *X* variable and cattle production numbers are the *Y* variable in the above models.

Causality Tests: Data

We obtained data on marketed cattle hide values from the U.S. Department of Agriculture's Agricultural Marketing Service (USDA AMS). Data for average per animal hide prices were available on a daily basis from 1995 through 2019 (USDA AMS). The most consistently reported series was steer hide prices. Several steer hide price series were collected, and the simple average of daily data were used to form weekly data. Weekly steer hide prices were aggregated to monthly, quarterly, and annual values using simple averages.

Although the prices of several different types of hides were reported over the time period, the price of butt branded steer hides was the most consistent series. USDA AMS also uses the price of butt branded steer hides to develop daily drop-value reports. These reports are used later in this report to develop non-hide byproduct values.

We use quarterly and annual butt branded steer hide prices for the period beginning in the first quarter of 1995 through the fourth quarter of 2019. We purposely did not include data for 2020 because of the impacts of the COVID-19 pandemic on cattle markets. Furthermore, a consistent set of hide data were not available prior to 1995. The price of butt branded steer hides was inflation-adjusted (deflated) using the Gross Domestic Product (GDP) Implicit Price Deflator. The term "real" is used to designate data that have been adjusted to account for inflation. The use of deflated (real) data is important in time-series statistical analyses. The GDP Implicit Price Deflator was scaled so that the fourth quarter of 2019 was set equal to 100.0. The purpose for this scaling is to put all price data into current dollar valuations so that empirical results are more easily interpreted relative to current market prices.

Data for the quantity of cattle slaughtered were obtained from the U.S. Department of Agriculture's Economic Research Service (USDA ERS). Monthly data for commercial steer slaughter numbers were aggregated to quarterly and annual values. The quantity of steers slaughtered was chosen as the production metric for the analyses because it is consistent with the hide price data (steer hides) and is the most likely to reflect any potential causal link in the statistical tests.

Granger causality tests require that the data under consideration be stationary. Nonstationary data can result in spurious (i.e., unreliable) estimation results. Therefore, Augmented Dickey Fuller (ADF) tests for stationarity were conducted on both variables using quarterly and annual frequencies. The results are reported in table 1.

Non-stationarity was rejected for the quarterly steer production data. However, ADF tests could not reject non-stationarity for annual steer production data or for the quarterly or annual steer hide price series. Because non-stationarity in time-series variables can generate errors in Granger causality tests, these three data series were first-differenced (converted to changes from the previous period). This is a common approach to account for non-stationarity in time-series data. After first-differencing the annual steer production and quarterly/annual steer hide price series, non-stationarity was rejected for all three variables. The resulting stationary series were used for the following causality tests.

Table 1. Augmented Dickey Fuller (ADF) Tests for Stationarity

Variable	Frequency	Form	N	ADF	*p*-value	Stationary?
Steer Slaughter	Quarterly	Levels	100	-3.790	0.022*	**Yes**
	Annual	Levels	25	-2.869	0.241	No
		1st Differences	24	-4.346	0.011*	**Yes**
Real Butt Branded Steer Hide Price	Quarterly	Levels	100	-1.662	0.717	No
		1st Differences	99	-4.905	<0.01*	**Yes**
	Annual	Levels	25	-1.368	0.813	No
		1st Differences	24	-4.010	0.023*	**Yes**

* Indicates significance (at least) at the 0.05 level.

Causality Testing: Specification and Results

Granger causality tests are used to determine if sufficient evidence exists of a direct effect of hide prices on cattle production. The expected producer response to an increase (decrease) in the price of a product, even a byproduct, is to increase (decrease) its production. Cattle production responses, however, are complicated by long production cycles. Calves are born once per year, and the process from breeding through gestation and growth is approximately three years in length. The only way to produce more cattle hides within a year is to reduce the number of replacement heifers added to the breeding herd or cull more cows. This has an additional effect of reducing cattle numbers in future years.

Because of the potential for changes within a year, causality tests were first conducted using quarterly data. A Granger test was specified using stationary quarterly steer slaughter quantity data in levels and first-differenced real butt branded steer hide prices to test the null hypothesis:

H_o: *Steer hide prices **do not** Granger cause steer slaughter quantities*

H_a: *Steer hide prices Granger **cause** steer slaughter quantities.*

Granger causality tests require that the number of lagged values for each variable (lag order, *m*) be specified *a priori*. Previous literature has shown that causality tests can be sensitive to the selected number of lags (Bruns and Stern, 2018; Thornton and Batten, 1985). The choice of an appropriate lag order should be based on both statistical grounds and judgement regarding the nature of the data, the industry, and the problem being addressed. The inclusion of large numbers of lags can result in spurious test results. Given the nature of cattle production, Granger causality tests on the quarterly data were conducted using a lag order of four (m=4) to accommodate an annual time period. This specification generated an F-statistic of 1.189 and an associated p-value of 0.321. Therefore, the null hypothesis that hide prices do not Granger cause steer slaughter quantities could not be rejected.

A model was also specified to test for the possibility of reverse causality. The null hypothesis for this test is:

H_o: *Steer slaughter quantities* ***do not*** *Granger cause steer hide prices*

H_a: *Steer slaughter quantities Granger* ***cause*** *steer hide prices.*

There was no statistical evidence for reverse causality (F-statistic=0.841, p-value=0.503).

Granger causality tests were also conducted on annual data. Because the annual data series contained only 25 observations (1995-2019) and both variables used in the annual model were first-differenced, the tests were somewhat constrained by available degrees of freedom. On the other hand, an annual data series is better matched to annual cattle production cycles. A lag order of three (m=3) was chosen for the annual model to span the three-year process of producing fed cattle. The model produced an F-statistic of 1.542 with a p-value of 0.247. Therefore, the test failed to reject the null hypothesis that steer hide prices do not Granger cause steer slaughter numbers. Once again, reverse causality was tested and could not reject the null hypothesis (F-statistic=0.790, p-value=0.519).

Causality Testing: Interpretation

Granger causality tests were used to determine if hide prices directly affect cattle production. The tests were conducted using both quarterly and annual data. Lag length selection was based on industry knowledge and statistical procedures. The test results provide no statistical evidence that steer hide prices Granger-cause steer production numbers. It is appropriate to also test for reverse causality in such models. Again, no evidence of causality was found.

Regression Analyses of the Indirect Impact of Hide Prices/Value on Cattle Production

Although no direct effect of hide prices on cattle production was found in the previous section, economic theory suggests that an indirect effect likely exists because hides produced by cattle processing are inputs into a wide variety of leather-containing products. Hence, hides have value, and processors are likely to increase cattle price bids when hide values (and the value of byproducts in general) increase. Higher cattle prices signal cattle producers to increase cattle production. The potential indirect impact of byproduct values on cattle production is investigated using linear regression techniques.

Background and Literature Review

Several studies have found that cattle slaughter byproduct values are positively related to cattle prices. Brester and Marsh (1983) use annual data from 1960-1980 to estimate various beef and cattle industry supply and demand equations. Their fed steer price equation includes cattle farm byproduct values as an explanatory variable. Hides are the primary component of cattle farm byproduct values. Their estimate of a short run price elasticity of fed steer prices with respect to farm byproduct values is statistically significant but relatively inelastic (0.10). That is, a 10% increase in farm byproduct values generates a 1.0% increase in fed steer prices.

Marsh and Brester (1989) use weekly data from January 1982 through December 1985 to estimate reduced form models for the price of boxed beef, the price of carcasses, and the price of fed steers. Farm byproduct values were included as an explanatory variable in the steer price equation. Their results indicate that, in the short run, the elasticity of fed steer prices with respect to the price of farm byproducts (which includes hides) is 0.16. In the long run, the elasticity is estimated to be 0.34. That is, a 10% increase (decrease) in farm byproduct prices cause a 3.4% increase (decrease) in fed steer prices. In addition, the long run elasticity of boxed beef prices with respect to the price of carcass byproducts was found to be 0.16.

Using annual data from 1970-1988, Brester and Marsh (2001) consider the impact of technological change on the cattle and hog processing industries. Their reduced form steer price equation indicates that a $0.10/lb increase in farm byproduct value causes an $0.80/cwt increase in fed steer prices. Using the means of the data, a short run elasticity of the change in fed steer prices with respect to a change in farm byproduct prices is calculated as 0.02. That is, a 10% increase in farm byproduct prices causes an (very inelastic) increase in fed steer prices of 0.20%.

Brester and Marsh (2004) used annual data to investigate changes in cattle/beef marketing margins. They estimated a steer price equation that included farm byproduct values as an explanatory variable. The empirical results show that a $0.10/lb increase in the price of farm byproducts increases the price of steers by $4.00/cwt. Relative to the earlier $0.80/cwt impact reported by Brester and Marsh (2001), it appears that steer prices were more responsive to byproduct values during the 1990s compared to the 1980s. Using their data and regression results, the short run elasticity of fed steer prices with respect to farm byproduct values is, nonetheless, relatively inelastic (0.10). That is, a 10% increase in farm byproduct values causes a 1.0% increase in fed steer prices. In addition, the long run elasticity of fed steer prices with respect of farm byproduct values is also quite inelastic (0.16).

Regression Analysis: Specification

The research methodology and specification used to quantify the impact of hide values on the price of fed cattle is based on published research. That is, we specify a reduced form equation in which the price of fed steers is the dependent variable. Previous research uses fed steer prices as a proxy for all fed cattle prices because the data are consistently reported. In addition, steers represent about two-thirds of total fed cattle production. The use of steer prices and slaughter numbers has been shown to be a good representation of fed cattle production.

The regression specification is a reduced form model, as both supply and demand factors are included as explanatory variables. A reduced form approach is used rather than the specification and estimation of separate demand and supply functions. The latter approach is valuable for many applications, but usually involves an (often insurmountable) identification problem. In addition, a reduced form approach is frequently used for evaluating factors that affect cattle prices (e.g., Brester and Marsh, 1989, 2001; McKendree, *et al*., 2020).

In a general form, we use the following reduced form specification:

(1) $$P_t^s = f(Q_t^{ss},\ P_t^{fc},\ P_t^c,\ P_t^w,\ V_t^{os},\ P_t^{sh})$$

where P_t^s is the price of fed steers (in time period *t*), Q_t^{ss} is the quantity of fed steers slaughtered, P_t^{fc} is the price of feeder cattle, P_t^c is the price of corn, P_t^w is the price of wholesale beef, V_t^{os} is the value of other steer byproducts (i.e., excluding hides), and P_t^{sh} is the price of steer hides.

The quantity of cattle slaughtered (Q_t^{ss}) in any time period is expected to have an inverse relationship with the price of fed steers (P_t^s). The price of feeder cattle (P_t^{fc}) and the price of corn (P_t^c) represent input costs into the production of fed steers. Consequently, increases in these prices cause the supply of fed cattle to decline, which increases the price of fed cattle. The price of wholesale beef (P_t^w) represents the price of the primary output produced by beef processing plants. Hence, the expectation is that the price of wholesale beef is positively related to the price of fed steers. The rationale is that as the price of beef produced by cattle processing firms increase, those firms can profitability increase their bid prices for fed steers (and heifers).

The value of other (non-hide) steer byproducts (V_t^{os}) and the price of steer hides (P_t^{sh}) are both expected to have a positive relationship with the price of fed steers. Although both are byproducts of cattle processing, they contribute to the profitability of processing firms.

Because of data availability, the final specification of equation (1) is:

(2) $$DP_t^{lc} = f\left(Q_t^{ss},\ DP_t^{fc},\ DP_t^{c},\ DP_t^{w},\ DV_t^{os},\ DP_t^{sh}\right)$$

where DP_t^{lc} is the deflated price of nearby Chicago Mercantile Exchange (CME) live cattle future contracts, Q_t^{ss} is the quantity of fed steers slaughtered, DP_t^{fc} is the deflated price of nearby CME feeder cattle futures contracts, DP_t^{c} is the deflated price of corn received by farmers, DP_t^{w} is the deflated price of wholesale beef, DV_t^{os} is the deflated value of other byproducts (i.e., excluding hides) obtained from steers, and DP_t^{sh} is the deflated price of butt branded steer hides (which also represents the value of hides per animal).

Regression Analysis: Data

Data sources for all variables are presented in table 2. The means and coefficients of variation of the data are also presented. The coefficients of variation allow for comparing the variability of each data series relative to their mean values. In addition to steer hide prices, we obtained data for the value of all byproducts attributable to steer processing for the years 1995 through 2019 (USDA AMS). Daily steer byproduct values were averaged and aggregated to quarterly values in the same manner as the hide price data described previously. The use of quarterly data provided sufficient degrees of freedom for the regression analysis, while allowing for a complete series of other explanatory variables to be collected. The price of butt branded steer hides is also used in the regression analysis. In addition to being the most consistently available data, this series most closely matches the dependent variable price series (i.e., steer prices).

It is recognized that hides obtained from heifers and cull cows are less valuable than those obtained from steers (figure 2). Nonetheless, figure 2 indicates that all three price series are highly correlated. Regression analyses require the use of time-series data that are consistently reported. In some quarters, the heifer and cow hide data in figure 2 represent only a few daily observations. Consequently, the regression analysis focuses on steer hide prices. However, the high degree of correlation among the hide price series suggests that similar marginal effects would likely be obtained if regression models could be developed for heifer or cow production.

Table 2. Variable Definitions, Data Sources, and Descriptive Statistics.

Variable	Source	Symbol	Mean	Coefficient of Variation
Live Cattle Futures Price (dollars/cwt, deflated)	Quandl, LC1	DP^{lc}	$116.06	0.17
Quantity of Steer Slaughter (million head – quarterly)	USDA ERS Livestock & Meat Domestic Data	Q^{ss}	4.272	0.08
Feeder Cattle Futures Price (dollars/cwt, deflated)	Quandl, FC1	DP^{fc}	$138.31	0.23
Price of Corn (dollars/bushel, deflated)	USDA ERS Feed Grains Yearbook	DP^{c}	$4.11	0.35
Price of Wholesale Beef (dollars/pound, deflated)	USDA ERS Meat Price Spreads	DP^{w}	$2.97	0.16
Value of All Steer Byproducts (dollars/cwt of live animal, deflated)	USDA Agricultural Marketing Service	n.a	$12.22	0.18
Price of Butt Branded Steer Hides (dollars/head, deflated)	USDA Agricultural Marketing Service	DP^{sh}	$83.91	0.23
Dressed Weight of Fed Steers (pounds/head)	USDA ERS Livestock and Meat Domestic Data	n.a.	830.7	0.05
Live Weight of Fed Steers (pounds/head)	Author Calculation	n.a.	1,318.6	0.05
Total Value All Steer Byproducts (dollars/head, deflated)	Author Calculation	n.a.	$161.26	0.19
Value of Other Steer Byproducts (dollars/head, deflated)	Author Calculation	DV^{os}	$77.35	0.29
Gross Domestic Product Implicit Price Deflator (2019,4=100)	Federal Reserve Bank of St. Louis	n.a.	n.a.	n.a.

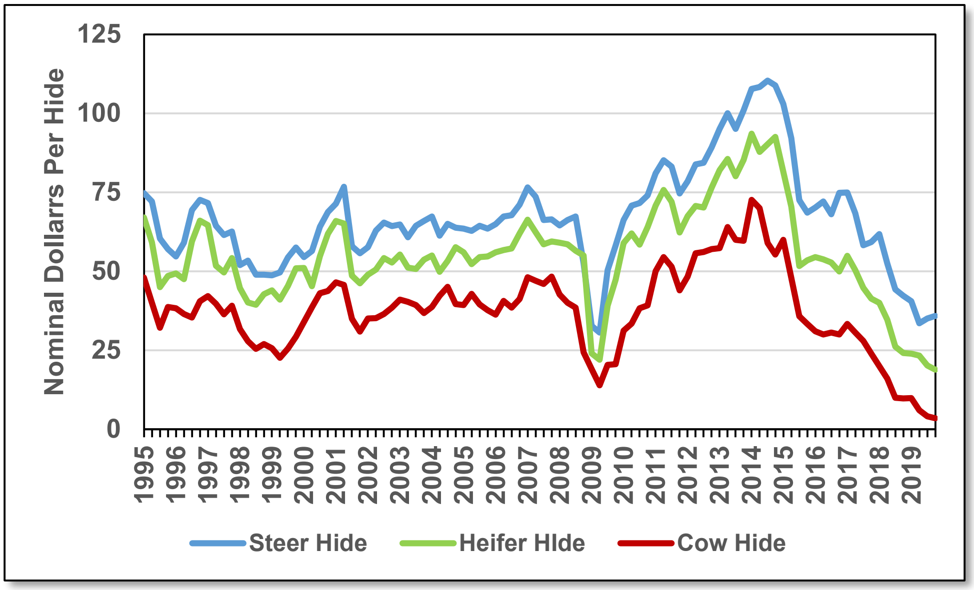

Figure 2. Quarterly Values of Steer, Heifer, and Cow Hides, 1995-2019.

Hide values were obtained on a per animal (i.e., per hide) basis, while the value of all byproducts were reported on a per hundredweight of live animal basis. Data on the average live weight of fed steers were not available. However, the monthly average dressed weight of steers was available for the entire data period (USDA ERS). Steer dressing percentages average 63% (Gould, Lindquist, and Schweihofer, 2018). Therefore, we estimate the monthly average live weight of fed steers by dividing fed steer dressed weights by 63%. The simple average of these monthly values was used to construct quarterly values. The value of all steer byproducts was then multiplied by the number of hundredweights per head of fed steers to obtain a total byproduct value per head. The price of hides (which is also the per head value) was subtracted from the value of all byproducts to obtain the value of all non-hide steer byproducts.

We use the weekly average of daily closing values from nearby CME live cattle futures contracts for the price of fed steers and CME feeder cattle futures contracts for the price of feeder cattle (Quandl). Futures prices were used because a consistent monthly/quarterly price series for fed steer and feeder cattle prices was unavailable for the time period considered. Weekly cattle futures prices are highly correlated with cash fed steer and feeder steer prices as the contracts are specific to those animals. Weekly values were aggregated to quarterly values using simple averages

Corn prices represent the per bushel price of number 2 yellow corn received by farmers (USDA ERS). The data were obtained on a monthly basis, and simple averages were used to develop quarterly prices. The price of wholesale beef was obtained from USDA ERS. The prices are reported in cents per pound on a monthly basis but were converted to dollars per pound for the analysis. Quarterly values were obtained using a simple average of monthly values. The number of steers slaughtered were obtained on a monthly basis and then summed to quarterly values (USDA ERS).

All price variables were deflated by the GDP Implicit Price Deflator, which was adjusted to reflect current dollar values as noted earlier.

Regression Analysis: Estimation

Ordinary Least Squares was initially used to estimate equation (2). Initial regression results indicated the presence of first-order autocorrelation among the residuals. This is a common occurrence when using time-series data. Therefore, final estimates were obtained from the Generalized Least Squares estimation of equation (2) so that the standard errors of the regression coefficients were consistently estimated. The statistical software package *R* (2012) was used for the regression analysis.

Regression Analysis: Results

Several variations of equation (2) were estimated, and the specification was augmented in several ways. For example, binary seasonal (quarterly) variables were included in initial regressions because of the seasonality of U.S. cattle production. However, the steer slaughter quantity variable (Q_t^{ss}) appears to account for this effect. Consequently, seasonal binary variables were not included in the final specification. In addition, a lagged dependent variable (DP_{t-1}^{lc}) was included in several specifications. Lagged dependent variables are often included in time-series regressions to account for industry dynamics. However, a lagged dependent variable was not statistically significant in any of the initial models.

The final regression specification and results are reported in equation (3):

$$
\begin{aligned}
(3) \quad DP_t^{lc} = 44.80 &- \underset{(-8.65)}{8.68}\, Q_t^{ss} + \underset{(9.50)}{0.24}\, DP_t^{fc} + \underset{(6.09)}{1.86}\, DP_t^{c} + \underset{(8.96)}{16.39}\, DP_t^{w} \\
&+ \underset{(1.48)}{0.046}\, DV_t^{os} + \underset{(8.70)}{0.181}\, DP_t^{sh} + \underset{(2.01)}{0.20}\rho_{t-1}
\end{aligned}
$$

Number of Observations: 100
Durbin-Watson Statistic: 1.572
Adjusted R^2: 0.974
Standard Error of Regression: 3.10
Degrees of Freedom: 93

where ρ_{t-1} represents a first-order autocorrelation parameter and the values in parentheses are *t*-values.

Regression Analysis: Model Selection

The two primary statistics used to select the final model specification were the standard error of the regression and the adjusted R^2. The standard error of the regression indicates the in-sample predictive capabilities of the selected model. Smaller values are indicators of better models. In equation (3), the standard error of the regression is 3.10. This indicates that 95% of the in-sample predictions of steer prices, provided by the estimated equation, fall within two standard errors on each side of the mean of the dependent variable ($116.06/cwt). In this case, the 95% confidence interval for the model's predictions would lie between $109.86/cwt and $122.26/cwt.

The adjusted R^2 statistic measures the amount of steer price variability that can be explained by the selected model after adjusting for the number of variables being used. Values for the adjusted R^2 can range from 0.0 to 1.0. The adjusted R^2 statistic of 0.974 is quite high and indicates that 97.4% of the variation in the price of steers is explained by the selected model.

The Durbin-Watson statistic is used to detect the presence of autocorrelated errors among the regression residuals. The presence of autocorrelation reduces the consistency of the parameter estimates, which causes the precision of those estimates to be incorrectly calculated. This generates incorrect estimates of *t*-values. The Durbin-Watson statistic was used in initial regression models to ascertain the presence of autocorrelation. After including an autoregressive error parameter (ρ_{t-1}) in equation (3), the Durbin-Watson statistic is 1.572. The lower critical value for 100 observations and 6 non-constant regressors is 1.550. Hence, the Durbin-Watson statistic for the selected model is unable to reject the null hypothesis that the regression errors are not autocorrelated.

Finally, the numbers in parentheses in equation (3) represent *t*-values, which are used to determine if the estimated coefficients are statistically different from 0. Given the number of observations used in the regression model, the critical (absolute value) *t*-value that provides a 95% probability that an estimated coefficient is not 0 is 1.99. That is, *t*-values that are greater in absolute value than 1.99 indicate that there is at least a 95% probability that the estimated coefficient is statistically different from zero. This is the standard level of significance used by most research studies.

All of the coefficient estimates are highly statistically significant with one exception. The *t*-value for the deflated value of other (non-hide) steer byproducts (DV_t^{os}) is 1.48. This indicates there is only an 85% probability that the estimated coefficient (0.046) on this variable is statistically different from zero. Given that excluding the variable from the specification would likely cause a specification error which could influence the other parameter estimates -- and that we are not specifically interested in its estimated value -- we decided to retain the variable in the final model specification.

Regression Analysis: Interpretation of Coefficient Estimates

The estimated coefficient (-8.68) on the steer production variable (Q_t^{ss}) in equation (3) indicates that a 1 million head increase in quarterly steer production (about a 25% increase) would cause the price of steers to decline by $8.68/cwt. It should be noted that this inverse relationship can also be interpreted for a decrease in steer production. The other coefficients in the model all have a positive relationship with fed steer prices. For example, a $1/cwt increase (decrease) in the price of feeder steers (DP_t^{fc}) would cause a $0.24/cwt increase (decrease) in the price of fed steers. The other "cost" driver in the reduced form equation is the price of corn (DP_t^{c}). A $1/bushel increase (decrease) in the price of corn would cause a $1.86/cwt increase (decrease) in the price of steers.

The remaining variables in equation (3) represent the value of output produced by cattle processors. When the price of wholesale beef (DP_t^{w}) increases by $1/lb (about 33% of the mean value), the price of fed steers increases by $16.39/cwt. Non-hide steer byproducts result from processing cattle. When the value of non-hide steer byproducts (DV_t^{os}) increases by $1/head, the price of fed steers increases by $0.046/cwt assuming that the estimated coefficient is statistically different from 0. Note that the same decrease in this variable would be associated with an identical decrease in steer prices.

Finally, the price (value) of steer hides (DP_t^{sh}) is also positively related to the price of steers. The estimated coefficient of 0.181 indicates that a $1/head increase in hide value (which is synonymous with a $1 increase in the price of butt branded steer hides) causes an $0.18/cwt increase in steer prices. Given that the mean value of steer prices in the data set is $116.06/cwt (table 2), an $0.18/cwt increase is quite small.

Another way to envision the scale of these effects is to consider the increase in hide values that would be necessary to cause a 1% increase in fed steer prices. Given the regression results and the means of the data, the value of steer hides would have to increase by $6.44/head to generate a 1% increase in the price of fed steers. That is, the value of hides would have to increase by almost 8% (relative to its mean value) in order to generate a 1% increase (i.e., $1.16/cwt) in fed steer prices.

Calculating the Indirect Impact of Hide Prices/Value on Cattle Production

Although the estimated coefficient for hide value in equation (3) is statistically different from zero, this does not mean it is necessarily *economically* significant. The statistical significance of an estimated coefficient is not subject to value judgements other than a researcher's desired probability level for significance. Conversely, ascertaining whether or not an estimated coefficient is economically significant certainly involves value judgements. Nonetheless, an examination of the relative size of such an estimate provides some weight to the discussion.

One way to evaluate the relative size of an estimated coefficient is to develop an elasticity based on the regression results. An elasticity is a unit-less measure of the impact that one variable has on another. Specific to this example, a measure of the responsiveness of steer prices to changes in the price of hides can be informative. To calculate this measure using the regression results, the estimated hide price coefficient of 0.181 in equation (3) is multiplied by the quotient of the average price of hides and the average price of steers. Using the data presented in table 2 and the coefficient estimate presented in equation (3), this elasticity is given by:

$$(4) \qquad E_{s,h} = \frac{percent\ change\ in\ steer\ price}{percent\ change\ in\ hide\ price} = \frac{\partial P^{lc}}{\partial P^{sh}} * \frac{\overline{P^{sh}}}{\overline{P^{lc}}} = 0.181 * \left(\frac{\$83.91}{\$116.06}\right) = 0.13,$$

where $E_{s,h}$ is the elasticity of steer prices with respect to steer hide prices. The interpretation of equation (4) is that for every 1% increase in hide price, steer prices increase by 0.13%. This value is very similar to elasticities reported in other published research with respect to farm byproduct values (Brester and Marsh, 1983; Marsh and Brester, 1989, 2004). It is often informative to consider the impact of a 10% increase in hide price rather than a 1% increase. Hence, a 10% increase in steer hide prices causes a 1.3% increase in fed steer prices. Because the elasticity estimate is much closer to 0 than to 1, the responsiveness of steer prices to changes in hide prices is considered to be highly inelastic (i.e., not very responsive).

The estimated elasticity in equation (4) can be combined with other research results to obtain an estimate of the indirect impact of hide prices on cattle production. McKendree, *et al*. (2020) estimate the long run own-price elasticity of fed cattle supply as 0.24 using quarterly data. Therefore, a 1% increase in the price of fed cattle would cause a 0.24% increase in the quantity supplied of fed cattle. Multiplying our estimate of a 1.3% increase in steer prices (caused by a 10% increase in the price of steer hides) with the fed cattle own-price elasticity of supply (0.24) yields a 0.31% increase in the number of steers produced. Therefore, the indirect effect of a 10% increase in the price of hides is expected to be a 0.31% (about one-third of 1%) increase in fed cattle production.

U.S. fed steer and heifer slaughter totaled 26.36 million head in 2019. Hence, a 10% increase in steer hide prices would cause an (0.0031*26.36 million) 81,700 head increase in steer slaughter numbers. Although the regression analysis uses steer prices and steer production numbers, the estimate of 81,700 head can be broadened to include a combination of steers and heifers. In addition, it is recognized that, if the U.S. cattle production system were to experience an 81,700 head increase in the production of fed cattle, then an additional 81,700 head of breeding cows (or probably a little more because of death loss, unsuccessful pregnancies, etc.) would be needed to produce those animals.

On January 1, 2019, the U.S. cattle inventory totaled 94.8 million head. An additional 163,400 head of cattle (cows plus steers and heifers) caused by a potential 10% increase in hide prices represents a 0.17% increase in the total U.S. cattle inventory. Stated differently, a 10% increase in hide value would likely increase cattle inventories by less than 2 head for every 1,000 head that currently exist. Because steer hides are more valuable than most other hide types, our analysis likely provides an upper bound on the effects of hide values on total cattle production.

Summary and Conclusions

In terms of total revenue, the cattle/beef industry is the largest U.S. food sector. More than 30 million head of cattle are processed annually. Most of these are grain-fed steers and heifers, while the remainder consist of cull cows, cull bulls, and some calves. The primary output of this process is beef products that are both consumed domestically and exported. The processing of cattle generates a wide variety and substantial amount of edible and inedible byproducts. Byproducts represent 8%-12% of the value of fed cattle. Consequently, increases or decreases in byproduct values likely influence cattle prices.

This report investigates whether a specific component of byproducts (hide values) influences cattle production numbers. This influence could be in the form of a *direct* effect in which changes in cattle hide values directly cause changes in the production of fed cattle. We investigate this possibility using Granger causality tests. Specifically, we test whether hide values have a direct causal relationship with cattle production numbers. Granger causality tests indicate that this direct relationship does not exist. That is, there is no quantitative evidence that cattle hide prices directly influence cattle production numbers.

It is possible (and given past research, probable) that hide values have an *indirect* effect on cattle production. Previous research indicates that cattle byproduct values influence cattle prices, and cattle prices influence cattle production. Several research efforts have found this to be a statistically significant, positive relationship. However, the size of this relationship has historically been found to be relatively small. Nonetheless, as cattle prices increase (decrease), cattle production will increase (decrease). Although the direction of these movements is not in question, the size of the impacts requires a quantitative evaluation. We use regression analyses and elasticity estimates to evaluate the potential indirect effect of hide values on cattle production. We follow published research methodologies and develop a reduced form regression model to estimate the impact of steer hide values on fed steer prices. The regression results indicate that a statistically significant relationship exists between these two metrics. Nonetheless, the size of this relationship is relatively small. We find the cross-price elasticity of steer prices with respect to hide prices to be very inelastic (0.13). That is, while steer prices respond to changes in hide prices, the response is quite small. For example, a 10% increase (decrease) in hide values is expected to cause a 1.3% increase (decrease) in fed steer prices. Although we use more recent data than previous studies, our results are consistent with prior published research.

We combine our estimated cross-price elasticity of steer prices to steer hide prices with a recent estimate of the own-price elasticity of fed cattle supply. The result is that a 10% increase in the price of hides is expected to cause a 0.31% (about one-third of 1%) increase in fed cattle production. Given the size of the U.S. cattle industry, we find that a 10% increase in the price of hides is likely to cause an additional 163,400 head of cattle (cows plus steers and heifers) to be produced. This represents about a 0.17% increase in the U.S. cattle inventory.

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