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Suggested citation format:

Chua, H. W., and William G. Tomek. 2010. "On the Relationship of Expected Supply and Demand to Futures Prices." Proceedings of the NCCC-134 Conference on Applied Commodity Price Analysis, Forecasting, and Market Risk Management. St. Louis, MO. [http://www.farmdoc.illinois.edu/nccc134].

On the Relationship of Expected Supply and Demand to Futures Prices

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Paper presented at the NCCC-134 Conference on Applied Commodity Price Analysis, Forecasting, and Market Risk Management
St. Louis, Missouri

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Expectations about future economic conditions are important determinants of commodity prices. This paper presents a relatively simple model that makes futures prices for corn a function of expected production and inventories and of variables that account for demand shifts. The intent is to provide an historical, objective context for new price and quantity observations, which may help market analysts.

Keywords: expected supply, futures prices, commodity prices

Introduction

Agricultural product prices have always been variable, but since 2005, this volatility has been especially large. Notably, in summer 2008, commodity prices were at record highs. These highs were followed by a sharp decline likely influenced by the impending world-wide economic recession. The context for this price behavior includes rising demands for grains and oilseeds, based importantly on increased demands for exports by China and India and on increased demands for corn and soybeans for bio-fuels. At the same time, uncertainty has grown about the ability of output to match the growth in demand, and supply shocks are always a possibility. Since short-run supply and demand functions are price inelastic, it is not surprising that commodity prices are volatile.

Increased price variability has also been attributed by some observers to increased speculation in commodity futures markets resulting in speculative bubbles. Unquestionably commodity prices depend importantly on market participants' expectations. As new information about expected supplies and demand enters a market, prices change, but this does not mean that previous prices were unwarranted. In an efficient market, current prices reflect existing information, and this information can turn out to be mistaken.

Whatever its source, the high level of price volatility experienced recently complicated the ability of firms to manage price risk and to establish positive margins for their business operations (Mark et al. 2008). The availability of forward contracts decreased in some regions; margin calls on futures positions became large enough to cause financial stress and even bankruptcy for firms; and options contracts, whose premiums increase with volatility, became more expensive.

This paper proposes simple graphic and regression analysis methods, based on readily available data, as an approach to evaluating the effects of changing expectations on futures contract prices. The variability of prices is apportioned into that associated with changing expectations about supply, other factors likely associated with changing demand, and a random component (which may or may not be associated with undo speculation). Our approach provides a context for evaluating new information. How do current price quotes compare with historical experience? Is a high price associated with an unusually small level of expected production (relative to demand)? Does the market appear to be expecting a larger demand? Etc. Our intended contribution, therefore, is to provide a way to appraise current market conditions relative to historical experience. This framework may be useful as a way to augment the outlook tools used by extension economists, agribusinesses, and other market analysts.

The futures market for corn is used as an illustration, and the paper is organized as follows. We begin with background information and a discussion of data. The next section discusses the development of a simple model that is perhaps best viewed as a starting point for exploring alternative models. Then, empirical results are presented and implications discussed. A concluding section emphasizes the exploratory nature of our model and possible ways to extend and improve on the results.

Background and Data

This paper is based on two ideas. One is that a futures market provides a sequence of prices that are estimates of the maturity month price, conditional on current information. In Working's (1962) terms, futures prices are reliable anticipatory prices. Or, in Fama's (1970) terms, markets are semi-strong form efficient, with prices reflecting all publically available information. More formally,

$$F_t = E[F_T|I_t],$$

where F represents a futures price, I represents publically available information, t is the current time period, and T is the maturity date. We believe, however, that our empirical results are informative even if the market is not fully reliable.

The second idea is from Tomek (1979). He argued that annual demand equations might be identified by using intra-year (monthly) observations on expected supply, from USDA crop reports, and on contemporaneous futures prices. If expected supply varies relative to expected demand, a demand equation is identifiable. The implementation of this idea has two potential problems: one is the limited number of observations per year and the other is the potential lack of variability in crop estimates (and/or possibly the instability of expected demand). Hence, the estimates of annual relations are often imprecise. Moreover, the emphasis on annual demand equations was not particularly useful, except as an exercise to obtain demand flexibility coefficients by year. Our current paper attempts to provide a more useful result by pooling intra-year data over a period of years, thereby obtaining a broader, historical picture of the effects of changes in expected supply and demand.

The principal data set used in our analysis is based on estimates of expected corn supply (e.g., as in WASDE 2009) and on corresponding futures prices for December delivery on the CBOT corn contract. Specifically, for expected supply, we use the sum of estimated new-crop production and estimated August 31 inventory (the carry-in to the new marketing year), in million bushels. The sample period is 1989 through 2009 (with the statistical estimates based on the data through 2008), and we use observations for five months per year, July through November.[1] The quantity estimates are predetermined by producers' planting decisions and by weather and other past conditions that effect yield. Likewise, inventory depends on previous

[1] The crop and inventory estimates come from the monthly WASDE reports. The July crop estimate is qualitatively different than the subsequent estimates, as July is not based on a farm sample of current conditions. But, the July estimate is assumed to represent new information that influences prices. As discussed subsequently in the text, a month effect is modeled.

production levels and user decisions. The corresponding (settlement) price for December futures is assumed to reflect market expectations as measured by the estimates contained in the WASDE balance sheet reports.[2] Stated another way, the observations may be viewed as points of equilibrium at the time the information is released.

The price-quantity data are plotted in Figure 1. This plot depicts much of the information that we wish to convey, though a formal model is estimated. Not surprisingly, a negative relationship exists between price and expected supply. In addition, the monthly observations tend to group by sets of years, with modest shifts to the right from the 1989-94 grouping through the 2004-05 grouping. The five data points for 2006 suggest a transition to a much higher price level relative to expected supply than had existed in earlier years, and the 2007-09 data form a new group with high prices notwithstanding record large supply levels. Prices in July, August, and September 2008 are very high "outliers."

The plot in Figure 1 implies a rather dramatic increase in demand relative to supply especially in recent years. Perhaps a change in the structure of demand occurred in 2006, but this needs to be validated by additional observations. Likewise, the data cannot tell us the reason for the unusually high prices in summer of 2008. In our framework, they can be viewed as the result of mistaken expectations about the future demand for corn, but whether the mistake relates to the psychology of speculators cannot be determined by our analysis. The three 2008 observations are aberrations relative to historical experience, while the October and November 2008 observations are consistent with the 2007 and 2009 experience. The general message we wish to convey is, however, that these data tell a story and provide a context for current conditions.

Although the purpose of this paper is not to evaluate the forecasting accuracy of the futures quotes, a plot of the monthly settlement prices (horizontal axis) against a price of the December corn contract in December (vertical axis) is provided in Figure 2. The December price is the settlement price on the date of release of the December WASDE report (near the 10th of the month). Not surprisingly, the July prices for the December contract have the largest forecast errors, and the forecast errors shrink as December approaches. This figure helps justify including a month effect in the statistical model presented in the next section, and it also illustrates the potential effect of large outliers on evaluations of the forecasting accuracy of futures quotes. As the reader will see from the statistical results, the July quote for the December contract appears to be biased upward, but the preferred treatment of seeming "outliers" (observable in Figures 1 and 2) and the interpretation of results is unclear, at least to us. Perhaps futures markets are not always as "reliably anticipatory" as Working thought.

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[2] The futures prices were obtained from Bloomberg. From 1989 to 1993 (which predates the wide use of electronic trading platforms), WASDE reports were released after the futures market closed, and we use the settlement price for the day after the release of the report. Since 1993, the WASDE reports have been released at 8:30 a.m., and we use the settlement prices for the date of release.

Fig 1. Expected supply estimates and December futures price, corn, July-Nov, 1989-2009

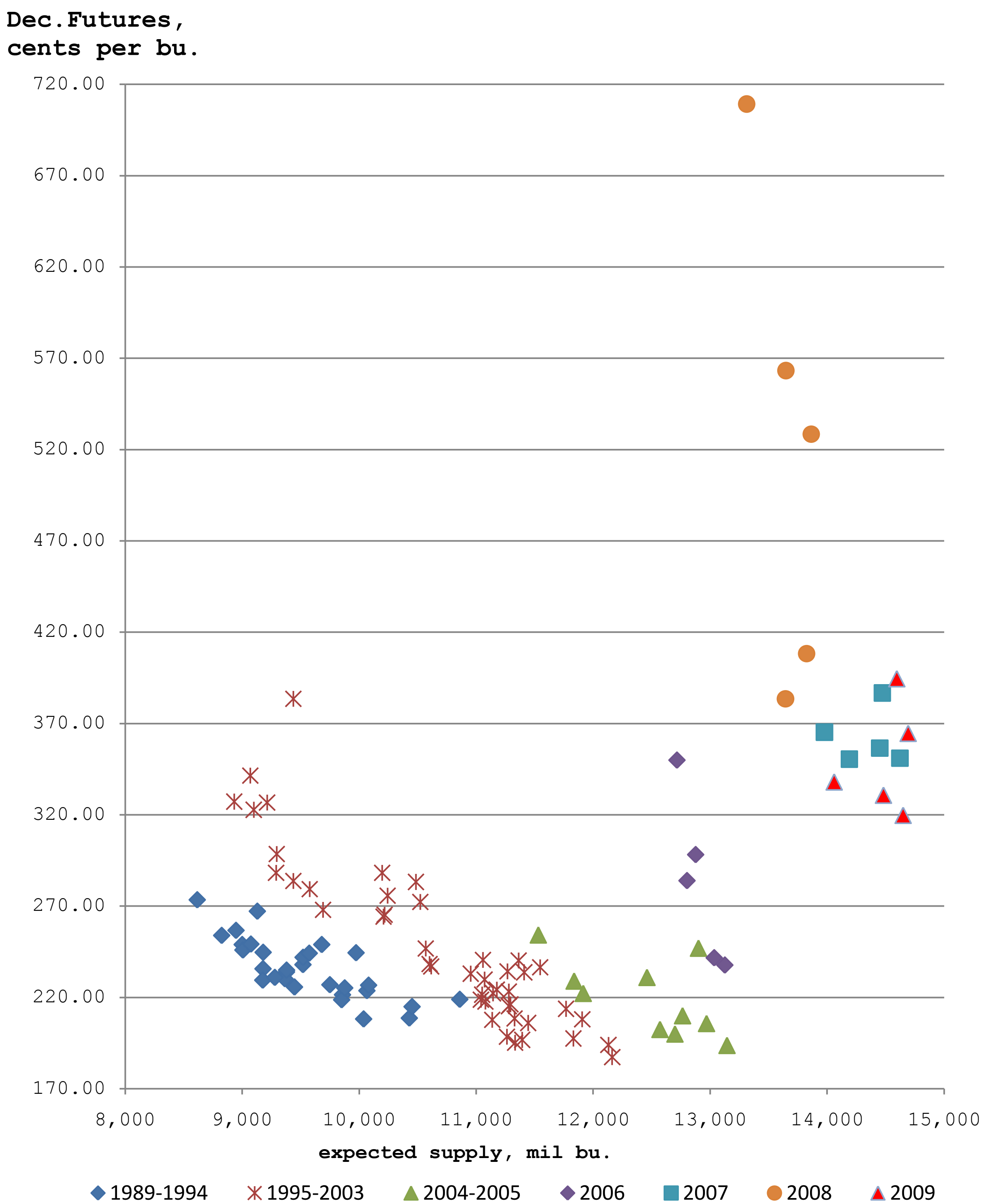
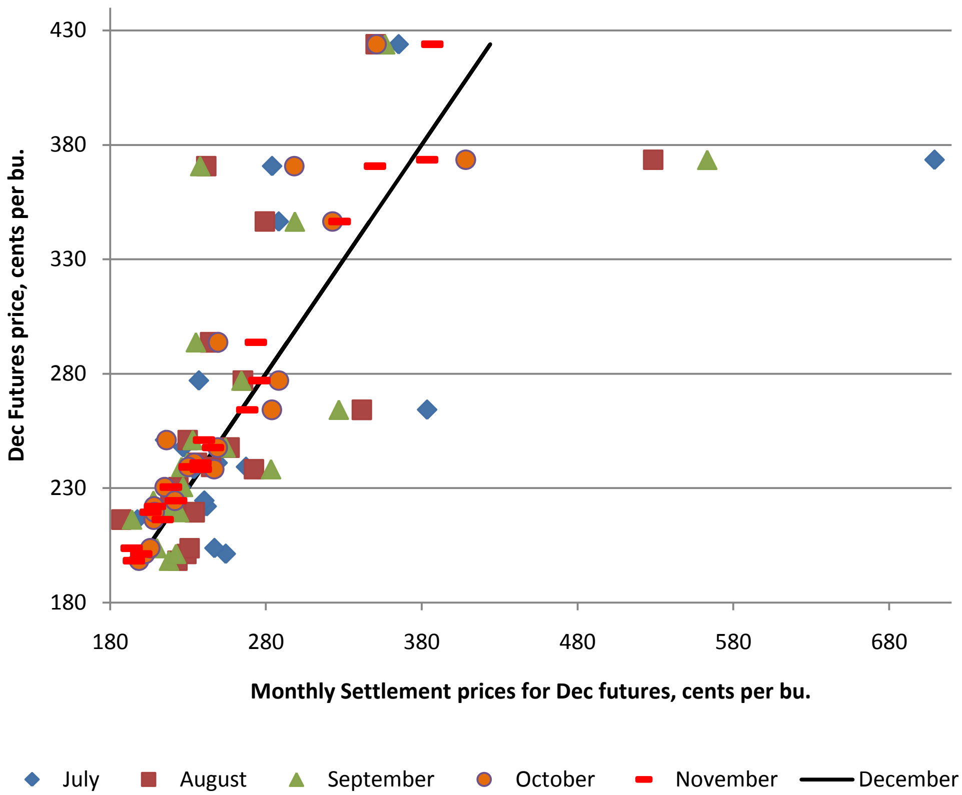


Figure 2. Relationship of the July through November prices to the December Futures Prices for Corn, 1989 to 2008.



Models

Our basic model makes prices of the December futures contract for corn a function of expected supply, defined as the sum of expected production and the estimated August 31 inventory, on the release date of the monthly WASDE reports for five dates each year. In addition, we include month-effect and year-effect dummy variables. The year-effect specification was used because Figure 1 suggests discrete shifts in the price-quantity relationship and also for convenience in modeling. As an alternative, it may be possible to develop proxies for expected demand; this is a possible direction of future research.

The monthly dummy variables are included, in part, as a test of whether the mean prices differ significantly by month, conditional on the other variables in the model and also because we include a month effect in a model of the residuals' variance. As discussed later, the interpretation of significant coefficients of the monthly dummies is not straight-forward.

Thus, the initial "general" model has 19 dummy variables for the years 1990-2008, with 1989 as the base year, and four monthly dummy variables for August to November, with July as the base month, as well as an intercept and the quantity variable. This model was fitted to the 100 pooled monthly and annual observations, giving 75 degrees of freedom. The model was then simplified by grouping years, based on the t-ratios of the individual year coefficients. An F-test suggests that the simpler, restricted model is an adequate representation of the data. Not surprisingly, this procedure is consistent with the groupings observable in Figure 1. Since July, August, and September 2008 are outliers, however, these three observations are treated as a group. The final model used in this paper, therefore, is:

$$P_{m,t} = \alpha + \beta Q_{m,t} + \sum_{n=Aug}^{Nov} \gamma_{n,t} d_{n,t} + \sum_{i=1}^{5} \delta_{m,i} f_{m,i} + e_{m,t} \tag{1}$$

where:

m	=	month (July to November)
t	=	year (1989 to 2008)
$Q_{m,t}$	=	supply estimates (expected production + beginning inventory) from WASDE Report in month m and year t (million bushels)
$P_{m,t}$	=	settlement price of December futures contract on the day of the release of the WASDE report (cents per bushel)
$d_{n,t}$	=	dummy variable for the month n; value is equal to 1 month m = n, and 0 otherwise; the base month is July
$f_{m,t}$	=	dummy variable for the i group of years; value is 1 if t Є {i group} and 0 otherwise, the base group of years is 1989-1994.

grouped years are as follows:

i	*Group of years*
1	1995-2003
2	2004-2005
3	2006
4	2007-2008 (Oct and Nov of 08 only)
5	2008 (July to Sept only)

The coefficients of the monthly dummies measure the difference in the mean prices each month from the July base, and significant differences imply that a potential bias exists in the July price (though the December price is not included in the sample). Furthermore, it is a reasonable hypothesis that the error term in equation (1) has a non-constant variance, and we examine this hypothesis by fitting the squared residuals obtained from equation (1) to the same set of explanatory variables.

$$\hat{e}_{m,t}^2 = \alpha + \beta Q_{m,t} + \sum_{n=Aug}^{Nov} \gamma_{n,t} d_{n,t} + \sum_{i=1}^{5} \delta_{m,i} y_{m,i} + w_{m,t} \tag{2}$$

We acknowledge that alternative specifications may exist that are "better." Our specification restricts the slope parameter of Q to be a constant over the entire sample. This is done to simplify the specification and thereby conserve degrees of freedom. Moreover, no logical basis appears to exist for a specific hypothesis about a reason for, and timing of, slope changes.[3]

[3] The effect of a change in estimated production on price may be larger later in the marketing year than early in the year. Before and at harvest, the market has most of the marketing year available to allocate supply among uses and ending inventory, but as the year progresses, the adjustments to new information must be larger. Thus, we conjecture that a surprise announcement about crop size in January, as happened in 2010, would have a larger effect

Also, a variety of models for pooling monthly and annual data exist, and we have not explored the alternatives. The year groupings are based on statistical tests, and as noted above, other measures of expected demand could be developed. In addition, the best way to handle the 2008 price extremes is unclear. As a practical matter, these prices did occur, and similar events could occur in the future. But, they are potentially influential data points if included in the sample. We do briefly explore the alternative of deleting the three price extremes versus modeling them, as in (1) above. Given these limitations, the paper should not be viewed as the "final word" on how to best model such data.

Results

The estimates of equation (1), using OLS for the 1989 to 2008 sample, are reported in Table 1. The residuals from this equation were squared, and used to estimate equation (2). These results are reported in Table 2, the "variance model."

Adjusted R^2 for the two equations are 92.1% and 42.4%, respectively. Equation (1) fits the data well and appears to be a reasonable representation of history, and the variance model suggests that the errors are heteroskedastic, with all of the coefficients having t-ratios of 1.5 or larger (in absolute values).

Table 1. Equation (1) estimates, 1989 – 2008 sample

price	*Coef.*	*Std. Err.*	*t*
quantity	-0.04213	0.003206	-13.14
august	-18.5333	6.961852	-2.66
september	-18.9632	6.962284	-2.72
october	-14.5013	6.998061	-2.07
november	-10.5291	6.997546	-1.5
yr95 to 03	60.77563	6.398312	9.5
yr04to 05	107.5057	12.3545	8.7
yr06	188.5076	15.13045	12.46
yr07to08	330.8255	17.44029	18.97
yr08*	535.8658	18.75351	28.57
_cons	650.3396	31.33382	20.76

*Yr 08 contains only the months of July to Sept 2008

on the March and other contract prices than found in our model, which is about the effects of July through November supply expectations on December prices.

Table 2. Equation (2), variance of error term results, 1989-2008 sample

$\hat{e}^2$	*Coef.*	*Std. Err.*	*t*
Quantity	-0.19325	0.106069	-1.82
August	-577.391	230.3223	-2.51
september	-725.699	230.3366	-3.15
October	-605.96	231.5202	-2.62
november	-333.781	231.5032	-1.44
yr95-03	431.3874	211.6785	2.04
yr04-05	642.0793	408.7299	1.57
yr06	1584.779	500.568	3.17
yr07-08	1064.75	576.9856	1.85
yr08*	4241.172	620.4316	6.84
_cons	2462.251	1036.632	2.38

*Yr 08 contains only the months of July to Sept 2008

A one million bushel increase in expected supply is estimated to reduce the price of December corn futures by 0.04213 cent (Table 1). That is, a 100 million bushel increase in expected supply is estimated to result in a 4.2 cents decline in price. With a linear equation, price flexibility estimates are conditional on the level of supply and on the month and year effects. Using various combinations of quantity and year and month effects, we obtain flexibilities that often fall in the range of -1.5 to -2.0. For example, the flexibility using October 2007 data, and the corresponding computed price, gives an estimated flexibility of -1.757, i.e., a price elasticity of roughly -0.57.[4] Many analysts would expect a more flexible price response, but it is important to remember that the relationship is estimated for the effect on December prices of changing expectations known early in the marketing year (see footnote 3).

The monthly dummies suggest that on average, the July price of the December contract is significantly above the analogous prices observed in the subsequent four months. This implies a bias in the sense that a speculative profit could have been obtained, on average, by selling December futures in July and buying in a subsequent month before maturity. The largest "profit" is associated with August and September. A concern is the degree to which the result is a consequence of the July 2008 observation. Even with the separate dummy variable for three months in 2008, the price in July 2008 may be so high that it is influencing the monthly comparisons. That is, the large variance is being split between the month and the year effect. Moreover, the month effects also suggest that WASDE reports released in October and November have less effect on the price (compared to July) than in August and September. We consider below the effect of dropping the July, August and September 2008 observations from the sample.[5]

[4] The price is computed for a quantity of 14,622 using the October and the 2007-08 dummy coefficients.
[5] The meaning of the significance month effect deserves additional analysis. Is it an artifact of the particular sample? Is there a persistent bias, and if so, why? Or? We do not undertake such an analysis in this paper.

The yearly dummies can be interpreted as capturing shifts in demand, and they confirm the qualitative results in Figure 1. The demand for corn, as measured by the December futures contract price, has increased rather dramatically. The coefficient for the 2007-08 dummy (seven observations) is a highly significant 330.8, which is a measure of the difference between 2007-08 and the 1989-94 base. The individual coefficients are, of course, *ceteris paribus* results, and supply has also increased from 1989-94 to the current time. Thus, current prices are not averaging 330.8 cents above those in 1989-94.

The monthly variances are thought to be affected by two things: a time-to-maturity effect and a seasonal effect. The time-to-maturity effect results in an increasing variance as contact maturity date approaches, but within five months to maturity this effect is likely small. The seasonal effect for a grain like corn is largest during the growing season and declines toward harvest and is smallest at harvest. The smaller coefficients for the monthly dummies presumably are importantly influenced by the seasonal effect. But, again, we have a concern about the potential effect of the unusually high prices for the three months in 2008. The squared residual for July 2008 is large, and likely influences our results.

The coefficients for the year effects are consistent with the variability of prices increasing over the sample period. The coefficient of the quantity variable is small in absolute value, with a modest t-ratio of -1.82. The negative effect of quantity on variance may be a result of a large supply being associated with lower and, hence, less variable prices.

As noted above, a concern exists about the effects of three high prices in 2008. Thus, as an alternative specification, we delete these observations from the sample. Our procedure uses three dummy variables that take the value of one only once for the particular month in question. These three variables replace the single dummy representing July, August, and September 2008. The effect of this specification is to provide estimates of the parameters of the other variables that are identical to those obtained by dropping the three observations, while forcing the residuals for the three months to be zero. Hence, the coefficients of the three monthly dummies are estimates of the "residuals" for these observations based on the new estimated equation.

The resulting regression is reported in the Appendix Table. We find that the coefficient of the quantity variable (-0.041) is essentially unchanged. The absolute magnitudes of the monthly dummies are smaller, but still statistically important. The results imply that even after omitting the July 2008 observation, the prices in August, September, and October are 10 or more cents lower than in July and with t-ratios of -1.64 or larger in absolute value. (The t-ratio for November is -1.0.) So, evidence continues to exist for a month effect.

The year effect remains highly important, and the coefficients with the deletions are nearly the same as those without the deletions. Not surprisingly, the "residuals" associated with the deleted observations are very large, but for the purposes of this paper, whether or not to delete the outliers appears not to be very important. It would be important if our emphasis was on the bias or lack of bias in the July prices as a forecast of the subsequent prices for the December contract.

We next suggest one way that estimates of equation (1), as reported in Table 1 or in the appendix, can be used. Namely, a predicted price can be made from the equation when the WASDE report is released, and the prediction can be compared with the corresponding settlement price. The difference (residual) is, in effect, a piece of information. Is the forecast from the model above or below the market price? In Table 3, we report forecasts for each of the months in 2009 for both equations (with and without the deletions). On July 10, 2009, the models' predictions were 384 and 389 cents per bushel respectively, while the settlement price was 338. Then, on August 12, the models' predictions were 356 and 352 cents, and the settlement price was 330.75. Subsequently, market prices rose relative to the forecasts. Since the supply estimates basically grew from July through November (Table 3), the increase in the settlement price presumably can be attributed to an increase in expected demand.

Ultimately, judgment is required to evaluate the implications of the forecast error between a model's result and the market's result. Our point is that the model provides a historical context for these judgments. A common practice in market analysis was to reason by analogy. Using a balance sheet like the ones reported in WASDE, a judgment prediction is based on comparisons of the current situation with similar conditions in the past. Our model, and variants thereof, can be viewed as a way to quantify the comparisons.

Table 3. Predictions of December corn futures price for 2009

2009 Prediction	Quantity	actual price	predicted price of model without 2008 data	% error	predicted price of model with 2008	% error
7/10/2009	14,060	338.00	384.17	13.659%	388.7611	15.018%
8/12/2009	14,481	330.75	355.81	7.576%	352.4894	6.573%
9/11/2009	14,649	319.75	347.10	8.553%	344.981	7.891%
10/9/2009	14,692	364.60	348.19	4.501%	347.6311	4.654%
11/11/2009	14,595	394.50	356.11	9.731%	355.6902	9.838%
			Average	8.804%		8.795%

The R-squared coefficients indicate that over 92% of the variation in price is associated with the explanatory variables in the model. Of course, the use of dummy variables cannot easily anticipate future shifts in levels of demand (though new data points can be compared with past observations) nor future outliers. Thus, we do not claim that we have a precise allocation of price variability between random events and measurable expectations. It appears, however, that much historical price behavior is associated with changing expectations.

Summary, Limitations and Possible Extensions

This paper presents an idea about organizing historical data to provide a context for market outlook. At a minimum, the data and models are informative about the effects of past representations of expected supplies and demands on prices. Clearly, the demand for corn has shifted to the right from the 1989-94 period until now, and in recent years, the growth in demand appears to have been larger than the growth in supply. Consequently, corn prices are at a high level relative to historical experience.

This information is likely to be most useful to analysts who have a deep knowledge of the corn market (or other commodity markets that might be analyzed). The difference between the model's prediction and the futures market's prediction has the potential to be informative to knowledgeable analysts. Of course, by definition, no one can predict the effects of surprises associated with new information, although the model can be used for sensitivity analysis: what if expected production increases 200 million bushels? Or?

Analysts certainly can (and should) explore alternative model specifications. Some data exists that might be treated as proxies for expected demand. The WASDE balance sheets contain estimates of expected exports, expected use for ethanol, etc. But, remember, supply and demand are equal in these balance sheets, so that using all of the measures of uses would create a singularity in a regression model.

We used nominal prices in our analysis because outlook work is typically about nominal prices. If an analyst wished to emphasize the effects of changing expectations on real prices, then a deflator must be selected, but the choice of an appropriate deflator is not obvious. The routine use of the CPI as a deflator is probably not logical for estimating real commodity prices. Also, price indexes from government sources are reported with time lags, and hence don't necessarily reflect contemporaneous expectations. Tomek (1979) constructed a deflator for corn futures prices from an index of livestock futures prices.

We also do not use a Feasible Generalized Least Squares Estimator, which is implied as needed by the heteroscedastic residuals. But, since our focus is not on the precision of estimates of particular parameters, an alternate estimator is a nicety that seemed unessential for our purposes. Our main hope in writing this paper is that we stimulate others to extend the research with improved models, alternate commodities, and appropriate estimators as may seem useful.

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Appendix Table. Equation (1) estimates, 1989 – 2008 sample, July, August, September 2008 observations deleted (via a dummy variable procedure)

price	*Coef.*	*Std. Err.*	*t*
quantity	-0.04105	0.002781	-14.76
august	-11.0767	6.184567	-1.79
september	-12.8881	6.183275	-2.08
october	-10.0322	6.107982	-1.64
november	-6.09211	6.106828	-1
yr9503	59.50935	5.540605	10.74
yr0405	104.3358	10.70445	9.75
yr06	184.87	13.1074	14.1
yr07to08	325.8364	15.11616	21.56
Jul-08	620.2549	22.25347	27.87
Aug-08	473.2009	23.18978	20.41
Sep-08	500.8952	22.86843	21.9
_cons	635.5129	27.23791	23.33