QUANTIFYING THE RELATIONSHIP BETWEEN BRAZILIAN CATTLE HIDE PRICES AND BRAZILIAN CATTLE PRODUCTION

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Executive Summary

A quantitative economic analysis of the potential impact of hide prices on Brazilian 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 prices 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 Brazilian cattle production quantities. These tests were conducted using annual hide prices obtained from the Leather and Hide Council of America and numbers of cattle slaughtered obtained from USDA-FAS. The Granger causality tests do not provide any evidence that hide prices directly influence the quantity of cattle slaughtered.

Several studies indicate that cattle hide prices (as well as other cattle processing byproduct prices) influence cattle prices. Because cattle prices influence cattle production, cattle hide prices may have an *indirect* effect on cattle production. To investigate the potential size of this *indirect* impact, a reduced form regression model is estimated to quantify the effect of Brazilian hide prices on "fat cattle" prices. The model estimates this relationship to be highly inelastic (0.15). This elasticity is combined with a recently published estimate of the U.S. 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 0.36% (i.e., just over one-third of 1%) increase in cattle production. Because this small increase in cattle production would necessitate an increase in breeding cattle numbers, the total *indirect* effect of a 10% increase in Brazilian hide prices would be an increase of 283,800 head of cattle (breeding cows plus calves). This represents about a 0.12% increase in Brazilian cattle inventories.

In summary, we find *no evidence of a direct effect* of cattle hide prices on cattle production and evidence of only a *small indirect effect*.

Quantifying the Relationship Between Brazilian Cattle Hide Prices and Brazilian Cattle Production

Introduction

This report presents a quantitative economic analysis of the relationship between Brazilian cattle hide prices and their potential impact on Brazilian cattle production. Cattle are produced to meet consumer demands for beef products. Cattle hides and edible/inedible byproducts result from the production of consumer beef products. Nonetheless, economic theory suggests that byproduct values 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 Brazilian hide prices have a direct effect on Brazilian cattle production. We use annual data from 1980-2019 for the number of cattle slaughtered as a measure of cattle production.

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 indirectly related to cattle production. Based on previously published research, however, this impact is likely to be small. We use linear regression techniques and annual data from 1997-2019 to quantify this relationship.

The Structure of the Brazilian Cattle and Beef Industry

Brazil's January 1, 2020 cattle inventory was just over 244 million head and represents the second largest in the world (USDA FAS). Brazilian beef production systems are primarily based on grass feeding (as opposed to high energy grain rations in the United States). Only about 14% of Brazilian cattle are fed grain rations, and most of those are fed for only a short time. The grass feeding approach causes the average slaughter age of Brazilian cattle to be 4 years compared to the U.S. average of 2 years. In addition, Brazilian cattle carcasses weigh about 33% less than U.S. carcasses (Gurney, 2018). In 2020, Brazil produced 10 million metric tons of beef. For comparison, the United States produced 12.4 million metric tons of beef in 2020 with a beginning cattle inventory of only 93.8 million head. Brazil exports about 20% of domestic production (USDA FAS). In addition, Brazil is the largest beef exporter and represents about 20% of total world beef exports (Zia, Hansen, Hjort, and Valdes, 2021). China and Hong Kong are the top export destinations for Brazilian beef exports.

Cattle processing produces meat and substantial amounts of byproducts. That is, only about 30% of the live weight of Brazilian cattle become edible beef products. The remaining 70% consists of various edible (e.g., hearts, kidneys, etc.) and inedible (e.g., hides, tallow, bone meal, etc.) byproducts. Hides are generally used by leather product manufacturing companies.

Granger Causality Testing for Direct Impacts of Hide Prices Brazilian 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 precede changes in another variable. These tests have been 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 variable. 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:

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

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

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 the price of hides lead to changes in the quantity of cattle slaughtered. Thus, the null hypothesis is that hide prices do not cause changes in slaughter quantities. Hide prices are the *X* variable and slaughter quantities are the *Y* variable in the above models.

Causality Tests: Data

The Leather and Hide Council of America provided data on Brazilian cattle hide values, which were labeled "*Estastica Preço Couro Verde*" (translated in English as "Green Leather Price"). These data contained two different hide price series: (1) the price of hides for "Branded Cows", and (2) a "unified price for Brazilian Hides." Both prices are expressed in U.S. dollars per kilogram of hide weight and were consistently available on an annual basis from 1980 through 2019. We use data for both hide types in our analysis.

Granger causality tests are often conducted on data that have been adjusted for inflation (i.e., deflated). The prices for Brazilian Hides and Branded Cow Hides, however, are reported in U.S. dollars. In addition, Brazil has experienced periodic high inflation rates and currency revaluations. Because of these complications, the following tests use nominal values.[1]

Data for the total quantity of cattle slaughtered in Brazil were obtained from the U.S. Department of Agriculture's Foreign Agricultural Service (USDA FAS). The annual data for total cattle slaughter numbers from 1980 through 2019 are expressed in millions of head.

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

Table 1 displays results of ADF tests for stationarity for Brazilian total annual cattle slaughter and both annual hide price series. The null hypothesis for the ADF test is that the data are non-stationary. The ADF tests failed to reject the null hypothesis for all three data series in levels, suggesting that all three are non-stationary in levels. Consequently, all three data series were first-differenced (converted to a series of changes from the previous period). This is a common approach to account for non-stationarity in time-series data. After first-differencing all three variables, the ADF test statistics rejected the null hypothesis at less than a 5% significance level. Therefore, the first-differenced data for all three variables are stationary and used for the following causality tests.

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[1] To test the sensitivity of the results to inflation adjustments, additional tests were conducted after deflating both price series using two different indices – the U.S. Consumer Price Index and the U.S. Gross Domestic Product Implicit Price Deflator. Deflating the data using these indices did not qualitatively affect the test results.

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

Variable	Form	N	Test Stat (*p*-value)	Stationary?
Brazil Total Cattle Slaughter	Levels	40	-1.858 (0.629)	No
	1st Difference	39	-4.219 (**0.012**)	**Yes**
Brazilian Hide Price	Levels	40	-2.735 (0.285)	No
	1st Difference	39	-6.874 (***<0.01***)	***Yes***
Brazilian Branded Cow Hide Price	Levels	40	-1.314 (0.843)	No
	1st Difference	39	-5.593 (***<0.01***)	***Yes***

Note: *p*-values shown in parentheses; **bold** or ***bold italics*** indicate significance at **5%** or ***1%*** levels, respectively. Results are displayed for ADF tests of lag order k=1.

Causality Testing: Specification and Results

The purpose of the causality tests is to determine if sufficient evidence exists of a direct effect of hide prices on cattle production. The expected producer supply 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 until a calf reaches slaughter weight takes 3 to 4 years in Brazil (Peck, 2005). The only way to produce more 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.

A Granger test was specified using stationary first-differenced annual cattle slaughter quantity data and Brazilian hide prices to test the null hypothesis:

H_o: *Cattle hide prices* ***do not*** *Granger cause cattle slaughter quantities*

H_a: *Cattle hide prices Granger* ***cause*** *cattle 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 annual data were conducted using a lag order of four (*m*=4) to span a roughly four-year process of producing slaughter cattle in Brazil. Tests were conducted using both hide price series. For Brazilian Hide prices, the test generated an *F*-statistic of 0.969, with an associated *p*-value of 0.441. For Brazilian Branded Cow hide prices, the test produced an *F*-statistic of 0.129 and associated *p*-value of 0.970. Therefore, the null hypothesis that hide prices do not Granger cause cattle slaughter quantities could not be rejected using either Brazilian hide price series.

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

H_o: *Cattle slaughter quantities* ***do not*** *Granger cause cattle hide prices*

H_a: *Cattle slaughter quantities Granger* ***cause*** *cattle hide prices.*

There was no statistical evidence for reverse causality in either case (Brazilian hide price: *F*-statistic = 0.857, *p*-value = 0.504; Brazilian branded cow hide price: *F*-statistic = 0.607, *p*-value = 0.662).

Causality Testing: Interpretation

Granger causality tests were used to determine if hide prices have a direct effect on cattle production. The tests were conducted using annual data for Brazilian Hide prices and Branded Cow Hide prices. Lag length selection was based on industry knowledge and statistical procedures. The test results provide no statistical evidence that Brazilian cattle hide prices Granger-cause Brazilian cattle slaughter 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 prices (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 in the United States. 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 to farm byproduct values is also quite inelastic (0.16).

Brester and Swanser (2021) use U.S. quarterly data from 1995 through 2019 to estimate the effects of steer hide prices and other byproduct values on fed steer prices. Their econometric estimates indicate that the elasticity of fed steer prices with respect to steer hide prices is 0.13. Thus, for a 10% increase in hide prices, fed steer prices increase by 1.3%. 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).

Regression Analysis: Specification

The research methodology and specification used to quantify the impact of hide values on the price of Brazilian cattle is based on published research. 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 a structural model in which separate demand and supply functions are estimated. 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).

Therefore, we specify a reduced form equation in which the price of Brazilian fat cattle is the dependent variable. In a general form, we use the following reduced form specification:

(1) $$P_t^c = f\left(Q_t^s,\ P_t^h,\ P_t^e,\ CPI_t^{us},\ T\right)$$

where P_t^c is the price of Brazilian fat cattle (in time period *t*), Q_t^s is the quantity of cattle slaughtered, P_t^h is the price of cattle hides, P_t^e is the price of Brazilain beef exports, CPI_t^{us} is the U.S. Consumer Price Index, and *T* is a time trend.

The quantity of cattle slaughtered (Q_t^s) is expected to have an inverse relationship with the price of fat cattle (P_t^c). The price of hides (P_t^h) is expected to have a positive relationship with the price of fat cattle. Although hides are a byproduct of cattle processing, they contribute to the profitability of processing firms. A price series for the Brazilian domestic price of beef (which is the primary output of cattle production) is not available. Therefore, we use the price of Brazilian beef exports (P_t^e) as a proxy. The expectation is that the export price of beef is a close proxy to the Brazilian domestic price of beef and positively related to the price of fat cattle. The U.S. consumer price index (CPI_t^{us}) is included in the model to account for general inflationary effects. That is, the prices of fat cattle, hides, and beef exports are all reported in U.S. dollars. Consequently, the U.S. consumer price index is included to account for inflationary effects on U.S. dollar denominations. A linear time trend (*T*) is also included in the model.

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 facilitate comparisons of the variability of each data series relative to their mean values. The price of Brazilian beef exports was calculated by dividing the total value of beef exports (in US $/kg) by the total kilograms of beef exports (UN Comtrade). The average price of beef exports over the period was US $4.96/kg.

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

Variable	Source	Symbol	Mean	Coefficient of Variation
Quantity of Cattle Slaughter (million head)	USDA FAS Production, Supply, and Disappearance Data	Q^s	37.154	0.11
Price of Brazilian Hides "Green Leather Price" (U.S. dollars/kg)	LCHA	P^h	$0.76	0.33
Price of Fat Cattle (U.S. dollars/kg)	CEPEA	P^c	$2.32	0.39
Price of Beef Exports (U.S. dollars/kg)	UN Comtrade	P^e	$4.96	0.28
U.S. Consumer Price Index (2019=100)	Federal Reserve Bank of St. Louis	CPI^{us}	n.a.	n.a.
Trend	n.a.	T	n.a.	n.a.

Regression Analysis: Estimation

Ordinary Least Squares was initially used to estimate equation (1). Preliminary 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 (1) so that the standard errors of the regression coefficients were consistently estimated. The statistical software package *R* (2020) was used for the regression analysis.

Regression Analysis: Results

Several variations of equation (1) were estimated, and the specification was augmented in several ways. The final regression specification and results are reported in equation (2):

(2) $$P_t^c = -18.28 - 0.10\, Q_t^s + 0.45\, P_t^h + 0.22\, P_t^e + 0.35\, CPI_t^{us} - 0.47\, T + 0.47\rho_{t-1}$$
$$(-5.80)\ (-2.88)\quad (2.45)\quad (2.98)\quad (4.89)\quad (-4.55)\quad (2.53)$$

Number of Observations: 23
Durbin-Watson Statistic: 0.999
Adjusted R^2: 0.896
Standard Error of Regression: 0.30
Degrees of Freedom: 16

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 (2), the standard error of the regression is 0.30. This indicates that 95% of the in-sample predictions of cattle prices, provided by the estimated equation, fall within two standard errors on each side of the mean of the dependent variable (US $2.32/kg). In this case, the 95% confidence interval for the model's predictions would lie between US $1.72/kg and US $2.92/kg.

The adjusted R^2 statistic measures the amount of fat cattle 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 0.896 is quite high and indicates that 89.6% of the variation in the price of fat cattle 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 of 0.999 indicates the presence of autocorrelation. Therefore, an autoregressive error parameter (ρ_{t-1}) is included in equation (2).

Finally, the numbers in parentheses in equation (2) represent *t*-values, which are used to determine if the estimated coefficients are statistically different from 0. Given the degrees of freedom in the regression model, the critical (absolute value) *t*-value that provides a 95% probability that an estimated coefficient is not zero is 2.11. That is, *t*-values greater in absolute value than 2.11 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 in equation (2) are statistically significant.

Regression Analysis: Interpretation of Coefficient Estimates

The estimated coefficient (-0.10) on the cattle production variable (Q_t^s) in equation (2) indicates that a 1 million head increase in annual cattle production (about a 2.5% increase from 2019 levels) would cause the price of cattle to decline by US $0.10/kg. It should be noted that this inverse relationship can also be interpreted for a decrease in cattle production. The price of Brazilian beef exports has a positive relationship with cattle prices. For example, a US $1/kg increase (decrease) in the price of beef exports (P_t^e) would cause a US $0.22/kg increase (decrease) in the price of fat cattle. The U.S. consumer price index (CPI_t^{us}) also has a positive relationship with fat cattle prices, while the linear trend variable (T) has a negative relationship with fat cattle prices.

Finally, the price of cattle hides (P_t^h) is positively related to fat cattle prices. The estimated coefficient of 0.45 indicates that an increase of US $1/kg in hide price causes a US $0.45/kg increase in fat cattle prices. However, the mean value of hide price is US $0.76/kg. Therefore, a US $1/kg increase in hide price would represent an (unrealistic) 130% increase relative to its mean value. The coefficient may be better interpreted by considering that a 10% increase in hide value relative to its mean (US $0.076/kg) would cause a US $0.03/kg increase in fat cattle prices which is a relatively small increase.

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

Although the estimated coefficient for hide price in equation (2) 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 fat cattle 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 0.45 in equation (2) is multiplied by the quotient of the average price of hides and the average price of fat cattle. Using the data presented in table 2 and the coefficient estimate presented in equation (2), this elasticity is given by:

$$(3) \qquad E_{c,h} = \frac{percent\ change\ in\ fat\ cattle\ price}{percent\ change\ in\ hide\ price} = \frac{\partial P^c}{\partial P^h} * \frac{\overline{P^h}}{\overline{P^c}} = 0.45 * \left(\frac{\$0.76}{\$2.32}\right) = 0.15,$$

where $E_{c,h}$ is the elasticity of fat cattle prices with respect to hide prices. The interpretation of equation (3) is that for every 1% increase in hide price, fat cattle prices increase by 0.15%. 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) and a recent elasticity estimate of 0.13 for the United States (Brester and Swanser, 2021). Because the elasticity estimate is much closer to 0 than to 1, the responsiveness of fat cattle prices to changes in hide prices is considered to be highly inelastic (i.e., not very responsive). 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 hide prices causes a 1.5% increase in fat cattle prices.

The estimated elasticity in equation (3) can be combined with other research results to obtain an estimate of the indirect impact of hide prices on cattle production. The procedure requires an estimate of the Brazilian own-price elasticity of supply of cattle. Such an estimate does not exist for the Brazilian industry. However, McKendree, *et al*. (2020) estimate the long run own-price elasticity of U.S. fed cattle supply as 0.24. Therefore, a 1% increase in the price of fed cattle would cause a 0.24% increase in the quantity supplied of fed cattle in the United States.

We use the estimate from the U.S. cattle industry as a proxy for Brazil's own-price elasticity of supply. We multiply our estimate of a 1.5% increase in fat cattle prices (caused by a 10% increase in the price of cattle hides) with the U.S. fed cattle own-price elasticity of supply (0.24) to yield a 0.36% increase in the number of Brazilian fat cattle produced. Therefore, the indirect effect of a 10% increase in the Brazilian price of hides is expected to be a 0.36% (about one-third of 1%) increase in Brazilian cattle production.

Brazil's cattle slaughter totalled 39.42 million head in 2020. Hence, a 10% increase in cattle hide prices would cause an (0.0036*39.42 million) 141,900 head increase in cattle slaughter numbers. If the Brazilian cattle production system were to experience a 141,900 head increase in the production of cattle, then an additional 141,900 head of breeding cows (or probably a little more because of death loss, unsuccessful pregnancies, additional bulls, etc.) would be needed to produce those animals.

On January 1, 2020, the Brazilian cattle inventory totalled 244.1 million head. An additional 283,800 head of cattle (cows plus calves) caused by a potential 10% increase in hide prices represents a 0.12% increase in the total Brazilian cattle inventory. Stated differently, a 10% increase in hide value would likely increase cattle inventories by just over one animal for every 1,000 animals that currently exist.

Summary and Conclusions

This report investigates whether a specific component of cattle byproduct values (Brazilian hide prices) influence Brazilian 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 cattle production. We investigate this possibility using Granger causality tests. Specifically, we test whether changes in hide values changes directly cause changes in cattle production numbers. The 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. Previous research of U.S. cattle markets has 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 this movement 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 Brazilian cattle production. We follow published research methodologies and develop a reduced form regression model to estimate the impact of cattle hide prices on fat cattle 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 price elasticity of fat cattle prices with respect to cattle hide prices to be very inelastic (0.15). That is, while fat cattle 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 1.5% increase (decrease) in fat cattle prices.

We combine our estimated elasticity of fat cattle prices to hide prices with a recent estimate of the own-price elasticity of U.S. fed cattle supply. We find that a 10% increase in the price of Brazilian hides is expected to cause a 0.36% (about one-third of one percent) increase in Brazilian cattle production. Given the size of the Brazilian cattle industry, a 10% increase in the price of hides is likely to cause an additional 283,800 head of cattle (cows plus calves) to be produced. This represents a 0.12% increase in the Brazilian cattle inventory.

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