Journal of Agribusiness 35, 2 (Special Issue, Fall 2017)

Forecasting Quality Grade and Certified Angus Beef Premiums

Jason Franken and Joe Parcell

We determine the mean squared error and mean absolute percentage error of alternative forecasts of quality grade and Certified Angus Beef® (CAB) premiums, which may be of interest to cow-calf producers, feeders, packers, retailers, and food service providers. A supply and demand model and a vector autoregressive (VAR) model outperform a naïve model accounting for only seasonal effects for all premiums except the strongly seasonal choice-select spread. While there is no significant difference between the supply and demand model and the VAR model in terms of mean squared error, the supply and demand model outperforms the VAR model based on the mean absolute percentage error in predicting the CAB-choice premium.

Key words*:* Beef Quality Grade, Certified Angus Beef, Forecast

Risk and uncertainty are prominent features of cattle feeding. Commercial feeders must decide to either market cattle at current weights or continue feeding, and several studies endeavor to forecast cattle prices to help inform such decisions (Bullock and Logan, 1970; Spreen and Arnade, 1984; Zapata and Garcia, 1990; Foster, Havenner, and Walburger, 1995). More recent studies investigate how marketing behavior of cattle feeders has been influenced by the transition from average lot pricing—the dominant form up to the 1990s—to a value-based (i.e., carcass-merit or grid) approach (Greer, Trapp, and Ward, 2000; Schroeder and Graff, 2000; Johnson and Ward, 2006; Fausti et al., 2014). Some studies model factors influencing one of the associated quality grade premiums/discounts (Hogan and Ward, 2003; Hogan and Ward, 2005; Hogan et al., 2012). Yet, no study attempts to forecast these values or premiums for branded programs like Certified Angus Beef® (CAB).

The objective of this study is to develop and compare the accuracy of alternative forecasts of weekly average prime-choice, CAB-choice, and choice-select premiums five months out or about the duration that cattle are on feed. Such forecasts may be useful for commercial feeders and possibly cow-calf and backgrounding operations, because producers of higher quality cattle and those who desire feedlot and carcass data for herd management decisions are more interested in retained ownership and backgrounding (Mark, Schroeder, and Jones, 2000; Franken et al., 2010; Pope et al., 2011). Additionally,

Jason Franken is an assistant professor in the School of Agriculture, Western Illinois University, Macomb. Joe Parcell is a professor in the Department of Agricultural and Applied Economics, University of Missouri, Columbia.

the retail and food service industries are becoming increasingly consolidated and sophisticated in procurement, working directly with packers in long-term formula and forward contracts (McCully, 2010). The forecasts described herein may be beneficial in facilitating exchange at this level as well.

The choice-select spread is a primary determinant of cattle feeding profitability (Anderson and Zeuli, 2001; Feuz, Ward, and Schroeder, 2002; Fausti et al., 2014; Fausti et al., 2015) and, hence, a number of studies have modeled this spread to identify factors influencing it (Hogan and Ward, 2003; Hogan and Ward, 2005; Hogan et al., 2012). Those studies find that the choice-select spread exhibits significant seasonality and is significantly explained by the percentage of beef grading choice and lagged values of the spread itself. These findings and studies forecasting cattle prices indicate that both supply-demand frameworks and time series approaches utilizing lagged values hold potential to forecast quality grade premiums. For instance, Bullock and Logan (1970) employ a supply-demand oriented framework to forecast slaughter steer prices as a function of lagged prices, predicted marketings of fed cattle, and quarterly dummy variables. Foster, Havenner, and Walburger (1995) and Zapata and Garcia (1990) develop forecasts of slaughter steer prices using various time series (e.g., autoregressive integrated moving average (ARIMA), VAR, and vector error correction) models. Spreen and Arnade (1984) compare ARIMA and supply-demand oriented models' forecasts of stocker cattle prices.

Based on these studies, one of our forecasts builds on a supply-demand oriented framework. The demand equation models grade premiums (i.e., the price of higher quality) as a function of pounds of beef carcasses by quality grade (e.g., prime, choice, select); annual U.S. population and gross domestic product (GDP); a logarithmic time trend; and monthly dummies to capture seasonality. Since cattle are fed in feedlots for around five or six months (Bullock and Logan, 1970; Foster, Havenner, and Walburger, 1995), the supply of U.S. beef in pounds grading prime, choice, select, and other is predicted by appropriately lagged Kansas City corn prices; feeder cattle and live cattle futures prices; grade premiums/discounts; and monthly reported average weight of cattle placed on feed, along with the trend and monthly dummies. These projections and U.S. Department of Agriculture (USDA) forecasts of U.S. population and real per capita GDP are entered into the demand equation to compute direct forecasts of quality grade and CAB-choice premiums. Out-of-sample performance, as measured by mean squared error (MSE) and mean absolute percentage error (MAPE), is compared to that of another direct forecast based on a naïve seasonal model and a dynamic forecast based on an autoregressive time series model that also includes lagged premiums. Recent research investigates the relative performance of direct forecasts at multiple periods out (i.e., horizon h>1) and dynamic (i.e., iterated) forecasts under various scenarios of structural shifts and statistical properties of the data with mixed results (Chevillon, 2006; Pesaran, Pick, and Timmermann, 2011).

The next two sections of this paper, respectively, describe the data and empirical procedures. Then the results are presented, followed by a discussion of their implications in the concluding section of the paper.

Data

The analysis utilizes publicly available data reported by the USDA and the CME Group spanning from November 2, 1996, through January 11, 2016 (Table 1).[1] The Livestock Marketing Information Center (LMIC) is the source of the data files constructed. Data on quality grade and CAB premiums, head of steers and heifers slaughtered, percentage of steers and heifers in each grade category, and average dressed weights for steers and heifers are available on a weekly basis. Each series on steers and heifers is multiplied to approximate the weekly supply of beef in pounds (lbs.) for each grade. The weekly data are aligned by date with daily spot corn prices and feeder and live cattle futures contract prices. Similarly, monthly average placement weights for cattle placed on feed and annual data on population and per capita GDP are included in the weekly dataset for corresponding months and years, respectively. Per capita GDP is multiplied by monthly seasonal factors for the consumer price index for uncooked beef steaks to account for seasonality in purchasing power.

Table 1. Data Sample Collected on a Weekly Basis and Sources.

Variable	Series Description	Sample Period	Original Source
P_G	Weekly average quality grade & CAB premiums & discounts ($/cwt)	11/4/1996-1/11/2016	*USDA-AMS report LM_CT155 (Pre-MPR, NW_LS195)*
Q_G	Weekly marketings by quality grade (lbs)		
	Weekly U.S. steer & heifer estimated grading (%)	2/15/1997-1/9/2016	*USDA-AMS report NW_LS196*
	× Weekly U.S. steer & heifer slaughter (1000 head)	2/15/1997-1/9/2016	*USDA-AMS report SJ_LS711*
	× Weekly average dressed weight of steers & heifers (lbs)	11/2/1996-1/9/2016	*USDA-AMS report SJ_LS711*
CARCASS_W	Weekly average dressed weight of steers & heifers (lbs)	11/2/1996-1/9/2016	*USDA-AMS report SJ_LS711*
PLACE_W	Monthly weighted average placement weight (lbs) computed from	11/1996-1/2016	*USDA-NASS Cattle on Feed report*
CORN	Daily Kansas City corn price ($/bu)	10/31/1996-1/7/2016	*USDA-AMS report SJ_Gr112*
FEEDER	Daily nearby closing feeder cattle futures price ($/cwt)	11/4/1996-1/11/2016	*CME Group*
FAT	Daily nearby closing live cattle futures price ($/cwt)	11/4/1996-1/11/2016	*CME Group*
POP	Annual U.S. population	1997-2016	*USDA-ERS International Macroeconomic Data Set*
GDP	Annual U.S. real per capita GDP (2010 $)	(2015, 2016 projected)	
	× (1 – (1 + monthly CPI seasonal factor))	1997-2016	*Bureau of Labor Statistics*

Premiums are graphed in Figure 1 for the sample period, and summary statistics are given in Table 2. Discounts for quality grades below choice are adjusted to positive

[1] Though the USDA grid summary report is the most readily available public source, it is not volume-weighted, meaning that the data may not represent actual market average premiums and discounts (Hogan, Anderson, and Schroeder, 2009).

values so that we can evaluate premiums for each incremental increase in quality grade, which simplifies the interpretation of regression results. Quality premiums vary considerably. *Prime-Choice* remains fairly steady from the start of the sample through the early 2000s and then trends upward overall with greater variation, which may reflect growing value placed on prime beef and changes in the characteristics of cattle that are marketed as CAB and choice over the sample period (Figure 1). A similar, though less pronounced, upward trend is visible in *CAB-Choice*, and *Select-Standard* also trends upward starting around 2005, but with much greater variability. Overall, *Choice-Select* exhibits the greatest variation and *CAB-Choice* the least with standard deviations of 4.25 and 1.03, respectively (Table 2). At $2.39/hundredweight (cwt), *CAB-Choice* is also the smallest premium on average, while *Standard-Select*, as the largest, is nearly five times as large.

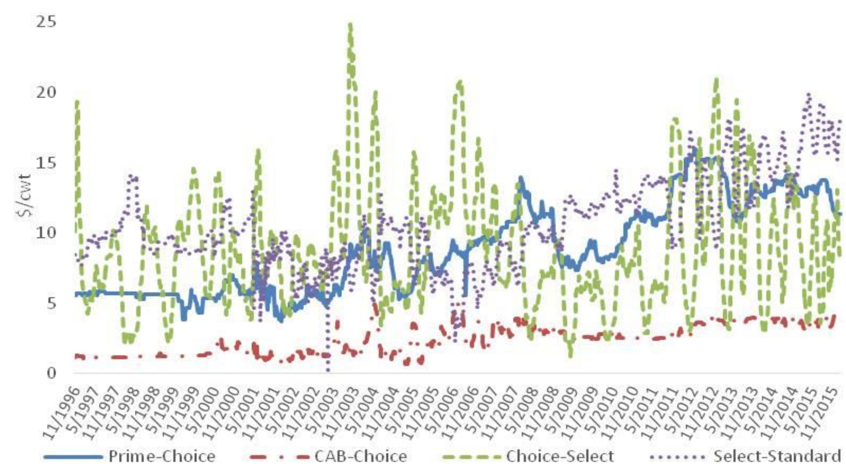


Figure 1. Beef Quality Grade and CAB Premiums, 11/4/1996-1/11/2016.

While placement and dressed weights also vary substantially, cattle are placed on feed at an average weight of about 705 lbs. and harvested with dressed weights of about 792 lbs. Steer & Heifer Slaughter ranges from about 308,260 to 656,360 head per week (Table 2). Multiplying this series by the percentage of cattle in each grade yields the number of head in each grade category, which is then multiplied by the average carcass dressed weight for all steers and heifers to approximate the pounds of each grade of beef on a weekly basis. Consistent with the variation in quality premiums, the quantity of choice and select beef varies markedly more than other grades. Much of the variation in the supply of choice and select beef is seasonal, which translates into strong seasonality in the Choice-Select premium relative to other grade premiums, as shown in Figure 2. According to Fausti et al. (2014), the choice-select price differential is the dominant premium/discount category explaining per-head revenue variability, and a change in the choice-select spread alters financial risk, the magnitude of which depends on cattle quality.

Table 2. Summary Statistics.

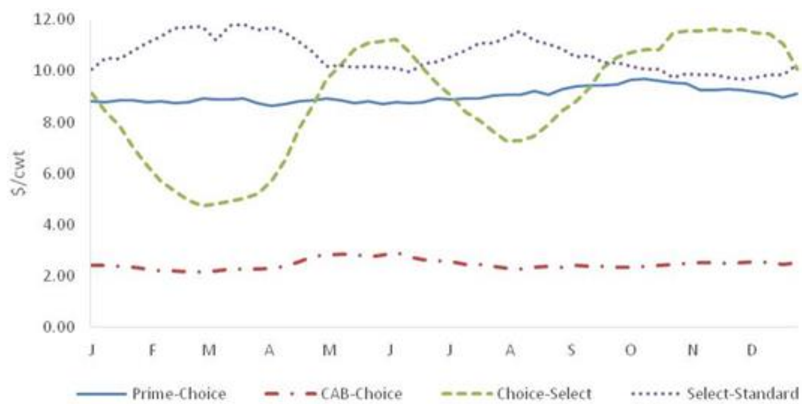
Variable	N	Mean	Standard Deviation	Minimum	Maximum
Prime-Choice ($/cwt)	1,002	8.84	3.20	3.69	15.96
CAB-Choice ($/cwt)	1,002	2.39	1.03	0.65	4.99
Choice-Select ($/cwt)[a]	1,002	8.79	4.25	1.22	24.87
Select-Standard ($/cwt) [a]	1,002	10.55	3.21	0.00	19.99
US Population (1,000,000)	987	299.00	14.70	273.00	324.00
US per capita GDP (2010$)	987	47434.23	2912.26	40184.10	54012.98
Steer & Heifer Slaughter (1000 head)	987	516.19	51.72	308.26	656.36
Steer & Heifer Dressed Weight (lb)	1,002	792.37	34.75	708.00	888.50
Prime (%)	987	0.03	0.01	0.02	0.07
Choice (%)	987	0.57	0.06	0.48	0.71
Select (%)	987	0.32	0.05	0.19	0.41
Standard (%)	987	0.07	0.02	0.04	0.15
Prime (1000 head)	987	16.20	3.18	7.56	30.20
Choice (1000 head)	987	291.73	24.12	194.94	353.84
Select (1000 head)	987	169.25	36.62	62.44	249.43
Standard (1000 head)	987	39.02	12.37	15.36	79.18
Prime (1000 lb)	987	12893.09	2851.95	5838.47	26791.61
Choice (1000 lb)	987	231494.80	22116.72	150490.70	281426.40
Select (1000 lb)	987	133379.80	25839.77	54290.69	192061.80
Standard (1000 lb)	987	30656.11	8838.57	12606.99	59557.70
KC Corn Price ($/bu)	1,002	3.49	1.74	1.54	8.36
Feeder Futures ($/cwt)	1,002	112.64	39.38	64.10	241.30
Live Cattle Futures ($/cwt)	1,002	93.27	26.72	57.92	171.00
Placement Weight (lb)	1,002	705.29	13.62	673.14	726.79

[a] Converted from discounts (negative values) to premiums (positive values).

Augmented Dickey-Fuller tests fail to reject the null hypothesis of nonstationarity only for spot corn prices, feeder and live cattle futures prices, and per capita GDP, all of which are employed only in the supply and demand model. All other data series are found to be stationary. Hence, for the supply and demand model in particular, using differenced data would be desirable if inferring coefficient significance was the primary objective of the study, but doing so generally produces poorer forecasts than when we run the model on data in levels. Since forecast accuracy is our primary concern, we report results for models run on data in levels.

Empirical Methods and Procedures

Futures market prices are typically considered the best benchmark against which to evaluate alternative forecasts. In the absence of futures markets for beef quality grade premiums, we consider a naïve seasonal model composed of only monthly dummy variables to account for seasonality (Figure 2) as a benchmark for comparison. Forecast models are calibrated using approximately 14 years of data from November 2, 1996, through December 31, 2010, saving the remaining observations for out-of-sample forecasting. Each forecast model is estimated using seemingly unrelated regression across equations for each grade.



Note: Plotted values are weekly data averaged across years to illustrate seasonal effects on average for the sample period.

Figure 2. Seasonality in Beef Quality Grade and CAB Premiums.

Following Bullock and Logan (1970), fed cattle prices may be modeled as a function of fed cattle marketings, and fed cattle marketings can be modeled as a function of appropriately lagged numbers of cattle placed on feed with dummy variables accounting for seasonality in both models. Adapting this general approach, we construct supply and demand models for various quality grades of cattle that are estimated using seemingly unrelated regressions.[2] The inverse demand equation is specified as

[2] As identified by an anonymous reviewer, Bullock and Logan's (1970) model differs from ours in a couple ways. Their inverse demand equation includes quarterly dummies and lagged prices (for the same month a year earlier), both of which appear to capture seasonality. We argue here that it is conceptually more consistent to include lagged premiums in the supply equation, given that current supply is determined by past decisions based on information about prices available at that time. Instead of including variables for each weight category of cattle on feed in the supply equation, as is done in Bullock and Logan, we use average placement weight which

(1) $P_{GT} = f(LN[Q_{GT}], POPULATION_T, GDP_T, LN[T], M_T)$,

where P_{GT} denotes the premium for quality grade *G* in time *T*, $LN[Q_{GT}]$ is the natural logarithm of pounds of beef marketed in each grade category, $POPULATION_T$ and GDP_T are the U.S. population and real per capita GDP in the respective year, $LN[T]$ is the natural logarithm of *T*, and M_T represents a vector of monthly dummy variables. $LN[Q_{GT}]$ variables for both grades represented by the premium P_{GT} are included in the respective demand equations. For instance, when modeling P_{PrimeT}, both $LN[Q_{PrimeT}]$ and $LN[Q_{ChoiceT}]$ are included in the inverse demand equation with negative and positive effects expected, respectively. The supply equation is specified as

(2) $LN[Q_{GT}] = f(P_{GT-t}, CORN_{T-t}, FEEDER_{T-t}, FAT_{T-t}, PLACE\_W_{T-t}, CARCASS\_W_{T-t}, LN[T], M_T)$,

where P_{GT-t} represents the premium for quality grade *G*, $CORN_{T-t}$ is the corn price in Kansas City, $FEEDER_{T-t}$ and FAT_{T-t} are the nearby feeder cattle and live cattle futures contracts, and $PLACE\_W_{T-t}$ and $CARCASS\_W_{T-t}$ are average placement weights and dressed weights for steers and heifers, all measured at the beginning of the feeding period. The lag *t* is initially assumed to be 22 weeks or about five months—the typical duration cattle are on feed. Alternative lags are considered for P_{GT-t}, and t=117 weeks (nearly 27 months) is determined to be appropriate, which corresponds to nine months gestation plus about a year and a half for a calf to reach slaughter weight and reflects cow-calf producers responding to grade premiums when making breeding decisions. Whereas shorter lags exhibit statistically negative effects in the supply equation, this lag returns more intuitive significantly positive effects for at least some quality grade pricing models. Once estimated, the supply model can be used to project relative supplies of cattle slaughtered at various grades five months out, based on information known when these animals are placed on feed; and those estimates, along with USDA projections for U.S. population and real per capita GDP, are entered into the demand equation to predict quality-grade premiums.

---

is computed as a weighted average of the number of cattle placed on feed by weight group. High correlation (>0.70) among some weight categories leads to multicollinearity and yields significant effects only for the supply of select beef. Our placement weight variable provides a better indication of the pounds of beef that will come to market in a given period, and yields significant and intuitive effects for more than one grade.

In addition to the variables described above, a dummy variable equal to one for year 2000 and thereafter, and zero otherwise, is included in each supply and demand equation to account for the influence of the Atkins' diet and related high-protein-diet trends toward consumption of leaner meats; and a corresponding dummy variable, accounting for a change in CAB yield grade specifications put into effect on January 23, 2007, is included in associated supply and demand equations (Corah and McCully, 2009).[3] The latter dummy variable is equal to one for year 2007 and thereafter, and zero otherwise.

Following Zapata and Garcia (1990), VAR models are of considerable interest for forecasting the value of fed cattle. Applying our notation to the standard form, a VAR model of beef grade premiums including monthly dummies M_T may be given by

$$(3) \qquad P_{GT} = f(P_{GT\text{-}t}, M_T) \text{ for } t = 1, \ldots, p,$$

where P_{GT} is a vector of G endogenous variables (e.g., prime, CAB, choice, select, and standard premiums/discounts) at time T that are functions of their lagged values up to $T\text{-}p$ and monthly dummies with error e_T. The optimal length of three lags is chosen based on minimizing Akaike information criterion (AIC).

Results

Naïve Seasonal Model

Regression results for the naïve seasonal model are presented in Table 3. Recall that discounts (negative values) are converted to premiums (positive values) for modeling purposes. R-squared values are notably low for these simplistic models, with the highest reaching nearly 16% for the strongly seasonal *Choice-Select* spread. Still, χ^2 statistics for the Wald test indicate that the monthly dummy variables jointly have some explanatory power for all premiums except *Prime-Choice*, meaning that most of the premiums exhibit some seasonality.

Consistent with Figure 2, significantly negative coefficients for February and March reflect that cattle tend to grade better and demand for middle-meats (i.e., tender rib and loin cuts, as opposed to cuts from tougher, outer, working muscles such as chuck, shoulder, and flank) is typically lower in this period (McCully, 2010). The substitutability of select and choice beef is lower and demand for both grades becomes more inelastic in

[3] "It should be noted that about 1.5 to 1.8 points (of a 40% increase in CAB acceptance rates from 2006 through 2009) occurred due to the change in the brand's yield grade specifications that went into effect January 23, 2007." (Corah and McCully, 2009, p. 3).

Table 3. Naïve Seasonal Model Regression Results.

	Prime-Choice	CAB-Choice	Choice-Select	Select-Standard
Feb	0.11	-0.16	-2.03***	0.70*
	(0.40)	(0.17)	(0.71)	(0.40)
Mar	0.13	-0.14	-2.21***	0.52
	(0.39)	(0.16)	(0.69)	(0.39)
Apr	-0.10	0.16	0.01	0.16
	(0.39)	(0.16)	(0.68)	(0.39)
May	0.07	0.45***	2.55***	-0.44
	(0.38)	(0.16)	(0.67)	(0.38)
Jun	0.06	0.33**	2.32***	-0.50
	(0.39)	(0.16)	(0.68)	(0.39)
Jul	0.21	0.03	0.74	0.01
	(0.39)	(0.16)	(0.68)	(0.38)
Aug	0.39	-0.13	0.21	0.25
	(0.39)	(0.16)	(0.68)	(0.38)
Sep	0.67*	-0.06	1.19*	0.08
	(0.39)	(0.16)	(0.68)	(0.39)
Oct	0.82**	-0.09	2.46***	-0.22
	(0.39)	(0.16)	(0.68)	(0.38)
Nov	0.39	-0.05	2.66***	-0.38
	(0.39)	(0.16)	(0.68)	(0.39)
Dec	0.23	0.06	2.11***	-0.41
	(0.39)	(0.16)	(0.68)	(0.38)
Constant	7.12***	2.00***	7.65***	9.23***
	(0.28)	(0.12)	(0.48)	(0.27)
R^2	0.02	0.04	0.16	0.03
χ^2 Statistic	11.14	31.12***	134.70***	21.64**

Notes: *N*=718. One, two, and three asterisks (*, **, ***) denote statistical significance at 10%, 5%, and 1% levels, respectively. Standard errors are reported in parentheses. Dependent variables are quality grade and CAB premiums. The χ^2 statistic is for the Wald test of the null hypothesis that the regression coefficients are jointly zero.

the spring and summer than in the fall and winter (Hughes, 2002). Significantly positive coefficients indicate greater premiums exist for choice beef during grilling season in May and June when demand for middle-meats is strong and cattle grade, on average, near seasonal lows (McCully, 2010). Similar grilling season effects are observed for the *CAB-Choice* spread. The *Choice-Select* spread typically rallies through the early fall as the relative supply of upper grades remains low and holiday rib and tenderloin demand strengthen, as reflected by significantly positive coefficients for October through December dummy variables. Similar effects are observed in September and October for the *Prime-Choice* spread. Since similar seasonal effects are apparent in alternative regressions presented below, coefficients for monthly dummy variables are omitted from reported results in the interest of space.

Table 4. Supply Model Regression Results.

	LN[Prime]	LN[Choice]	LN[Select]	LN[Standard]
Prime-Choice, Lag 117	0.007**	–	–	–
	(0.003)			
CAB-Choice, Lag 117	–	0.012***	–	–
		(0.003)		
Choice-Select, Lag 117	–	-0.002***	–	–
		(0.001)		
Select-Standard, Lag 117	–	–	0.002	0.003
			(0.002)	(0.004)
KC Corn Price, Lag 22	0.021**	-0.007	-0.029***	0.008
	(0.008)	(0.004)	(0.005)	(0.011)
Feeder Futures, Lag 22	0.001	-0.001***	0.002***	0.004***
	(0.001)	(0.001)	(0.001)	(0.001)
Live Cattle Futures, Lag22	-0.007***	2.00×10^{-4}	0.002**	0.005**
	(0.002)	(0.001)	(0.001)	(0.002)
Placement Weight, Lag 22	-0.001	0.001*	0.002***	0.001
	(0.001)	(0.001)	(0.001)	(0.001)
Carcass Weight, Lag 22	0.002***	0.001***	3.00×10^{-4}	0.002***
	(0.001)	(3.00×10^{-4})	(4.00×10^{-4})	(0.001)
LN[t]	-0.168***	-0.060***	-0.179***	-0.450***
	(0.035)	(3.00×10^{-4})	(0.021)	(0.045)
Post-2000 Dummy	0.198***	0.037***	0.107***	0.163***
	(0.029)	(0.014)	(0.018)	(0.037)
Post-2007 Dummy	–	0.088***	–	–
		(0.008)		
Constant	9.721***	10.875***	10.901***	9.455***
	(0.760)	(0.379)	(0.459)	(0.971)
R^2	0.389	0.474	0.623	0.358
χ^2 Statistic	403.190***	675.140***	1028.090***	346.830***

Notes: *N*=622. One, two, and three asterisks (*, **, ***) denote statistical significance at 10%, 5%, and 1% levels, respectively. Standard errors are reported in parentheses. The term Lag represents weeks the variable was lagged in the model. Dependent variables are natural logarithms of each grade of beef in pounds. The χ^2 statistic is for the Wald test of the null hypothesis that the regression coefficients are jointly zero.

Supply and Demand Model

Results for supply and demand regressions are presented in Tables 4 and 5, respectively. R-squared values are notably better for these models than for the naïve seasonal models. Unfortunately, reliable data on the supply of beef qualifying for CAB is unavailable for the sample period and, hence, supply is estimated only for the four quality grades. Supply regressions model the natural logarithm of pounds in each grade category as a function of premiums observed 27 months (i.e., 117 weeks) earlier when cow-calf producers made breeding decisions that produced the corresponding slaughter animals, and several other variables lagged five months (22 weeks) when those slaughter animals were initially placed on feed. The lagged *Prime-Choice* premium has a statistically positive effect on the supply of prime beef 27 months later which may reflect some responsiveness by cow-calf producers to incentives inherent in that premium.[4] Similarly, the *CAB-Choice* premium has a statistically positive effect on the supply of choice beef, while the *Choice-Select* premium conversely has a statistically negative effect. The *Select-Standard* premium has no significant influence on supplies of select or standard beef.

The lagged Kansas City corn price, when significant, has counterintuitive effects with higher corn prices leading to more prime beef and less select beef (Table 4). Perhaps corn price levels closer to the time of slaughter might have more intuitive effects, but such relationships would be uninformative for forecasting five months out. Feeder and live cattle futures contract prices generally have significantly negative effects on the supply of higher quality beef and positive effects on that of lower quality beef. It may be that profitable prices encourage slaughter and lighter weights, while cattle are fed to heavier weights in search of quality premiums when prices are not as good. When placement weights and carcass weights are heavier, supplies of beef generally tend to increase across grade categories five months later. The logarithmic trend variable and post-2000 and post-2007 dummies, described above, are also included and exhibit consistently significant effects. The post-2007 dummy variable, corresponding to the change in CAB specifications to allow yield grade four in addition to the prior standard of yield grade three, is included only in the choice supply equation and exhibits a statistically positive effect consistent with the push to qualify more cattle to meet demand for CAB. The post-

---

[4] This might be coordinated by cattle producers selling breeding stock, and allowing purchasers of their genetics to bring progeny to "roundups" that accumulate lots of like cattle for feedlots. According to the most recent 2007-08 USDA National Animal Health Monitoring System survey, cow-calf producers have been slow to adopt artificial insemination technology, but continue to invest in bulls for natural breeding. On average, a producer will replace almost one-third of the bulls for the herd each year. Thus, producers are able to respond by making breeding decisions (i.e., select sires with expected progeny differences) that most align with current market signals.

2000 dummy variable has statistically positive effects in each supply equation, while the logarithmic trend variable indicates declining supply in each grade category for the sample period overall.

Table 5. Demand Model Regression Results.

	Prime-Choice	CAB-Choice	Choice-Select	Select-Standard
LN[Prime]	-0.88**	-0.77***	–	–
	(0.43)	(0.21)		
LN[Choice]	-1.10	1.67***	-19.51***	–
	(0.92)	(0.46)	(1.50)	
LN[Select]	–	–	21.61***	-5.84***
			(1.41)	(0.85)
LN[Standard]	–	–	–	-0.95**
				(0.37)
US Population	0.03*	-0.01	0.22***	0.15***
(1,000,000)	(0.01)	(0.01)	(0.04)	(0.02)
US per capita GDP	0.62***	0.28***	-0.26**	-0.70***
(1,000)	(0.05)	(0.02)	(0.13)	(0.07)
LN[t]	-0.83***	-0.15**	0.60**	-0.19
	(0.13)	(0.07)	(0.29)	(0.18)
Post-2000 Dummy	-0.30	-0.08	-1.94**	-0.32
	(0.19)	(0.10)	(0.46)	(0.26)
Post-2007 Dummy	1.97***	0.42***	-1.58***	–
	(0.19)	(0.10)	(0.42)	
Constant	-3.92	-21.32***	-59.92***	77.40***
	(8.76)	(4.55)	(21.02)	(11.24)
R^2	0.75	0.61	0.56	0.46
χ^2 Statistic	2168.33***	1127.84***	889.92***	605.99***

Notes: *N*=622. One, two, and three asterisks (*, **, ***) denote statistical significance at 10%, 5%, and 1% levels, respectively. Standard errors are reported in parentheses. Dependent variables are quality grade and CAB premiums. The χ^2 statistic is for the Wald test of the null hypothesis that the regression coefficients are jointly zero.

The inverse demand equations model premiums as a function of lbs of beef for associated grades, macroeconomic variables (population and per capita GDP), as well as the logarithmic trend and post-2000 and post-2007 dummies (Table 5). Intuitively, supplies of the higher and lower grade associated with particular premiums often have significantly negative and positive effects, respectively. For instance, a greater supply of choice beef tends to decrease the *Choice-Select* premium, while a greater supply of select beef tends to increase it. Growth in annual per capita GDP increases premiums for high quality beef and decrease those for choice and lower quality beef, which tend to increase with population growth. The logarithmic trend term indicates declining valuation of CAB and higher quality beef and an increasing *Choice-Select* spread. The post-2000 dummy has negative effects for each premium which is statistically significant for the *Choice-Select* premium and may reflect preferences for leaner meat influenced by the Atkins' diet and related nutritional regimes. The post-2007 dummy has a statistically positive effect on *Prime-Choice* and *CAB-Choice,* and a statistically negative effect on *Choice-Select* premiums, which may reflect changing availability and demand for CAB and choice beef.

Vector Autoregressive Model

Estimation results from VAR models are reported in Table 6. Monthly dummy variables, although not reported here, are included in the model to account for seasonality. The optimal lag length of three weeks was identified based on minimizing AIC and final prediction error. R-squared values are strong, suggesting that these models would be effective forecasting one week ahead in-sample. However, such predictive power may not hold when iterating the forecast out to the 22-week horizon of the supply and demand model for equitable comparison. While other premiums sometimes have significant effects, typically at least two of the three lags of the dependent variable for each equation are statistically significant and often positive, particularly in the case of the first lag. That is, the premium last week tends to be a positive indicator of the premium this week.

Forecast Performance

For each regression model, coefficient estimates were applied to data from January 2011 to January 2016 to generate out-of-sample forecasts. Forecasts commonly have been evaluated in terms of MSE (e.g., Spreen and Arnade, 1984; Zapata and Garcia, 1990) because of its theoretical relevance in statistical modeling (Hyndman and Koehler, 2006). MSE is defined as MSE = $\Sigma (X_i - F_i)^2/n$, where Σ is the summation symbol and X_i and F_i, respectively, are realized and forecasted values for $i = 1, \ldots, n$ observations. Some scholars criticize using MSE due to its sensitivity to outliers (Armstrong, 2001). Another common measure of forecast accuracy is MAPE, which has the appealing feature of being scaled (i.e., divided by) realized values to compute a percentage statistic (Armstrong, 2001; Hyndman and Koehler, 2006). Using the same notation, MAPE = $\Sigma \left| (X_i - F_i) / X_i \right| / n$.

Table 6. VAR Model Regression Results.

	Prime-Choice	CAB-Choice	Choice-Select	Select-Standard
Prime-Choice, Lag 1	0.73***	-2.3×10^{-3}	0.02	0.03
	(0.04)	(0.02)	(0.07)	(0.07)
Prime-Choice, Lag 2	0.24***	0.05*	0.01	-0.01
	(0.05)	(0.03)	(0.09)	(0.09)
Prime-Choice, Lag 3	0.01	-0.02	-0.01	-0.01
	(0.04)	(0.02)	(0.07)	(0.07)
CAB-Choice, Lag 1	-0.03	0.81***	0.49***	-0.38***
	(0.06)	(0.04)	(0.12)	(0.11)
CAB-Choice, Lag 2	-0.06	0.15***	-0.14	0.23
	(0.07)	(0.05)	(0.15)	(0.15)
CAB-Choice, Lag 3	0.12**	-0.06	-0.41***	0.17
	(0.05)	(0.04)	(0.12)	(0.12)
Choice-Select, Lag 1	0.09***	0.04***	1.23***	-0.18***
	(0.02)	(0.01)	(0.04)	(0.04)
Choice-Select, Lag 2	-0.10***	0.02	-0.04	0.03
	(0.03)	(0.02)	(0.06)	(0.06)
Choice-Select, Lag 3	0.02	-0.06***	-0.24***	0.13***
	(0.02)	(0.01)	(0.04)	(0.04)
Select-Standard, Lag 1	0.06***	-2.5×10^{-3}	0.05	0.56***
	(0.02)	(0.01)	(0.04)	(0.04)
Select-Standard, Lag 2	-0.01	-0.01	-0.06	0.19***
	(0.02)	(0.01)	(0.04)	(0.04)
Select-Standard, Lag 3	-0.04*	0.01	-0.02	0.19***
	(0.02)	(0.01)	(0.04)	(0.04)
Constant	-0.03	0.04	0.42	0.68***
	(0.13)	(0.09)	(0.27)	(0.27)
R^2	0.97	0.94	0.97	0.89
χ^2 Statistic	25775.99***	11106.72***	23551.62***	6095.63***

Notes: N=716. One, two, and three asterisks (*, **, ***) denote statistical significance at 10%, 5%, and 1% levels, respectively. Standard errors are reported in parentheses. The term Lag represents the number of weeks the variable was lagged in the model. Dependent variables are quality grade and CAB premiums. The χ^2 statistic is for the Wald test of the null hypothesis that the regression coefficients are jointly zero.

Table 7 contains results of the Diebold-Mariano test of differences in forecast MSE (Diebold, 2015). MSE for both the supply and demand model and the VAR model are significantly lower than that of the naïve model for all premiums except the strongly seasonal *Choice-Select* premium, for which the naïve model performs better but not significantly so. Notably, no significant difference between the supply and demand model and the VAR model is detected for any premium. Table 8 shows the results of t-tests of differences in forecasts' MAPE, which mostly corroborate the findings for MSE. The exception is that, based on MAPE criterion, the supply and demand model is significantly better than the VAR model for the *CAB-Choice* premium (p<0.10) and significantly worse than the naïve seasonal model for the *Choice-Select* premium (p<0. 01).

Table 7. Diebold-Mariano Test of Forecasts' Mean Squared Error (MSE).

		Naïve (Seasonal) Model	VAR Model	Difference
Prime-Choice	MSE	26.38	3.16	23.22***
	S&D	3.73	3.73	
	Difference	22.65***	-0.57	
CAB-Choice	MSE	1.73	0.24	1.49***
	S&D	0.17	0.17	
	Difference	1.56***	0.07	
Choice-Select	MSE	13.21	16.67	-3.46
	S&D	15.04	15.04	
	Difference	-1.83	1.63	
Select-Standard	MSE	25.81	5.11	20.70***
	S&D	5.11	5.11	
	Difference	20.70***	0.00	

Notes: Each set of comparison is in matrix notation for a particular quality grade. All statistics are reported as $/cwt. One, two, and three asterisks (*, **, ***) indicate statistical significance at 10%, 5%, and 1% levels, respectively.

Graphs of premium forecasts and 95% confidence intervals along with realized values provide greater insights regarding sources of forecast errors (Figures 3 through 6). For each premium, the naïve model at least partly captures seasonality but fails to reflect trends better represented by other models. Though the supply and demand model initially misses a jump in *CAB-Choice* in 2012, it catches up due to the trend effect, while the VAR model better predicts the 2012 jump but also exaggerates a subsequent fall in later 2013 before recovering (Figure 4). The supply and demand model also misses jumps in the *Prime–Choice* premium that is logically captured with a lag by the structure of the VAR model (Figure 3). All three models underestimate the amplitude of strong seasonal effects in the *Choice-Select* premium, which may be becoming more variable as choice increasingly reflects only the lower two-thirds of the grade, and upper choice is more often sold as CAB or through other branded programs (Figure 5).[5]

[5] "Product sold and reported as USDA Choice is lower quality than it was before branded beef programs. … (T)he commodity Choice boxed beef price, from which the C-S is calculated, does not represent all Choice beef. Rather, the commodity Choice price is the very bottom quality of Choice product that is not sold into a branded

Table 8. T-Test of Differences in Forecasts' Mean Absolute Percentage Error (MAPE).

		Naïve (Seasonal) Model	VAR Model	Difference
Prime-Choice	MSE	36.96	10.71	26.25***
	S&D	11.41	11.41	
	Difference	25.55***	-0.70	
CAB-Choice	MSE	34.74	10.35	24.39***
	S&D	9.06	9.06	
	Difference	25.68***	1.28*	
Choice-Select	MSE	33.46	34.69	-1.23
	S&D	36.35	36.35	
	Difference	-2.89**	-2.27	
Select-Standard	MSE	30.55	12.83	17.72***
	S&D	13.18	13.18	
	Difference	17.37***	-0.34	

Notes: Each set of comparison is in matrix notation for a particular quality grade. All statistics are reported as $/cwt. One, two, and three asterisks (*, **, ***) indicate statistical significance at 10%, 5%, and 1% levels, respectively. Degrees of freedom = 262.

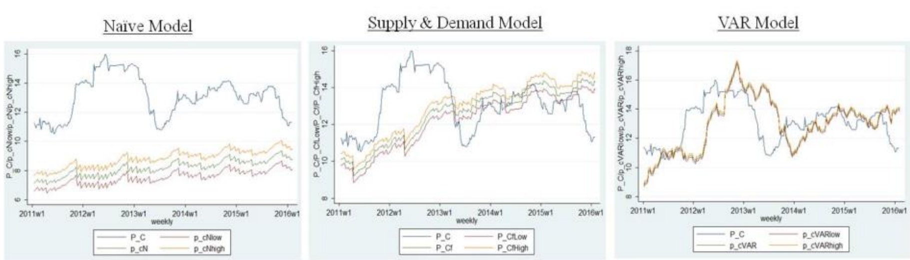


Figure 3. Prime-Choice Forecasts.

---

program. … When Choice production is seasonally high, it is not uncommon for packers to substitute Choice beef onto their Select orders. … In the reporting process, Choice product gets reported with a Select price." (McCully, 2010, p. 5-6).

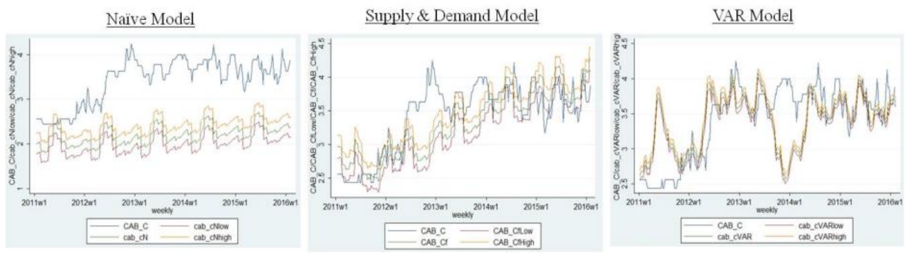


Figure 4. CAB-Choice Forecasts.

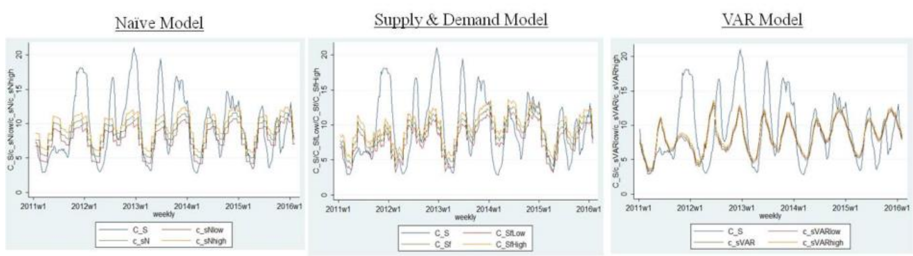


Figure 5. Choice-Select Forecasts.

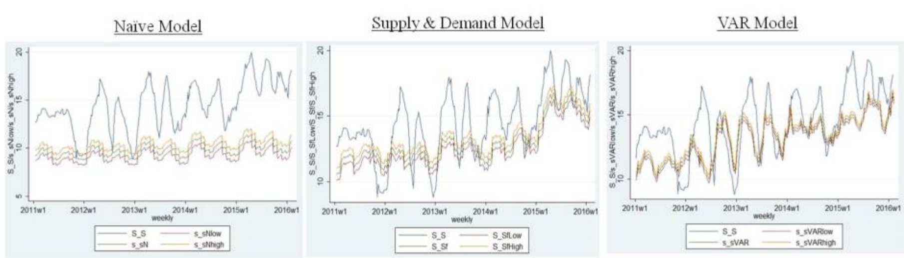


Figure 6. Select-Standard Forecasts.

Conclusions

We assess the predictive ability of alternative forecasts of weekly beef quality premiums five months out, or about the typical duration cattle are fed in feedlots. A naïve seasonal model is established as a benchmark for comparison with another direct forecast derived from a supply and demand framework and with an indirect forecast derived by iterating predicted values from a VAR model. The analysis stands to contribute to a growing literature debating the relative merits and performance of direct and iterated forecasts under alternative circumstances.

Overall, the results suggest that both approaches—direct forecasts from the supply and demand model and iterated forecasts from the VAR model—outperform a simple, naïve model accounting only for seasonality. However, neither alternative to the naïve model appears to be significantly better than the other for our purposes. Future research may consider whether either of these alternatives encompass the other, or if information from both approaches may be combined to make a better forecast.

References

Anderson, J.D., and K.A. Zeuli. (2001). "The revenue risk of value-based pricing for fed cattle: A simulation of grid vs. average pricing." *The International Food and Agribusiness Management Review* 4(3), 275-286.

Armstrong, J.S. (2001). "Evaluating forecasting methods." In J. Scott Armstrong (ed.), *Principles of forecasting: A handbook for researchers and practitioners* (pp. 443-472). Norwell, Mass.: Kluwer Academic Publishing.

Bullock, J.B., and S.H. Logan. (1970, May). "An application of statistical decision theory to cattle feedlot marketing." *American Journal of Agricultural Economics* 52(2), 234-241.

Chevillon, G. (2006). "Multi-step forecasting in unstable economies: Robustness issues in the presence of location shifts." Discussion Paper Series, University of Oxford.

Corah, L., and M. McCully. (2009). "Quality grade: What is driving the recent upswing." Certified Angus Beef LLC, Wooster, OH.

Diebold, F.X. (2015, January). "Comparing predictive accuracy, twenty years later: A personal perspective on the use and abuse of Diebold–Mariano tests." *Journal of Business and Economic Statistics* 33(1), 1-1.

Fausti, S., M. Diersen, B. Qasmi, and B. Adamson. (2015, January). "The influence of market power and market trends on grid market signals." *Journal of Agricultural and Resource Economics* 40(1), 112-123.

Fausti, S.W., Z. Wang, B.A. Qasmi, and M.A. Diersen. (2014, September). "Risk and marketing behavior: Pricing fed cattle on a grid." *Agricultural Economics* 45, 601–612.

Feuz, D.M., C.E. Ward, and T.C. Schroeder. (2002, March). "Understanding grid pricing." Managing for Today's Cattle Market and Beyond. Available at http://cattlemarketanalysis.org/Pubs/Understanding_Grid_Pricing.pdf.

Foster, K.A., A.M. Havenner, and A.M. Walburger. (1995, November). "System theoretic time-series forecasts of weekly live cattle prices." *American Journal of Agricultural Economics* 77(4), 1012-1023.

Franken, J., J.L. Parcell, D. Patterson, M. Smith, and S. Poock. (2010, Spring). "Cow-calf producer interest in retained ownership." *Journal of Agribusiness* 28(1), 49-59.

Greer, H.C., J.N. Trapp, and C. Ward. (2000, April 17). "Impact of alternative grid pricing structures on cattle marketing decisions." Paper presented at NCR-134 Conference on Applied Commodity Price Analysis, Forecasting, and Market Risk Management, Chicago, Ill.

Hogan, R., D. Anderson, and T. Schroeder. (2009). "Grid pricing of fed cattle." AgriLife Extension Report E-557 RM1-11.0, 03-09, Texas A&M System, College Station.

Hogan, R.J., J.G. Carlberg, C.E. Ward, and D.S. Peel. (2012, February 6). "Factors affecting quality grade discounts for fed cattle." Paper presented at the annual meeting of the Southern Agricultural Economics Association, Birmingham, Ala.

Hogan, R.J., and C.E. Ward. (2003, July 13-16). "Models estimating beef quality and yield grade discounts." Paper presented at the annual meeting of the Western Agricultural Economics Association, Denver, Colo.

Hogan, R.J., and C.E. Ward. (2005, February 8). "Examining the fed cattle choice-select discount." Paper presented at the annual meeting of the Southern Agricultural Economics Association, Little Rock, Ark.

Hughes, H. (2002). "The changing market structure for the American beef industry." *Journal of Animal Science,* 80(E-Suppl_1), 1-24.

Hyndman, R.J., and A.B. Koehler. (2006, October-December). "Another look at measures of forecast accuracy." *International Journal of Forecasting* 22(4), 679-688.

Johnson, H.C., and C.E. Ward. (2006, April). "Impact of beef quality on market signals transmitted by grid pricing." *Journal of Agricultural and Applied Economics* 38(1), 77-90.
Mark, D.R., T.C. Schroeder, and R. Jones. (2000, Fall). "Identifying economic risk in cattle feeding." *Journal of Agribusiness* 18(3), 331-344.
McCully, M.A. (2010). "Trends in the choice-select spread and implications to cattle producers." Certified Angus Beef LLC, Wooster, OH.
Pesaran, M.H., A. Pick, and A. Timmermann. (2011, September). "Variable selection, estimation and inference for multi-period forecasting problems." *Journal of Econometrics* 164(1), 173-187.
Pope, K.F., T.C. Schroeder, M.R. Langemeier, and K.L. Herbel. (2011, November). "Cow-calf producer risk preference impacts on retained ownership strategies." *Journal of Agricultural and Applied Economics* 43(4), 497-513.
Schroeder, T.C., and J.L. Graff. (2000, Spring-Summer). "Estimated value of increased pricing accuracy for fed cattle." *Review of Agricultural Economics* 22(1), 89-101.
Spreen, T.H., and C.A. Arnade. (1984, July). "Use of forecasts in decision making: The case of stocker cattle in Florida. *Southern Journal of Agricultural Economics* 16(01), 145-150.
U.S. Department of Agriculture National Animal Health Monitoring System Survey. (2007-2008).
Zapata, H.O., and P. Garcia. (1990, July). "Price forecasting with time-series methods and nonstationary data: An application to monthly US cattle prices." *Western Journal of Agricultural Economics* 15(1), 123-132.