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Measuring and Explaining Skewness in Pricing Distributions Implied from Livestock Options

by

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Implied from Livestock Options

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Measuring and Explaining Skewness in Pricing Distributions

Implied from Livestock Options

Earlier work has examined implied volatilities (IVs) derived from security prices and has shown that IVs differ across strike prices, giving rise to what are commonly called volatility smiles or smirks. In particular, these patterns are observed when out-of-the-money options exhibit higher volatility levels than those near-the-money. The relationship between implied volatilities (IV) and option moneyness, called the implied volatility function (IVF), has drawn much attention in the finance literature. Much of the impetus for this work stems from observations that since the stock market crash of 1987, IVs derived from S&P 500 index options have exhibited negatively sloped IVFs (Bates, 1991; Bates, 2000; Rubenstein, 1994; Gemmill, 1996; Doran, Peterson, and Tarrant, 2007). However, comparatively little work has examined commodity futures prices in general and agricultural commodities in particular.

In this paper we summarize IVFs and characteristics of the implied pricing density function in the live cattle market. Thomsen and McKenzie (2010) using daily settlement price data found evidence of a significant leftward skew in the pricing density for live cattle and live/lean hogs that exists from the inception of options trading in the mid 1980's through to the present time. However, these results suffer from potential problem of stale prices – an artifact of using daily settlement prices. Stale pricing occurs when the actual transaction time for an options contract – upon which the options settle price is based – does not coincide with the transaction time for a futures contract – upon which the futures settle price is based. Accurate measures of IVs and IVFs should be based upon futures and options prices generated from simultaneous transaction times. To this end we revisit the issue of skewness in livestock options using CME

“Time and Sales” tick data. Moreover, we compare the live cattle IVF to IVFs in feeder cattle, corn and wheat markets.

We also examine IVFs just before releases of USDA reports. Pre-report IVFs may reflect risk preferences post report price reactions expectations of market participants and so may depart, in important ways, from the true *ex ante* physical returns distribution. Previous work has shown that when there are market frictions, differences in expectations or risk preferences among market participants can induce persistent skews in implied pricing densities. Bollen and Whaley (2004) argue that at some point, the marginal cost of writing additional options at a given strike becomes an increasing function of the number of contracts written. In support of this argument, they present empirical evidence showing that demand for out-of-the-money puts, used to hedge against large stock market declines, pushes up the implied volatilities on low strike options. Similarly, Buraschi, and Jiltsov (2006) illustrate how heterogeneous beliefs among market traders can better account for smirks in S&P 500 index options than alternative volatility models. Their modeling approach is motivated by the idea that agents with a more pessimistic expectation of future returns demand state-contingent insurance protection from agents with a more optimistic outlook, which results in greater demand and relatively higher prices for out-of-the-money puts than would be predicted by the Black-Scholes model. Han (2008) finds statistically significant relationships between slopes of IV functions from S&P 500 index options and several proxies of bullish or bearish sentiment. He shows that the strength of relationships between sentiment and slope are affected by impediments to arbitrage.

Data and Methods

As noted above, we use CME Time and Sales data. We use a continuous nearby series for IVF estimation. This is constructed from contracts nearest to maturity with rollovers on the 15th of the month prior to expiration. For instance, in the case of live cattle, we would roll over to the February contract from the December contract on November 15th. Our intent with this rollover strategy is to avoid irregularities which are systematic as options approach expiration and as time value in the options goes to zero. We excluded data lines with non-missing cancellation codes or that were indicated as cabinet trades. We matched each at-the-money or out-of-the money option to the most recently recorded futures price in the time and sales data regardless of trading platform (pit or Globex). Black's (1976) pricing model was then applied to all remaining at-the-money or out-of-the-money options to recover implied volatilities. Rates from 6-month T-bills were used as the risk-free interest rate for Black's (1976) model. In our IVF estimation we use all options that were at the money or out of the money.

After computing the IVs, we estimate IVF model specifications similar to those used by Dumas, Flemming and Whaley (1998).

(1) $IV = \beta_0$

(2) $IV = \beta_0 + \beta_1 X$

(3) $IV = \beta_0 + \beta_1 \text{Put} + \beta_2 X + \beta_3 \text{Put} \times X$

(4) $IV = \beta_0 + \beta_1 \text{Put} + \beta_2 X + \beta_3 \text{Put} \times X + \beta_4 X^2 + \beta_5 \text{Put} \times X^2$

Where X is moneyness measured as (Strike – Futures) ÷ Futures. Model 1 is the correct specification if Black's (1976) model correctly price IVs across strikes without regard to moneyness. Model 2, includes moneyness as an explanatory variable and β_1 would differ from zero if there were a systematic leftward or rightward skew. Model 3, allows the relationship to differ by type of option and would accommodate higher or lower IVs as either puts or calls move away from the money. Model 4, is model 3 augmented with quadric terms.

Models 1 through 4 were estimated for options on nearby live cattle contracts from February 2009 through October 2014. All models included contract fixed effects. Results and residual plots are presented in table 1 and figure 1, respectively. Residual plots show clear smile patterns in the models 1 and 2, implying that both out-of-the-money options are more expensive than would be suggested by Black's (1976) model. Models 3 and 4 include an interaction term for type of option and best accommodate this phenomenon. Mispricing relative to the Black model is especially pronounced for out-of-the-money put options. A careful examination of these residual plots shows that the IVF is skewed to the left. The estimates for moneyness (X) reported in table 1 are much larger in absolute value when interacted with the binary variable indicating put options. The estimate for the put option binary is significant statistically but is very small and is not significant economically. In other words there is no evidence that at-the-money puts are priced differently than calls. Based on table 1 and figure 1, we adopt the quadratic specification in model 4 as our preferred specification and proceed with that in the analysis that follows.

Hedging Pressures from Liquidity and Sentiment

The results presented in table 1 confirm earlier observations of a leftward skew in the implied pricing density function for live cattle. We now turn to an investigation of whether hedging pressures can explain the shape of the IVF in this market. To do this we construct measures of liquidity and market sentiment, which are then used to augment our preferred specification.

To assess liquidity we propose two measures. The first measure we name “own volume”. This is the volume in each recorded option transaction divided by the total volume of all options of the same type that were transacted within the most recent five-minute interval. Our second measure, “total volume”, is calculated similarly. It is the volume in each recorded options transaction divided by all options irrespective of type that were transacted in the most recent five-minute interval. Both of these liquidity measures are bounded between zero and one. Measures closer to one imply less liquidity. A measure of one is observed when the transaction in question is the only transaction within the last five minutes.

Market sentiment may also be indicative of hedging pressure. The measure of sentiment we use here is calculated as the difference between call option volume and put option volume divided by total volume in all options. If traders are bearish, we would expect there to be more puts transacted as market participants seek downside protection. If only puts were transacted this measure would equal negative 1. Similarly if only calls were transaction this measure would equal 1 consistent with bullish outlook. We refer to this measure in the models as “Bull-Bear”. Again this is computed over the most recent five-minute interval.

Estimates from models with the liquidity measures and sentiment measure are reported in table 2. Only Globex transactions contain information about volume. For this reason, table 2 results are based only on electronic session trades. Estimates from the liquidity measures in the first two columns of table 2 are statistically significant with one or two exceptions. However, they do little to explain the shape of the IVF. This is most readily seen in the first panel of figure 2. Forecasts of the IVF through the quartiles of the liquidity measure, “total volume”, are nearly identical suggesting that although there is statistical significance, the liquidity measure is of little practical significance. Although not shown, a similar conclusion is reached with respect to the other measure of liquidity. Likewise, column 3 of table 2 shows that most estimates for the sentiment measure are significant. Again, however, there is little evidence that sentiment meaningfully alters the IVF (Panel (b) of figure 2).

Hedging Pressures around Known Informational Events

While there is little evidence that market-microstructure meaningfully alters the IVF for live cattle, it is possible that known informational events could increase demand for out-of-the-money options and thereby amplify the shape of the IVF. Previous research has shown that government reports impact livestock markets. These studies have addressed whether the reports contain unanticipated information and if livestock futures markets react efficiently to new information (Koontz, Hudson, and Purcell 1984; Colling and Irwin 1990; Schroeder, Blair, and Mintert 1990; Schaefer, Myers, and Koontz 1990; Grunewald, McNulty, and Biere 1993; Carter and Galopin 1993; Mann and Dowen 1996; Mann and Dowen 1997; Isengildina, Irwin, and Good 2006). Two general conclusions of these studies are that statistically large futures price movements are often observed following the report release dates and futures markets appear to be efficient at impounding the new information. With this in mind, we now turn to whether the IVF for live cattle is different around release of the monthly *Cattle on Feed* report.

As above, our quadratic specification of the IVF is augmented with additional measures indicating nearness of report release. To include more *Cattle on Feed* report releases we expand the time period of the analysis back to April 2005 and continue through October 2014. There were few electronic trades early in this time period.

Figure 3, presents forecasts of the IVF using binary indicator variables from one hour to five days prior to report release. These are compared to other trading days as a benchmark.

Visually, the shape of the IVF is amplified in the last hour prior to report release. Otherwise, there are few noticeable differences in IVF irrespective of nearness to report.

Figure 4 shows actual volume from Globex transactions around report releases. Again, this would be heavily weighted towards the more recent release dates. The figures show averages by hour and it should be kept in mind that Globex volume was steadily increasing over the period shown in the figures. Despite the visual difference in the IVF that shows up just prior to report release, there does not appear to be any systematic patterns to volume in either puts or calls in the last hour before reports are released.

Comparison of Live Cattle IVF to Other Commodities

To this point, there is little evidence that hedging pressures play a major role in the shape of the IVF for live cattle. However, there may be liquidity differences across markets that translate into lower transactions costs for out-of-the-money positions and hence reduce the likelihood of hedging pressures impacting the IVF. To investigate this issue we estimated the quadratic specification for other agricultural markets including feeder cattle, corn, and wheat. Plots of the estimated IVFs for these commodities are presented in figure 5.

The striking feature of figure 5 is that while grain markets are much more volatile than the cattle markets, the volatility smile also is much less pronounced. This may be related to hedging pressures because markets for corn and wheat are much more liquid than livestock markets shown in the figure. Especially noteworthy is that the grain markets lack the clear leftward skew that is present in markets for live cattle and feeder cattle. However, there may be non-liquidity, structural explanations for these differences in the IVF across these commodities.

Conclusion

We find strong evidence of pronounced patters in the IVF for live cattle. Out-of-the-money options trade for a premium relative to that which would be expected under the Black model. This is especially pronounced for out-of-the-money put options. That said characteristics of the live cattle market that can be attributed to sentiment or trading pressure over short intervals do not explain these patterns. There is some evidence that the shape of the IVF is amplified just prior to the release of government reports, but the difference is not especially large. While there is little evidence that hedging pressures within the market are effecting the shape of the IVF, there may be differences across markets. In comparison to live cattle, we present evidence that the IVF for grain markets is much flatter despite there being a much higher level of volatility across all strikes.

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Table 1. Baseline IVF models for live cattle, February 2009 through October 2014

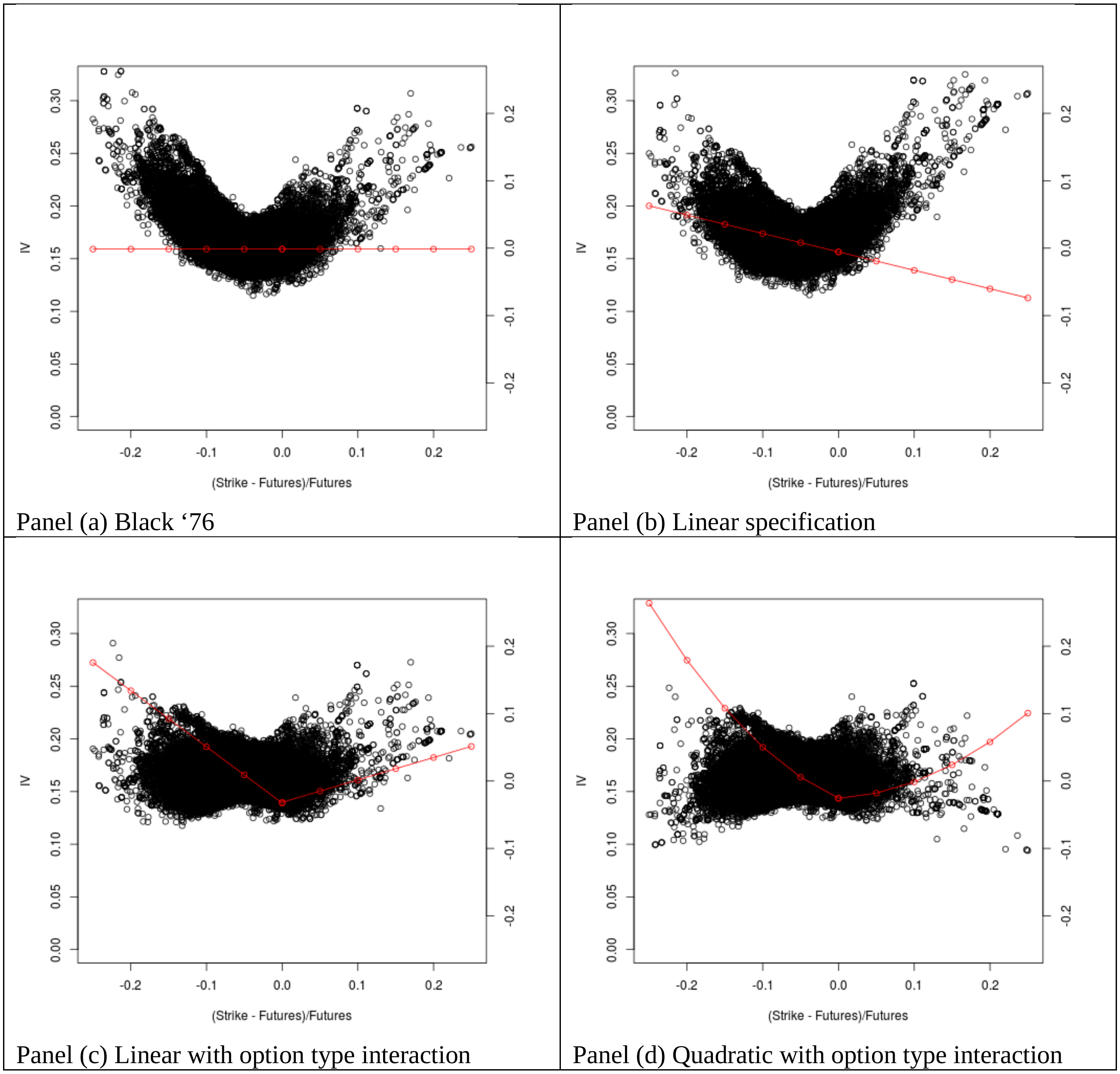
	Black '76	Linear	Linear by Type	Quadratic by Type
Intercept	0.246^{***}	0.249^{***}	0.225^{***}	0.226^{***}
	(0.000)	(0.000)	(0.000)	(0.000)
X		-0.175^{***}	0.212^{***}	0.044^{***}
		(0.001)	(0.001)	(0.002)
X^2				1.120^{***}
				(0.011)
Put			-0.001^{***}	0.000^{**}
			(0.000)	(0.000)
Put × X			-0.746^{***}	-0.355^{***}
			(0.002)	(0.003)
Put × X^2				0.595^{***}
				(0.020)
R^2	0.712	0.761	0.858	0.867
Adj. R^2	0.712	0.761	0.858	0.867
Num. obs.	323,824	323,824	323,824	323,824

Notes: $^{***}p < 0.001$, $^{**}p < 0.01$, $^{*}p < 0.05$. Standard errors are in parentheses. X is calculated as (strike – futures)/futures. All models were estimated with contract fixed effects.

Table 2. Live Cattle IVF with hedging pressures, February 2009 – October 2014 Globex transactions

	Measure of Hedging Pressure		
	Own Vol.	Total Vol.	Bull-Bear
(Intercept)	0.142***	0.142***	0.141***
	(0.001)	(0.001)	(0.001)
Put	−0.000***	−0.000	0.001***
	(0.000)	(0.000)	(0.000)
X	0.029***	0.028***	0.044***
	(0.003)	(0.003)	(0.003)
X^2	1.217***	1.233***	1.160***
	(0.017)	(0.016)	(0.019)
Put × X	−0.363***	−0.359***	−0.366***
	(0.004)	(0.004)	(0.004)
Put × X^2	0.501***	0.469***	0.524***
	(0.027)	(0.026)	(0.029)
Hedging Pressure	−0.002***	−0.002***	−0.000
	(0.000)	(0.000)	(0.000)
Put × Hedging Pressure	0.003***	0.003***	0.001***
	(0.000)	(0.000)	(0.000)
X × Hedging Pressure	0.049***	0.072***	−0.015***
	(0.008)	(0.010)	(0.004)
X^2 × Hedging Pressure	−0.292***	−0.474***	0.003
	(0.049)	(0.057)	(0.025)
Put × X × Hedging Pressure	0.039**	0.028	0.021***
	(0.013)	(0.016)	(0.006)
Put × X^2 × Hedging Pressure	0.275***	0.533***	0.043
	(0.079)	(0.095)	(0.040)
R^2	0.851	0.851	0.851
Num. obs.	296,168	296,168	296,168

Notes: ***p < 0.001, **p < 0.01, *p < 0.05. Standard errors are in parentheses. X is calculated as (strike – futures)/futures. Own Vol. is calculated as the number of contracts reported in the transaction divided by total options contracts of the same type (put or call) traded within the previous five minutes of market activity. Total Vol. is calculated as the number of contracts reported in the transaction divided by the volume of all options contracts regardless of type within the previous five minutes of market activity. Bull-bear is measured as the difference in the volume of calls and puts divided by total volume in calls and puts over the previous five minutes of market activity.



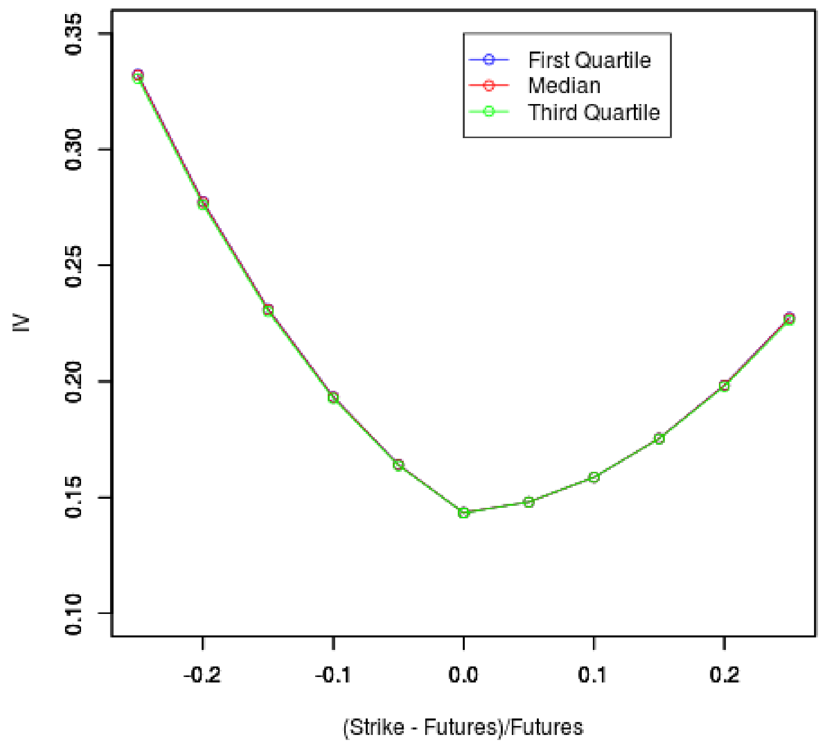
Panel (a) Black ‘76

Panel (b) Linear specification

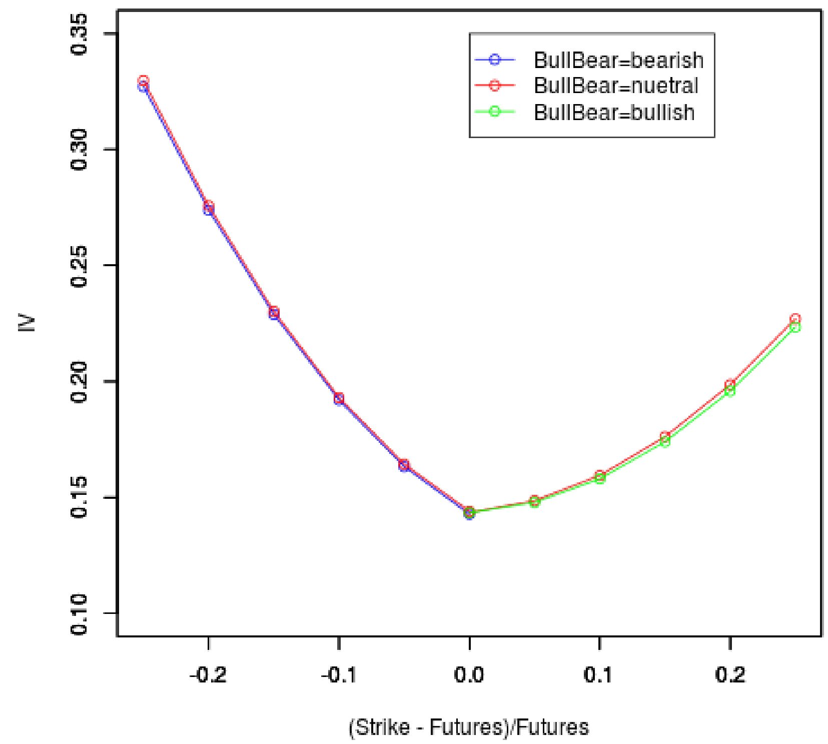
Panel (c) Linear with option type interaction

Panel (d) Quadratic with option type interaction

Figure 1. Residual plots from alternative IFV specifications



Panel (a) IVF forecasts through quartiles of transaction volume to total volume over the last five minutes (total vol. measure)



Panel (b) IVF forecasts through values of the sentiment index of -1 (bearish), 0 (neutral), and 1 (bullish) computed over the last five minutes.

Figure 2. Live Cattle IVF and measures of market microstructure that may indicate hedging pressures, February 2009 through October 2014 Globex transactions.

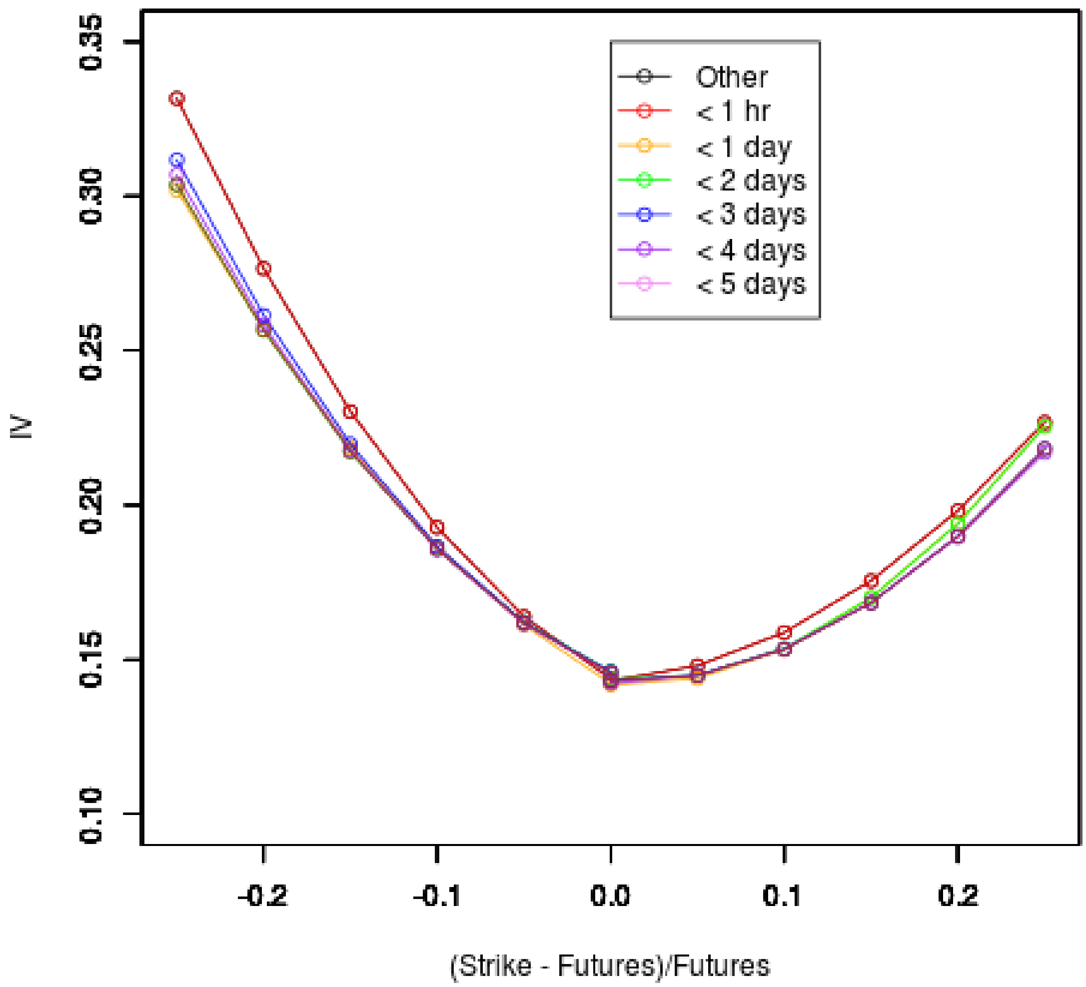


Figure 3. Live cattle IVF leading up to the release of *Cattle on Feed* reports, April 2005 through October 2014

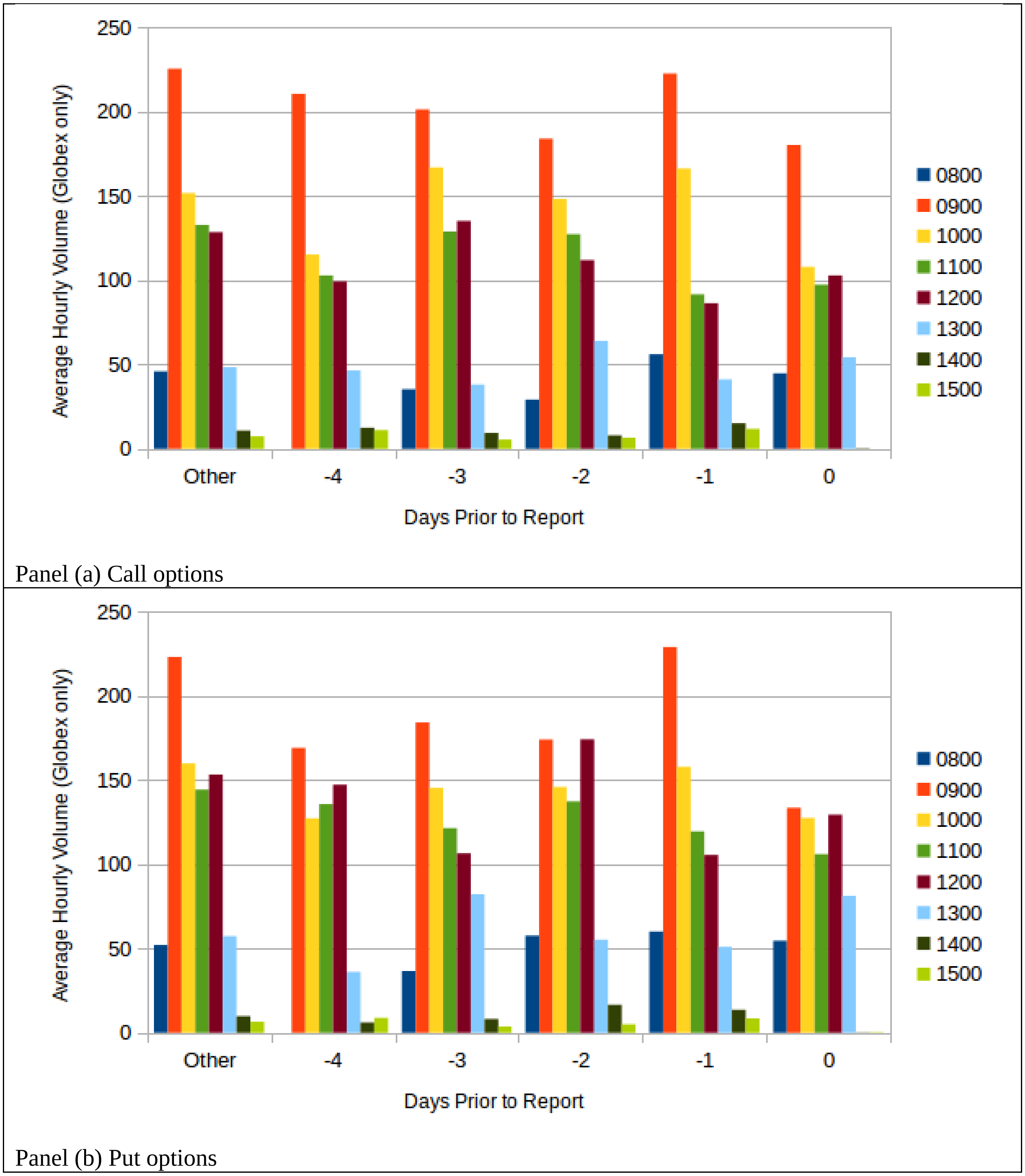


Figure 4. Average hourly volume in at-the-money and out-of-the-money options on days leading up to the release of *Cattle on Feed* reports, Globex transactions only.

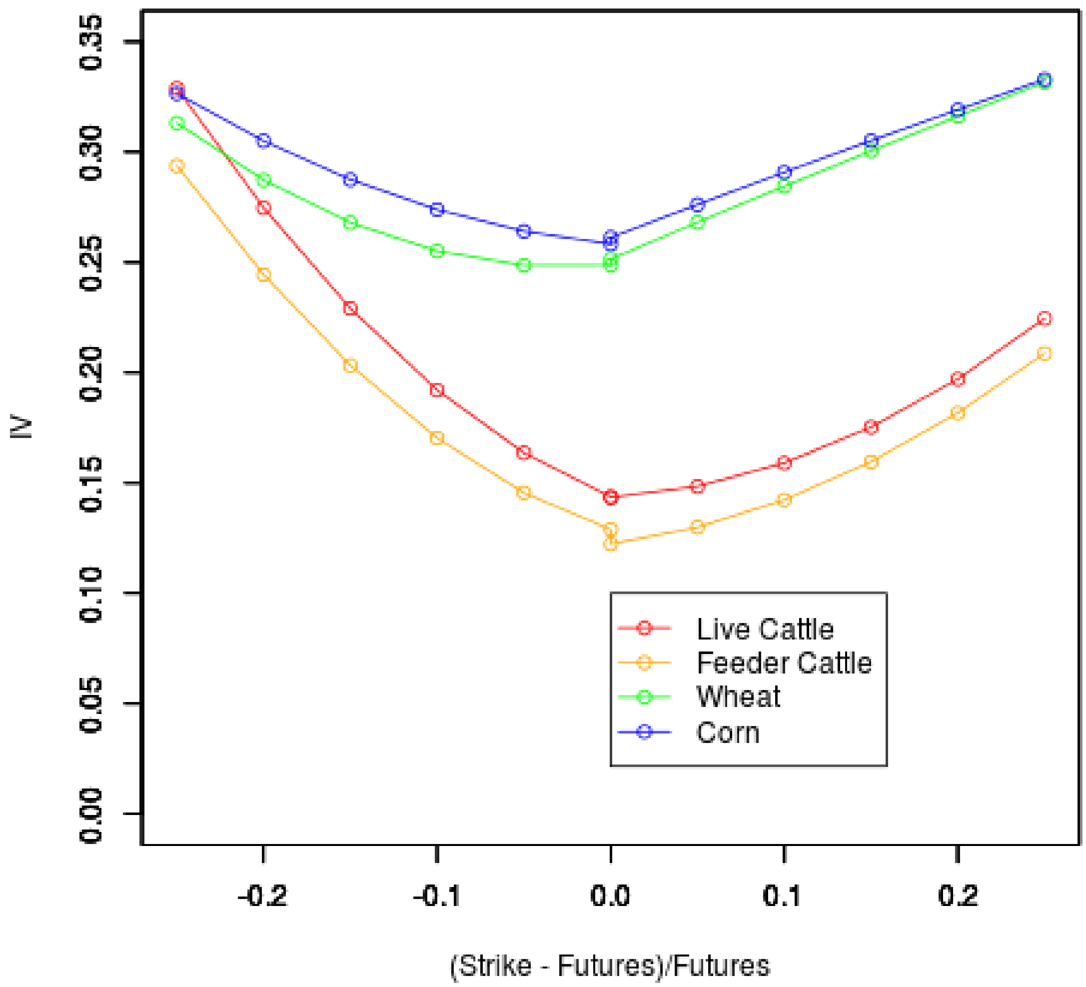


Figure 2. Comparison of live cattle IVF with those for feeder cattle, wheat, and corn over the period 2009-2014.