Structural Change and Forecasting of Agricultural Commodity Realized Volatilities

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Abstract:

This decade has seen movements in agricultural commodity futures markets never seen before. There are many factors that have intensified price movements and volatility behavior. Whatever the reasons are for price movements, it is clear that the volatility behavior in commodity markets constantly change, and risk managers need updated understanding to mitigate price risk. This study identified market structural breaks of weekly realized volatility in corn, wheat, soybeans, live cattle, feeder cattle and lean hogs futures markets. Furthermore, this study analyzed the forecasting performance of implied volatility, historical volatility, a composite approach and a naïve approach as pragmatic forecasters of realized volatility. Results indicate there are multiple market structural breaks present in all six commodities. Differences in the forecasting performance of the analyzed methods were examined when individual market regimes were analyzed. Implied volatility encompasses all the information contained in the historical volatility and the naïve measure across each identified market regime in all six commodities. Overall there is evidence that indicates superiority of implied volatility over historical volatility, composite and naïve approaches. Combined this suggest implied volatility is a sound forecast for 1-week ahead volatility in agricultural commodity markets.

Keywords: agricultural commodity, crops, historical, implied, forecasting, livestock, volatility

1. Introduction:

The factors that shape and intensify volatility in agricultural commodities are ever changing. Those factors likely altering supply and demand include governmental policy within and outside of the U.S, weather shocks, geopolitical conflicts, food safety concerns, etc. Whatever the reasons are for price movements, it is clear that the volatility behavior in commodity markets constantly change, and risk managers need to use current and efficient tools to mitigate price risk.

There is wide interest not only to understand but also to predict volatility in agricultural markets. Price variability or “volatility” is commonly predicted using two distinct approaches. The first approach is a backward looking measure called “Historical Volatility.” Historical volatility generally predicts price variability by calculating the variance of a historical price series. The second approach is a forward looking measure based on market expectations of price movements, this is called "Implied Volatility." There is not a direct way to calculate implied volatility. The most common way to approximate an implied volatility measure is to use the Black Scholes (1973) options pricing formula. Alternatively a combination of the backward looking measure with the markets forward-looking expectations of the markets has been analyzed as an alternative composite forecaster of volatility. As a benchmark for those three mentioned methods, this study also analyzed the performance of a naïve approach as an estimate for future realized volatility. The naïve approach conceives the next period's volatility forecast as the realized volatility estimate for the current period. This naïve approach could be of interest in the absence of access to implied and historical volatility estimates or to practioners interested in the simplest of effective forecasts.

Several studies have analyzed the forecasting performance of implied volatility, a times series alternative and a composite approach in and outside the agricultural commodities arena. Jorion (1995) discussed that implied volatility might provide better forecasts because it is able to consider forward macro economical events, as opposed to historical volatility which is a backward looking measure. Manfredo, Leuthold and Irwin (2001) found that in corn, feeder cattle and fed cattle markets implied volatility and historical volatility performed similarly in predicting cash price volatility. Manfredo and Sanders (2004) found implied volatility to be biased and an inefficient forecaster of short term futures market price volatility in live cattle markets. More recently, Brittain, Garcia and Irwin (2011) found implied volatility to be upwardly biased and an inefficient predictor of realized volatility in live cattle and feeder cattle markets.

The literature offers a variety of methods to specify a time series approach and they vary from simple moving averages to complex mathematical models. There seems to be evidence that favors simple specifications of historical volatility. Time Series forecasts like GARCH, specially the GARCH (1,1) are agreed to be a good specification of conditional volatility in agricultural price returns (e.g., Bollerslev, Chou. and Kroner, 1992; Yang and Brorsen, 1992). However, it has not been proved that GARCH specifications provide superior volatility forecasts to simpler time series alternatives (Manfredo, Leuthold and Irwin, 2001). Brittain, Garcia and Irwin (2011) analyzed the forecasting performance of different GARCH methods on live and feeder cattle option markets and found superiority in the implied volatility method over the time series alternative in the live cattle markets but the time series alternative showed smaller forecast errors in the feeder cattle markets.

Composite approaches can be specified in different ways varying from simple averaging techniques to assigning weights generated from OLS regressions of past realized volatilities. A composite approach is appealing because it takes advantage of past information combined with the forward looking nature of implied volatility. Different studies suggest that combining implied volatility with a time series alternative provides additional valuable information in forecasting future realized volatility (Manfredo et al, 2001; Benavides, 2004; Benavides and Capistran, 2012).

The definition of market regimes before analyzing the performance of different methods in predicting agricultural futures prices volatility is not common in the literature. In the literature, volatility has usually been analyzed over a determinate period of time from which the data series are extracted from. However, given different market conditions affecting the volatility in markets at different times, we believe there is a need to characterize data periods according to their volatility behavior in order to better understand the performance of the volatility prediction methods. This is not known without a focused assessment of volatility, and forecasters of volatility, as offered in this study.

Practically, we characterize realized volatility by identifying market regimes in each commodity combining a statistical approach with a qualitative approach. The Chow (1960) test and the Bai and Perron (2003) test were the methods employed in the statistical approach. There is not a consensus on whether the Chow test is more appropriate than the Bai and Perron test but studies have combined both approaches in identifying shocks. Wakamatsu and Aruga (2013) studied the impact of the shale gas revolution on the U.S. and

Japanese natural gas market. The authors first used the Chow test to test for a single break and subsequently applied the Bai and Perron approach to test for unknown number of breaks and accompanying event dates. In this study we follow a similar approach.

Studies outside the agricultural arena have conceived the idea of combining the statistical approach with an ad-hoc more qualitative approach to identifying structural breaks. Kar et. al (2013) discussed how combining both methods helps to avoid the limitations of each approach alone. The limitations of a pure statistical approach include the results are limited to power of the tests applied. The shortcomings of the qualitative approach alone are it lacks consistency across commodities and across studies.

Summarizing, this study contributes to the literature in three main ways. First, this study looks at a wide array of agricultural commodities that includes three grains and three livestock futures markets as opposed to the more common approach of studying one commodity in isolation. Second, this study defines market regimes in each commodity and assesses volatility forecasting in each of the identified regimes in addition to the full period of time for each commodity. Lastly, this study complements the commonly used econometric, forecasting performance tests by also assessing accuracy measures (Mean Absolute Errors, Root Mean Square Errors and Mean Absolute Percentage Errors) in both the full period of time and individual regimes for each commodity. In doing the above, this study uses data sources, estimation methods and evaluation methods that will offer value to the decision making of risk managers in the agribusiness arena. Moreover, this provides an example approach of broader value to applications outside the agricultural commodities arena.

2. Data Sources:

This analysis was performed using futures and options market data for corn, wheat, soybeans, live cattle, feeder cattle and lean hogs from the CME Group. Specifically, the data was obtained from Bloomberg Professional Service data terminals and consist of weekly series of futures' contracts closing price, put and call option contract's based implied volatility, and historical volatility of futures prices over the period of time beginning January 13th, 1995 and ending April 25th, 2014. The weekly futures price consists of the last closing price of a specific commodity, the last trading day of the week. Manfredo and Sanders (2004) emphasized that a risk manager is likely to compute implied volatility to forecast 1-week realized volatility highlighting the importance of analyzing forecasting optimality in a short term 1-week horizon.

To avoid using data close to the delivery time, the prices and volatilities were defined to have at least 15 days before the expiration date. This method is consistent with other studies in the agricultural commodities volatility forecasting arena (i.e. Manfredo and Sanders, 2004). Furthermore, by rolling over to the next available contract 15 days before the expiration of the current contract, we are using a highly liquid contract at the time the forecast is analyzed.[1]

The futures' closing price data series were used to estimate realized volatility as true realized volatility is not observable (Manfredo and Sanders, 2004). Jorion (1997) proposed a common method for developing a proxy for realized volatility. This proxy is accepted in the risk management arena and defines realized volatility as the square root of the average of squared returns over a particular time horizon:

(1) $$\sigma_{t+h} = \sqrt{\frac{1}{h}\sum_{j=1}^{h} R_{t+j}^2}$$

Where σ_{t+h} is realized volatility, h is the time horizon and is the continuously compounded return estimated as:

(2) $$R_t = \ln(P_t) - \ln\,(P_{t-1})$$

where and $_{-1}$ are the futures market prices observed in time period t and t-1, respectively. Since we focus on 1-week ahead realized volatility (h=1), the realized volatility equation reduces to:

$$\sigma_{t+1} = \sqrt{R_{t+1}^2} \quad (3)$$

Because implied volatility theoretically represents the annualized average volatility expected over the remaining life of the option contract (Manfredo and Sanders, 2004), the realized volatility measure is annualized to be consistent with the implied volatility:

$$\sigma_{t+1} = \sqrt{R_{t+1}^2 * 52} \quad (4)$$

The composite approach was created by regressing the realized volatility measure against one period lagged implied volatility and historical volatility. The weights for each method were then determined by the regression coefficients in each variable. Accordingly, in each commodity and in different market regimes the weights of implied and historical volatility in their composite approach vary.

The naïve expectation was defined as the realized volatility measure of one period behind for the period analyzed. That is, the naïve volatility forecast for week *t* would be the realized volatility value in week *t-1*. Table 1 shows summary statistics for implied volatility, historical volatility and realized volatility in each commodity for the full time period of evaluation.

Table 1. Descriptive statistics for Realized Volatility, Implied Volatility and Historical Volatility (expressed as %), full period of time (January 1995-April 2014)

Commodity	Variable	# Obs	Mean	Std. Dev.	Min	Max
Corn	Realized Volatility	997	21.705	19.946	0.000	136.123
	Implied Volatility	997	27.445	8.415	11.225	60.590
	Historical Volatility	997	26.834	11.489	6.940	113.890
Wheat	Realized Volatility	1007	23.730	19.923	0.000	135.419
	Implied Volatility	1005	28.852	8.220	3.800	74.040
	Historical Volatility	1007	29.901	10.660	7.810	89.420
Soybeans	Realized Volatility	1003	18.939	16.999	0.000	150.354
	Implied Volatility	1003	24.560	7.521	10.685	54.720
	Historical Volatility	1003	23.215	9.780	6.090	66.760
Live Cattle	Realized Volatility	1001	13.490	12.170	0.000	111.788
	Implied Volatility	1001	15.277	4.254	6.620	56.870
	Historical Volatility	1001	16.092	6.613	4.880	47.870

Feeder Cattle	Realized Volatility	982	11.653	10.403	0.000	80.873
	Implied Volatility	982	12.531	4.080	3.405	66.590
	Historical Volatility	982	13.442	5.100	5.320	44.250
Lean Hogs	Realized Volatility	986	23.893	25.037	0.000	198.853
	Implied Volatility	986	23.139	7.083	9.810	79.140
	Historical Volatility	986	29.929	15.173	9.420	125.050

3. Methods & Results:

a. *Market Structural Breaks*:

First for every commodity we performed the Chow test for market structural changes using SAS (9.4) statistical package. The Chow test examines for regime change at a priori known dates. Since an important limitation of the Chow test is the break date must be known a priori (Hansen, 2001), we applied the test simultaneously to every possible observation in the data set. The Chow test proved statistically significant for more than one data point in each of the six commodities. This leads us to believe that there is more than one structural break in each data set.

We then proceeded to perform the Bai and Perron (BP) tests for multiple market structural changes to define the number and dates of the breaks. The BP test allows for multiple unknown breakpoints and is a sequential method that starts by testing for a single structural break. If the test rejects the null hypothesis that there is no structural break, the sample is split in two and the test is reapplied to each subsample. This sequence continues until each subsample test fails to find evidence of a break (Hansen, 2001). For consistency across all six commodities after analyzing all the different test outputs we decided that allowing the BP test for a maximum of 20 breaks (i.e. M=20) was the most adequate with the length of each regime of at least 25 weeks. We think that market structural changes in our agricultural commodities context are largely driven by supply and demand shocks, therefore this mentioned period of time would provide enough time for those factors to interact and reveal a new equilibrium.

To interpret the BP test results we follow the strategy suggested by Bai and Perron (2003). They suggested to first look at the UD max to see if at least one break is present. If the UD max test's null hypothesis is rejected, meaning the test indicates the presence of at least one break, we move to the supF(l+1|l) sequential examination to decide the number of breaks. As shown in table 2, the UDmax proved statistically significant at the 95% level of confidence for corn, wheat, soybeans, live cattle, feeder cattle and lean hogs. This result confirms conclusions from the Chow test, suggesting there is at least one break present in each commodity. The next step is to identify the number of breaks and their dates.

Bai and Perron (2003) explained that the supF(l+1|l) statistics are constructed using global minimizers for the break date, this test selects M (the number of breaks), such that the test supF(l+1|l) are significant for l>= m. For every M, the supF(l+1|l) test presents the null hypothesis of no break and the alternative hypothesis of l+1 breaks, l=0 up to l=M. At the 95% level of confidence, this test stops rejecting the null hypothesis of no additional break at different "l" for each commodity. This suggests a different number of breaks, at different dates, in the realized volatility series of each commodity. Table 2 shows summary results of the Bai and Perron test for each commodity. Overall, the BP test identified a total number of 3 breaks in corn,

[1] There was a small percentage of implied volatility missing observations across the six commodities at the beginning of the data series. Those observations were deleted for the purpose of this analysis.

6 in wheat, 5 in soybeans, 13 in live cattle, 16 in feeder cattle and 21 in lean hogs.[2]

Table 2. Summary results of the Bai and Perron tests

Commodity	UDmaxF	supF(l+1|l) Tests		Total Breaks
		supF(l+1|l)	l	
Corn	119.496*	102.251*	2	3
Wheat	84.627*	43.007*	5	6
Soybeans	168.844*	59.918*	4	5
Live Cattle	168.712*	50.904*	12	13
Feeder Cattle	75.000*	101.065*	15	16
Lean Hogs	127.964*	338.158*	20	21

*The statistic is statistically significant at the 95% level of confidence.

The qualitative approach was then added to refine conclusions regarding structural breaks. A rule to merge regimes in which the mean of realized volatility was within 20% of the previous regime was defined such that a smaller set of breaks for each commodity could further be identified for subsequent assessment. That is, if the BP process suggested a break that identified two regimes with average realized volatility within 20%, this method collapsed these two regimes down to one regime. Each new set of regimes was analyzed and sequentially merged using the same procedure. The same procedure was applied for each of the six commodities. Table 3 shows realized volatility summary statistics in the full period of time and in individual regimes for each commodity after the statistical and the qualitative approach were combined. The combined procedure identified 4 regimes in corn, 7 regimes in wheat, 5 in soybeans, 9 in live cattle, 8 in feeder cattle and 8 in lean hogs.

Table 3. **Realized volatility summary statistics in merged regimes**

Corn	Dates	# Obs	Mean	Std. Dev.	CV	Min	Max
Full Period	1/13/1995-4/25/2014	997	0.217	0.199	0.919	0.000	1.361
Regime 1	1/13/1995-1/11/2008	670	0.196	0.174	0.888	0.000	1.102
Regime 2	1/18/2008-12/12/2008	48	0.410	0.356	0.870	0.000	1.361
Regime 3	12/19/2008-6/21/2013	236	0.250	0.209	0.833	0.000	0.936
Regime 4	7/5/2013-4/25/2014	43	0.149	0.124	0.831	0.004	0.725
Wheat	**Dates**	**# Obs**	**Mean**	**Std. Dev.**	**CV**	**Min**	**Max**
Full Period	1/13/1995-4/25/2014	1007	0.237	0.199	0.840	0.000	1.354
Regime 1	1/13/1995-4/5/1996	65	0.202	0.145	0.717	0.005	0.764
Regime 2	4/12/1996-4/18/1997	54	0.266	0.242	0.911	0.000	1.184
Regime 3	4/25/1997-11/16/2007	552	0.212	0.167	0.790	0.000	1.006
Regime 4	11/23/2007-1/16/2009	61	0.390	0.298	0.765	0.011	1.354
Regime 5	1/23/2009-1/1/2010	50	0.266	0.197	0.740	0.014	0.758

Regime 6	1/8/2010-12/3/2010	48	0.325	0.279	0.860	0.008	1.325
Regime 7	12/10/2010-4/25/2014	177	0.236	0.197	0.832	0.006	1.099

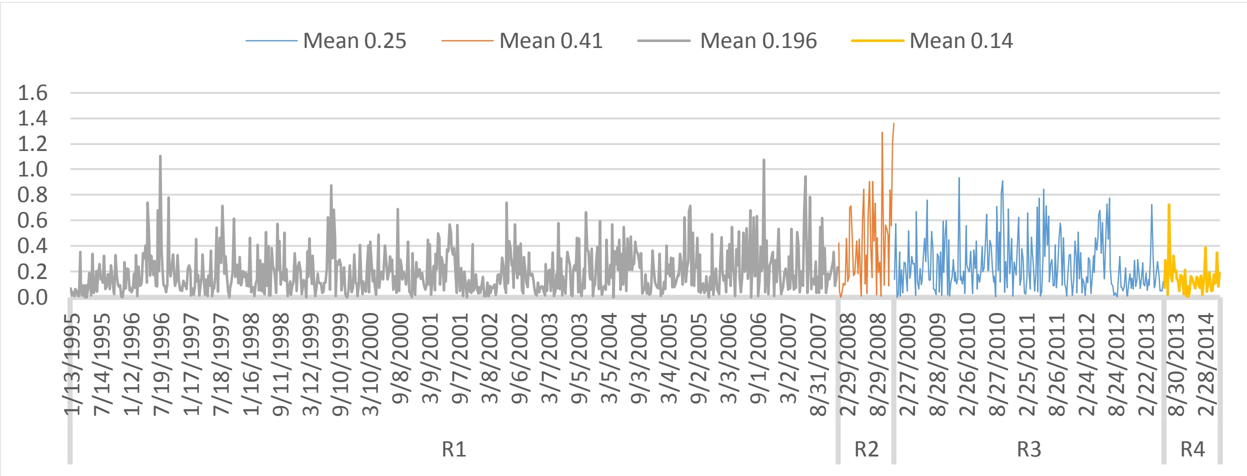
Soybeans	**Dates**	**# Obs**	**Mean**	**Std. Dev.**	**CV**	**Min**	**Max**
Full Period	1/13/1995-4/25/2014	1003	0.189	0.170	0.898	0.000	1.504
Regime 1	1/13/1995-8/22/2003	446	0.155	0.135	0.871	0.000	0.901
Regime 2	8/29/2003-7/1/2005	97	0.250	0.215	0.859	0.002	1.104
Regime 3	7/8/2005-11/9/2007	123	0.184	0.138	0.749	0.002	0.582
Regime 4	11/16/2007-9/4/2009	95	0.318	0.269	0.847	0.011	1.504
Regime 5	9/11/2009-4/25/2014	242	0.180	0.141	0.783	0.000	0.772

Live Cattle	**Dates**	**# Obs**	**Mean**	**Std. Dev.**	**CV**	**Min**	**Max**
Full Period	1/13/1995-4/25/2014	1001	0.135	0.122	0.902	0.000	1.118
Regime 1	1/13/1995-4/5/1996	65	0.126	0.094	0.746	0.000	0.379
Regime 2	4/12/1996-10/11/1996	27	0.190	0.165	0.873	0.005	0.661
Regime 3	10/18/1996-7/17/1998	92	0.106	0.080	0.759	0.000	0.347
Regime 4	7/24/1998-6/18/1999	48	0.171	0.137	0.802	0.003	0.654
Regime 5	6/25/1999-4/6/2001	94	0.088	0.071	0.810	0.003	0.388
Regime 6	4/13/2001-2/14/2003	97	0.150	0.138	0.920	0.003	0.687
Regime 7	2/21/2003-1/21/2005	95	0.203	0.173	0.853	0.000	1.118
Regime 8	1/28/2005-10/21/2011	352	0.136	0.117	0.859	0.000	0.683
Regime 9	10/28/2011-4/25/2014	131	0.106	0.095	0.896	0.000	0.541

As an example, figure 1 illustrates the behavior of corn realized volatility in each regime to highlight the notable changes at play in the full period of analysis.

[1] For brevity the appendix shows the dates of the breaks identified with the BP test and corresponding summary statistics of realized volatility for each commodity.

Figure 1. Corn realized volatility by regime



The corn market regime with the highest average realized volatility (0.41) is regime 2 spanning from 1/18/2008 to 12/12/2008. This coincides with the U.S. and world financial crisis, which was also a period where grains futures prices spiked. Though regime start and end dates varied across grains, all the grains have a period with highest average realized volatility that contained at least the 2008 period [3]

b .Forecasting Characteristics Assessment:

To assess the ability of implied volatility, 20-days historical volatility, a linear composite approach and a naïve approach in predicting future one week ahead realized volatility we first applied econometric tests. Four tests commonly used in existing literature on price volatility were conducted: test for forecast bias, test for forecast efficiency, test for forecast encompassing and the test for time change. Additionally this study analyzes forecasting ability by analyzing the forecast errors from each method using three measurements of accuracy: mean absolute errors, root mean square errors and mean absolute percentage errors. These econometric and forecasting accuracy assessments were first made using the full period of time and later applied in each individual regime of each commodity. Results for each commodity when the full period of time was analyzed are shown in tables 4-8. Results for each individual regime, in each commodity, are included in the Appendix.

Test for forecast bias:

The following OLS regression is used to determine if the forecast is unbiased and is consistent with the one used by Pons (2000):

(5) e_t

Where e_t is the difference between the realized volatility measure and the volatility forecast estimate (Implied volatility method, historical volatility method, the composite approach or naïve method). The forecast is unbiased if we fail to reject the Ho: γ=0. The alternative hypothesis γ<0 suggests that the forecast systematically overestimates the realized volatility and γ>0 suggests that the forecast systematically underestimates the realized volatility.

Table 4 shows the result for this test in the full period of time for all of the commodities. Across the grains

[3] Specifically, regime 4 for wheat covered 11/23/2007 to 1/16/2009 and regime 4 for soybeans spanned from 11/16/2007 to 9/4/2009.

and livestock markets implied volatility, historical volatility, a composite approach and a naïve approach were all unbiased forecasters of 1 week ahead realized volatility. Since the implied volatility and the historical volatility were both unbiased forecasters of realized volatility, it is not surprising that the linear combination of both is also unbiased. This conclusion holds for the full time period analysis and for the different market regimes analyzed.

Table 1. Test for forecast bias in the full period of time (January 1995-April 2014)

Forecast bias	Corn	Wheat	Soybeans	Live Cattle	Feeder Cattle	Lean Hogs
1. IV model	Y	Y	Y	Y	Y	Y
2. HV model	Y	Y	Y	Y	Y	Y
3. Composite model	Y	Y	Y	Y	Y	Y
4. Naïve model	Y	Y	Y	Y	Y	Y

*Y= The forecast method is unbiased.
*N= The forecast method is biased.
* From equation 5.

Test for forecast efficiency:

Weak form forecast efficiency is tested using the following OLS regressions as described by Manfredo and Sanders (2004):

(6) $$e_t$$

(7) $$e_t = \alpha_2 + \rho e_{t-1} + v_{t2}$$

Equation 6 is known as the Beta efficiency test and equation 7 is known as the Rho efficiency test. The condition for weak efficiency is that $\beta = 0$ and $\rho = 0$ respectively. If we fail to reject the null hypothesis of $\beta = 0$ in equation 6 then we can say that the forecast is efficient, meaning that the forecast method incorporates all the information regarding future volatility and the forecast pass this condition of weak efficiency. In equation 7, if we fail to reject the null hypothesis of $\rho = 0$, then we can say that there is no time series pattern to the forecast errors and that the forecast passes this condition for weak efficiency. Both conditions need to be fulfilled in order to call the forecast method efficient.

Table 5 shows the result for this test in the full period of time for all of the commodities. In the full period of time, implied volatility, historical volatility, a composite approach and a naïve approach were all found efficient forecasters of 1-week ahead realized volatility across the corn, wheat and soybeans markets using the beta efficiency and the rho efficiency condition tests. Results for individual market regimes varied across these three commodities and across the three forecast methods.

In the live cattle and lean hogs markets implied volatility, historical volatility, the composite forecast and the naïve method were all efficient forecasters of 1-week realized volatility when the full spectrum of the data was analyzed. In the feeder cattle market and using the full period of time implied volatility, the composite method and the naïve approach were efficient but the historical volatility forecast method was inefficient at forecasting 1 week- ahead realized volatility. When the market regimes where analyzed separately the results were mixed across regimes and across forecast methods.

Table 2. Test for forecast efficiency in the full period of time (January 1995-April 2014)

Forecast efficiency	Corn	Wheat	Soybeans	Live Cattle	Feeder Cattle	Lean Hogs
***Beta efficiency**						
1. IV model	Y	Y	Y	Y	Y	Y
2. HV model	Y	Y	Y	Y	Y	Y
3. Composite model	Y	Y	Y	Y	Y	Y
4. Naïve model	Y	Y	Y	Y	Y	Y
***Rho efficiency**						
1. IV model	Y	Y	Y	Y	Y	Y
2. HV model	Y	Y	Y	Y	N	Y
3. Composite model	Y	Y	Y	Y	Y	Y
4. Naïve model	Y	Y	Y	Y	Y	Y

*Y= The forecast passes the beta efficiency/rho efficiency test for weak efficiency.
*N= The forecast fails the beta efficiency/rho efficiency test for weak efficiency.
*From equations 6 and 7.

Test for forecast encompassing:

We also have an interest in studying if implied volatility, being a forward looking measure, encompasses all the information contained in alternative forecasts. Harvey et al. (1998) described a framework to test the ability of a forecast to encompass an alternative forecast using the following OLS regression:

$$e_{1t} = \alpha + \lambda(e_{1t} - e_{2t}) \quad (8)$$

Where e_{1t} is the forecast error series of the preferred forecast and e_{2t} is the forecast error series of the competing forecast. Manfredo and Sanders (2004) explained that the null hypothesis of λ=0 suggests that the covariance between the preferred forecast error series (e_{1t}) and the difference between the preferred and competing series ($e_{1t} - e_{2t}$) is zero. In other words, the preferred forecast encompasses the competing forecast and the competing forecast contains no useful information beyond the preferred.

Table 6 shows the result for this test in the full period of time for all of the commodities. Across all commodities, implied volatility proved to encompass all the information contained in the historical volatility forecast when the full period of time was analyzed. On the other hand, historical volatility was found not to encompass all the information contained in the implied volatility forecast across all six commodities in the full period of time. This suggests that the historical volatility method provides no further information relative to the implied volatility method in forecasting one week ahead realized volatility in all six commodities.

Across all commodities, implied volatility encompassed all the information contained in the naïve forecast when the full period of time was analyzed. On the other hand, the naïve forecast was found not to encompass all the information contained in the implied volatility forecast across all six commodities in the full period of time when compared to implied and historical volatility. When individual market regimes were analyzed, implied volatility encompassed all the information contained in the historical volatility method in all of the regimes across commodities except for regime 4 in corn. This reinforces the full period based conclusion of implied volatility containing all information available in historical volatility.

Table 3. Test for forecast encompassing in the full period of time (January 1995-April 2014)

Forecasting encompassing	Corn	Wheat	Soybeans	Live Cattle	Feeder Cattle	Lean Hogs
Preferred forecast						
1. Implied Volatility	Y	Y	Y	Y	Y	Y
2. Historical Volatility	N	N	N	N	N	N
Preferred forecast						
1. Implied Volatility	Y	Y	Y	Y	Y	Y
2. Naïve model	N	N	N	N	N	N
Preferred forecast						
1.Historical Volatility	Y	Y	Y	Y	N	Y
2. Naïve model	N	N	N	N	N	N

*Y= The forecast encompasses the information contained in the alternative forecast.
*N= The forecast does not encompass the information contained in the alternative forecast.
*From equation 8.

Test for time change:

It is also of interest to find out if the quality of forecasts is changing overtime. Manfredo and Sanders (2004) discussed some of the reasons why this is of interest including advances in computer technology, option pricing models, market liquidity and statistical forecasting techniques that might have improved the market's ability to forecast volatility over time. Alternatively we contemplate the idea that the forecast errors might have been increasing over time in some cases given increases in realized volatility levels during our study period (e.g. regime 2 for corn in Figure 1). In this case, the analyzed forecasts techniques may have decreased their ability to forecast future volatility as the underlying level of realized volatility may have increased making all approaches less accurate. This could be due to an increase in the complexities of the markets given more globalized trade systems and new forms of market regulations. In order to analyze time change in the forecast methods, Bailey and Brorsen (1998) proposed the following OLS regression where the absolute values of the forecast errors are regressed against a time trend as follows:

$$|e_t| = \alpha + \theta Trend_t \qquad (9)$$

The null hypothesis of this test is $\theta = 0$ and suggests no systematic change in the forecast over time. This conclusion would suggest that the forecast errors are not getting bigger or smaller over the analyzed time period, therefore the forecast method ability to predict realized volatility, has stayed the same overtime.

Table 7 shows the result for this test in the full period of time for all of the commodities. The test results show that the forecast performance of the four forecast methods in the corn, wheat and soybeans markets has gotten worse over time while forecasts for live cattle, feeder cattle and lean hogs have not changed, using the full period of the data. Our perception about this conclusion is that the market complexities have intensified over the time period analyzed, making it harder for the forecast methods to predict volatility. When the individual market regimes where analyzed results varied but in general very few regimes across commodities actually showed time change in one or more forecast methods.

The difference in the nature of the conclusions regarding the volatility forecast performance in the grain and livestock markets might be explained in part by the nature of their underlying futures contracts. The CME Group (2014) describes their grain futures contracts as global benchmarks where people from all over the world offset risk. Conversely, the livestock contracts for live cattle, feeder cattle and lean hogs, are comparatively more regional where nearly all of their hedging customers are located within the United State.

Although now it is clear that the grain markets and livestock markets enjoy more depth and liquidity, the average trading volume of corn, wheat and soybeans averaged about 17% higher than the average volume of live cattle, feeder cattle and lean hogs in 2014. Future research may further compare grains and livestock patterns in the forecasting performance arena.

Table 4. Test for forecast change in the full period of time (January 1995-April 2014)

Time change	Corn	Wheat	Soybeans	Live Cattle	Feeder Cattle	Lean Hogs
1. IV model	Y^+	Y^+	Y^+	N	N	N
2. HV model	Y^+	Y^+	Y^+	N	N	N
3. Composite model	Y^+	Y^+	Y^+	N	N	N
4. Naïve model	Y^+	Y^+	Y^+	N	N	N

*Y^+= The forecast errors are getting bigger overtime.
*Y^- = The forecast errors are getting smaller overtime.
*N= The forecast does not show systematic change over time.
*From equation 9.

C. Benchmark for forecasting optimality tests: Mean Absolute Errors, Root Mean Square:

Errors and Mean Absolute Percentage Errors:

Table 8 shows results of complementing our econometric assessments by analyzing alternative forecast methods based on three measures of accuracy: Mean Absolute Errors (MAE), Root Mean Squared Errors (RMSE) and Mean Absolute Percentage Errors (MAPE). We found evidence that support our previous results regarding the forecasting performance of alternative methods and differences in forecasting performance when specific regimes are analyzed. When MAE and RMSE were analyzed in all commodities in the full period of time, the composite method ranked best numerically, followed by implied volatility in the full period of time. The varying mix of weights on IV and HV in the composite approach should be noted in these numerical comparisons. The worst performing method across all commodities in the full period of time was the naïve approach based on MAE, RMSE and MAPE. When MAPE were analyzed in the full period of time, the composite approach ranked highest in corn, wheat and soybeans while implied volatility ranked highest in live cattle, feeder cattle and lean hogs.

We then compared the MAE, RMSE and MAPE estimates from implied volatility, historical volatility and the naïve approach using paired t-tests to assess if differences are statistically significant. The composite approach was not compared because implied volatility and historical volatility are embedded in it at different weights across commodities and regimes which may mislead paired t-test results. Implied volatility had statistically lower MAEs than historical volatility in corn, soybeans, live cattle, feeder cattle and lean hogs in the full period of time. Implied volatility also had statistically lower MAEs than the naïve approach across all commodities in the full period of time. Historical volatility yielded statistically lower MAEs than the naïve approach in the corn, wheat and soybeans markets.

Utilizing RMSE as an accuracy measure, for the full period of time, implied volatility is statistically better than both historical volatility and naïve approaches for all six commodities. Similarly, historical volatility is superior to a naïve approach in the corn, wheat and soybeans markets.

As a final measure, MAPEs were compared to provide a relative (percentage rather than levels) assessment. Based upon MAPEs, implied volatility is statistically superior to historical volatility in the corn, live cattle, and lean hog markets and more accurate than a naïve approach for all six commodities. Historical volatility yields significantly lower MAPEs than the naïve approach in all six markets.

Table 5. Mean Absolute Errors (MAE), Root Mean Square Errors (RMSE) and Mean Absolute Percentage Errors (MAPES) in the full period of time (January 1995-April 2014)

MAE	**Corn**[abc]	**Wheat**[bc]	**Soybeans**[abc]	**Live Cattle**[ab]	**Feeder Cattle**[ab]	**Lean Hogs**[ab]
Implied Volatility	0.139	0.144	0.117	0.085	0.073	0.163
Historical Volatility	0.144	0.145	0.119	0.089	0.075	0.166
Composite Approach	0.139	0.144	0.116	0.085	0.073	0.163
Naïve Approach	0.149	0.148	0.122	0.089	0.076	0.167
RMSE	**Corn**[abc]	**Wheat**[abc]	**Soybeans**[abc]	**Live Cattle**[ab]	**Feeder Cattle**[ab]	**Lean Hogs**[ab]
Implied Volatility	0.186	0.190	0.159	0.115	0.097	0.244
Historical Volatility	0.192	0.193	0.162	0.121	0.101	0.249
Composite Approach	0.186	0.190	0.159	0.114	0.097	0.244
Naïve Approach	0.197	0.197	0.168	0.121	0.102	0.249
MAPE	**Corn**[abc]	**Wheat**[bc]	**Soybeans**[bc]	**Live Cattle**[abc]	**Feeder Cattle**[b]	**Lean Hogs**[ab]
Implied Volatility	2.417	2.180	2.737	2.605	2.526	2.951
Historical Volatility	2.526	2.228	2.751	2.727	2.608	3.032
Composite Approach	2.414	2.181	2.724	2.616	2.531	2.956
Naïve Approach	2.610	2.303	2.891	2.766	2.658	3.074

a: Implied volatility and historical volatility point estimates are statistically different at $p<0.1$.
b: Implied volatility and the naïve approach point estimates are statistically different at $p<0.1$.
c: Historical volatility and the naïve approach point estimates are statistically different at $p<0.1$.

As shown in the appendix, the relative relationship of implied volatility, historical volatility, composite and naïve approaches in the full period assessment also hold in the majority of cases when examining the individual regimes of each commodity. The main adjustment is specific findings regarding statistical evidence of forecasting approach differences vary by regime and commodity more than found in the full period examination. This is not surprising given the notable reduction in observations for each comparison within each regime evaluated.

4. Conclusions:

When it comes to decision making, the availability of resources is a key factor in identifying a feasible and ultimately preferable way to project upcoming price volatility. The data used in this study is available to general public but it requires investment and ongoing manipulation for regular use. Risk managers should be aware of the importance of having a comprehensive risk management plan that uses the most adequate techniques according to their own circumstance. When users have available both implied volatility data and historical volatility, the process required to combine those approaches is not difficult. However, this research shows very limited forecasting improvement by creating a linear combination of implied volatility and historical volatility as forecaster of 1 week realized volatility of the analyzed agricultural commodities. Furthermore, this study shows that implied volatility encompasses all the information contained in the historical volatility and the naïve approach measures analyzed. It is important to keep in mind that the historical volatility measure used in this study is a 20 day moving average. Past literature shows that a simple historical approach might be superior to other time series alternatives that involve complex mathematical models. Additionally, 20-days historical volatility is more widely available than measures that come from more complex time series approaches, therefore is a more accessible tool for risk managers.

The bottom-line for a risk manager exposed to agricultural commodity price risk involves deciding what forecast method to forecast future volatility. We recognize that the several steps taken in this study include the identification of the market regimes which requires expertise that is not available to market participants all of the time. Though we recognize the importance of the market structural breaks in our data, the question that rises is how do we identify those regimes contemporarily? Maybe the good news is that if that expertise is not available to the decision maker, we found enough evidence to support the idea that no matter in what market regime the decision might have to be taken, implied volatility, historical volatility and the composite method could offer a decent estimate of future realized volatility in the short term based on bias and efficiency. When our analysis was complemented by estimating the mean absolute errors, the root mean squared errors and the mean absolute percentage errors we found equal superiority in the composite and implied volatility forecast methods. Furthermore, considering the extra steps required for the estimation of a composite approach, it is advisable for a decision maker to use implied volatility as forecaster of realized volatility in the short term.

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Appendix

The main article focuses on providing tables highlighting results based upon the full period of time analyzes. As noted throughout the main text, this appendix is included to show parallel results for individual market regimes across all commodities.

Table A shows the individual regimes identified using the Bai and Perron test, before being combined with the ad-hoc approach, in each commodity. Comparing this table with table 3 in the main article informs readers of how the qualitative approach impacts conclusions regarding breaks.

Tables A.4.1 to A.4.9 are a continuation of table 4 in the main article and show the assessment of bias for each commodity in individual regimes. Tables A.5.1 to A.5.9 are a continuation of table 5 in the main article and show the assessment of efficiency for each commodity in individual regimes. Tables A.6.1 to A.6.9 are a continuation of table 6 in the main article and show the assessment of forecast encompassing for each commodity in individual regimes. Tables A.7.1 to A.7.9 are a continuation of table 7 in the main article and show the assessment of forecast change for each commodity in individual regimes.

Tables A.8.1 through A.8.9 are a continuation of table 8 in the main article and show the result for mean absolute errors, root mean square errors and mean absolute percentage errors in each commodity for individual regimes.

Table A.9 shows the coefficients for implied volatility and historical volatility in estimating the composite approach for all commodities in the full period of time and in each market regime.

Table A. Summary of the regimes identified with the BP test

Corn	**Dates**	**# obs**	**Mean**	**SD**	**Min**	**Max**	**% Change***
Regime1	1/13/95-1/11/08	679	0.196	0.174	0.000	1.102	
Regime2	1/11/08-12/12/08	48	0.410	0.356	0.000	1.361	208.961
Regime3	12/12/08-6/21/13	236	0.250	0.209	0.000	0.936	61.111
Regime4	6/21/13-4/25/14	44	0.149	0.124	0.004	0.725	59.531
Wheat	**Dates**	**# obs**	**Mean**	**SD**	**Min**	**Max**	**% Change***
Regime1	1/13/95-4/5/96	65	0.2020	0.145	0.005	0.764	
Regime2	4/5/96-4/18/97	54	0.266	0.242	0.000	1.184	131.685
Regime3	4/18/97-11/16/07	552	0.212	0.167	0.000	1.006	79.637
Regime4	11/16/07-1/16/09	61	0.390	0.298	0.011	1.354	184.158
Regime5	1/16/09-1/1/10	50	0.266	0.197	0.014	0.758	68.265
Regime6	1/1/10-12/3/10	48	0.325	0.279	0.008	1.325	121.852
Regime7	12/3/10-4/25/14	177	0.236	0.197	0.006	1.099	72.796
Soybeans	**Dates**	**# obs**	**Mean**	**SD**	**Min**	**Max**	**% Change***
Regime1	1/13/95-8/22/03	450	0.157	0.138	0.000	0.901	
Regime2	8/22/03-7/1/05	97	0.250	0.215	0.002	1.104	158.967
Regime3	7/1/05-11/9/2007	123	0.184	0.138	0.002	0.582	73.639
Regime4	11/9/07-10/3/08	47	0.309	0.256	0.016	1.153	168.214
Regime5	10/3/08-9/4/09	48	0.326	0.284	0.011	1.504	105.393
Regime6	9/4/09-8/15/14	258	0.185	0.150	0.000	0.877	56.595
Live Cattle	**Dates**	**# obs**	**Mean**	**SD**	**Min**	**Max**	**% Change***
Regime1	1/13/95-4/5/96	65.000	0.126	0.094	0.000	0.379	
Regime2	4/5/96-10/11/96	27.000	0.190	0.165	0.005	0.661	150.801
Regime3	10/11/96-7/17/98	92.000	0.106	0.080	0.000	0.347	55.911
Regime4	7/17/98-6/18/99	48.000	0.171	0.137	0.003	0.654	161.204
Regime5	6/18/99-4/6/01	94.000	0.088	0.071	0.003	0.388	51.419
Regime6	4/6/01-3/8/02	48.000	0.147	0.144	0.005	0.687	167.843
Regime7	3/8/02-2/14/03	49.000	0.153	0.133	0.003	0.578	103.701
Regime8	2/14/03-1/2/04	46.000	0.216	0.219	0.000	1.118	#REF!
Regime9	1/2/04-1/21/05	55.000	0.199	0.117	0.011	0.534	92.504
Regime10	1/21/05-12/28/07	153.000	0.124	0.109	0.002	0.683	62.382
Regime11	12/28/07-12/5/08	49.000	0.168	0.157	0.000	0.668	134.724
Regime12	12/5/08-3/11/11	118.000	0.134	0.099	0.003	0.477	79.930
Regime13	3/11/11-10/21/11	32.000	0.148	0.132	0.003	0.507	110.784
Regime14	10/21/11-5/30/14	136.000	0.104	0.094	0.000	0.541	70.083

*Percentage change was calculated used the mean realized volatility for each regime, compared to the previous regime.

Table A. Summary of the regimes identified with the BP test (continuation)

Feeder Cattle	Dates	# obs	Mean	SD	Min	Max	% Change*
Regime1	1/13/95-4/19/96	67	0.120	0.090	0.003	0.353	
Regime2	4/19/96-3/21/97	48	0.137	0.149	0.003	0.734	114.233
Regime3	3/21/97-5/29/98	62	0.115	0.085	0.002	0.309	83.920
Regime4	5/29/98-5/14/99	50	0.152	0.107	0.015	0.495	131.803
Regime5	5/14/99-1/26/01	89	0.056	0.041	0.002	0.163	36.907
Regime6	1/26/01-3/01/02	57	0.089	0.084	0.004	0.413	158.056
Regime7	3/1/02-2/07/03	49	0.105	0.086	0.002	0.394	118.382
Regime8	2/7/03-01/09/04	48	0.145	0.154	0.004	0.809	138.433
Regime9	1/09/04-4/01/05	64	0.140	0.115	0.003	0.510	96.247
Regime10	4/01/05-5/05/06	57	0.110	0.083	0.006	0.385	78.426
Regime11	5/05/06-11/03/06	26	0.134	0.143	0.003	0.540	122.064
Regime12	11/03/06-5/16/08	80	0.122	0.090	0.002	0.429	91.376
Regime13	5/16/08-6/5/09	55	0.171	0.137	0.002	0.505	140.003
Regime14	6/05/09-6/10/11	105	0.109	0.089	0.005	0.374	63.816
Regime15	6/10/11-5/25/12	50	0.137	0.111	0.003	0.508	125.346
Regime16	5/25/12-5/17/13	51	0.112	0.086	0.000	0.397	81.604
Regime17	5/17/13-4/25/14	49	0.066	0.053	0.001	0.200	58.692

*Percentage change was calculated used the mean realized volatility for each regime, compared to the previous regime.

Table A. Summary of the regimes identified with the BP test (continuation)

Lean Hogs	Dates	# obs	Mean	SD	Min	Max	% Change*
Regime1	01/13/95-12/08/95	48	0.217	0.236	0.005	1.186	
Regime2	12/08/95-01/10/96	47	0.211	0.154	0.006	0.652	97.120
Regime3	01/10/96-01/16/98	63	0.142	0.158	0.000	0.884	67.333
Regime4	01/16/98-12/11/98	47	0.377	0.414	0.003	1.989	265.463
Regime5	12/11/98-11/05/99	47	0.332	0.276	0.007	1.343	88.118
Regime6	11/05/99-10/06/00	48	0.231	0.269	0.005	1.321	69.658
Regime7	10/06/00-9/07/01	48	0.193	0.191	0.006	1.126	83.707
Regime8	09/07/01-8/02/02	47	0.317	0.348	0.000	1.906	163.971
Regime9	08/02/02-08/08/03	53	0.307	0.289	0.024	1.317	96.676
Regime10	08/08/03-07/09/04	49	0.210	0.191	0.002	0.919	68.565
Regime11	07/09/04-07/22/05	53	0.208	0.187	0.002	0.805	98.874
Regime12	07/22/05-06/23/06	48	0.232	0.223	0.003	1.230	111.749
Regime13	06/23/06-05/18/07	47	0.197	0.214	0.000	1.182	84.827
Regime14	05/18/07-04/04/08	46	0.287	0.280	0.041	1.446	145.702
Regime15	04/04/08-05/15/09	58	0.307	0.261	0.023	1.446	106.806
Regime16	05/15/09-04/02/10	46	0.294	0.292	0.013	1.317	95.939
Regime17	04/02/10-03/18/11	50	0.171	0.161	0.002	0.611	58.213
Regime18	03/18/11-09/23/11	28	0.205	0.182	0.008	0.783	119.427
Regime19	09/23/11-08/03/12	44	0.196	0.267	0.008	1.639	96.004
Regime20	08/03/12-02/01/13	26	0.167	0.102	0.013	0.379	85.215
Regime21	02/01/13-08/21/13	26	0.199	0.210	0.039	1.099	118.767
Regime22	08/21/13-04/25/14	38	0.177	0.160	0.006	0.671	89.094

*Percentage change was calculated used the mean realized volatility for each regime, compared to the previous regime.

Table A.4.1. Test for forecast bias in regime 1

Forecast bias	Corn	Wheat	Soybeans	Live Cattle	Feeder Cattle	Lean Hogs
1. IV model	Y	Y	Y	Y	Y	Y
2. HV model	Y	Y	Y	Y	Y	Y
3. Composite model	Y	Y	Y	Y	Y	Y
4. Naïve model	Y	Y	Y	Y	Y	Y

*Y= The forecast method is unbiased.
*N= The forecast method is biased.
* From equation 5.

Table A.5.1. Test for forecast efficiency in regime 1

Forecast efficiency	Corn	Wheat	Soybeans	Live Cattle	Feeder Cattle	Lean Hogs
***Beta efficiency**						
1. IV model	Y	Y	Y	Y	Y	Y
2. HV model	Y	Y	Y	Y	Y	Y
3. Composite model	Y	Y	Y	Y	Y	Y
4. Naïve model	Y	Y	Y	Y	Y	Y
***Rho efficiency**						
1. IV model	N	Y	Y	Y	Y	N
2. HV model	Y	Y	Y	Y	Y	N
3. Composite model	N	Y	Y	Y	Y	N
4. Naïve model	Y	Y	Y	Y	Y	Y

*Y= The forecast passes the beta efficiency/rho efficiency test for weak efficiency.
*N= The forecast fails the beta efficiency/rho efficiency test for weak efficiency.
*From equations 6 and 7.

Table A.6.1. Test for forecast encompassing in regime 1

Forecasting encompassing	Corn	Wheat	Soybeans	Live Cattle	Feeder Cattle	Lean Hogs
Preferred forecast						
1. Implied Volatility	Y	Y	Y	Y	Y	Y
2. Historical Volatility	N	Y	N	N	N	Y
Preferred forecast						
1. Implied Volatility	Y	Y	Y	Y	Y	N
2. Naïve model	N	N	N	N	N	Y
Preferred forecast						
1.Historical Volatility	Y	Y	Y	Y	Y	N
2. Naïve model	N	N	N	Y	Y	Y

*Y= The forecast encompasses the information contained in the alternative forecast.
*N= The forecast does not encompass the information contained in the alternative forecast.
*From equation 8.

Table A.7.1. Test for forecast change in regime 1

Time change	Corn	Wheat	Soybeans	Live Cattle	Feeder Cattle	Lean Hogs
1. IV model	Y^+	N	N	N	N	N
2. HV model	Y^+	N	N	N	N	N
3. Composite model	Y^+	N	N	N	N	N
4. Naïve model	Y^+	N	N	N	N	N

*Y^+= The forecast errors are getting bigger overtime.
*Y^- = The forecast errors are getting smaller overtime.
*N= The forecast does not show systematic change over time.
*From equation 9.

Table A.4.2. Test for forecast bias in regime 2

Forecast bias	Corn	Wheat	Soybeans	Live Cattle	Feeder Cattle	Lean Hogs
1. IV model	Y	Y	Y	Y	Y	Y
2. HV model	Y	Y	Y	Y	Y	Y
3. Composite model	Y	Y	Y	Y	Y	Y
4. Naïve model	Y	Y	Y	Y	Y	Y

*Y= The forecast method is unbiased.
*N= The forecast method is biased.
* From equation 5.

Table A.5.2. Test for forecast efficiency in regime 2

Forecast efficiency	Corn	Wheat	Soybeans	Live Cattle	Feeder Cattle	Lean Hogs
***Beta efficiency**						
1. IV model	Y	Y	Y	Y	Y	Y
2. HV model	Y	Y	Y	Y	Y	Y
3. Composite model	Y	Y	Y	Y	Y	Y
4. Naïve model	Y	Y	Y	Y	Y	Y
***Rho efficiency**						
1. IV model	Y	N	Y	Y	Y	Y
2. HV model	Y	N	Y	Y	Y	Y
3. Composite model	Y	Y	Y	Y	Y	Y
4. Naïve model	Y	Y	Y	Y	Y	Y

*Y= The forecast passes the beta efficiency/rho efficiency test for weak efficiency.
*N= The forecast fails the beta efficiency/rho efficiency test for weak efficiency.
*From equations 6 and 7.

Table A.6.2. Test for forecast encompassing in regime 2

Forecasting encompassing	Corn	Wheat	Soybeans	Live Cattle	Feeder Cattle	Lean Hogs
Preferred forecast						
1. Implied Volatility	Y	Y	Y	Y	Y	Y
2. Historical Volatility	Y	N	N	Y	Y	Y
Preferred forecast						
1. Implied Volatility	Y	Y	Y	Y	Y	Y
2. Naïve model	Y	N	N	Y	Y	Y
Preferred forecast						
1.Historical Volatility	Y	N	Y	Y	Y	Y
2. Naïve model	Y	Y	N	Y	Y	Y

*Y= The forecast encompasses the information contained in the alternative forecast.
*N= The forecast does not encompass the information contained in the alternative forecast.
*From equation 8.

Table A.7.2. Test for forecast change in regime 2

Time change	Corn	Wheat	Soybeans	Live Cattle	Feeder Cattle	Lean Hogs
1. IV model	Y^+	N	N	N	N	N
2. HV model	N	N	N	N	N	N
3. Composite model	N	N	N	N	N	N
4. Naïve model	N	Y^-	N	N	N	N

*Y^+= The forecast errors are getting bigger overtime.
*Y^- = The forecast errors are getting smaller overtime.
*N= The forecast does not show systematic change over time.
*From equation 9.

Table A.4.3. Test for forecast bias in regime 3

Forecast bias	Corn	Wheat	Soybeans	Live Cattle	Feeder Cattle	Lean Hogs
1. IV model	Y	Y	Y	Y	Y	Y
2. HV model	Y	Y	Y	Y	Y	Y
3. Composite model	Y	Y	Y	Y	Y	Y
4. Naïve model	Y	Y	Y	Y	Y	Y

*Y= The forecast method is unbiased.
*N= The forecast method is biased.
* From equation 5.

Table A.5.3. Test for forecast efficiency in regime 3

Forecast efficiency	Corn	Wheat	Soybeans	Live Cattle	Feeder Cattle	Lean Hogs
***Beta efficiency**						
1. IV model	Y	Y	Y	Y	Y	Y
2. HV model	Y	Y	Y	Y	Y	Y
3. Composite model	Y	Y	Y	Y	Y	Y
4. Naïve model	Y	Y	Y	Y	Y	Y
***Rho efficiency**						
1. IV model	Y	Y	Y	Y	Y	Y
2. HV model	Y	Y	Y	Y	Y	N
3. Composite model	Y	Y	Y	Y	Y	Y
4. Naïve model	Y	Y	Y	Y	Y	Y

*Y= The forecast passes the beta efficiency/rho efficiency test for weak efficiency.
*N= The forecast fails the beta efficiency/rho efficiency test for weak efficiency.
*From equations 6 and 7.

Table A.6.3. Test for forecast encompassing in regime 3

Forecasting encompassing	Corn	Wheat	Soybeans	Live Cattle	Feeder Cattle	Lean Hogs
Preferred forecast						
1. Implied Volatility	Y	Y	Y	Y	Y	Y
2. Historical Volatility	N	N	N	Y	Y	N
Preferred forecast						
1. Implied Volatility	Y	Y	Y	Y	Y	Y
2. Naïve model	N	N	N	Y	Y	Y
Preferred forecast						
1.Historical Volatility	Y	Y	Y	Y	Y	N
2. Naïve model	Y	N	N	Y	Y	Y

*Y= The forecast encompasses the information contained in the alternative forecast.
*N= The forecast does not encompass the information contained in the alternative forecast.
*From equation 8.

Table A.7.3. Test for forecast change in regime 3

Time change	Corn	Wheat	Soybeans	Live Cattle	Feeder Cattle	Lean Hogs
1. IV model	N	Y^+	N	N	N	N
2. HV model	N	Y^+	N	N	N	N
3. Composite model	N	Y^+	N	N	N	N
4. Naïve model	N	Y^+	N	N	N	N

*Y^+= The forecast errors are getting bigger overtime.
*Y^- = The forecast errors are getting smaller overtime.
*N= The forecast does not show systematic change over time.
*From equation 9.

Table A.4.4. Test for forecast bias in regime 4

Forecast bias	Corn	Wheat	Soybeans	Live Cattle	Feeder Cattle	Lean Hogs
1. IV model	Y	Y	Y	Y	Y	Y
2. HV model	Y	Y	Y	Y	Y	Y
3. Composite model	Y	Y	Y	Y	Y	Y
4. Naïve model	Y	Y	Y	Y	Y	Y

*Y= The forecast method is unbiased.
*N= The forecast method is biased.
* From equation 5.

Table A.5.4. Test for forecast efficiency in regime 4

Forecast efficiency	Corn	Wheat	Soybeans	Live Cattle	Feeder Cattle	Lean Hogs
***Beta efficiency**						
1. IV model	Y	Y	Y	Y	Y	Y
2. HV model	Y	Y	Y	Y	Y	Y
3. Composite model	Y	Y	Y	Y	Y	Y
4. Naïve model	Y	Y	Y	Y	Y	Y
***Rho efficiency**						
1. IV model	Y	Y	Y	Y	N	Y
2. HV model	Y	Y	Y	Y	N	Y
3. Composite model	Y	Y	Y	Y	N	Y
4. Naïve model	Y	Y	Y	Y	Y	Y

*Y= The forecast passes the beta efficiency/rho efficiency test for weak efficiency.
*N= The forecast fails the beta efficiency/rho efficiency test for weak efficiency.
*From equations 6 and 7.

Table A.6.4. Test for forecast encompassing in regime 4

Forecasting encompassing	Corn	Wheat	Soybeans	Live Cattle	Feeder Cattle	Lean Hogs
Preferred forecast						
1. Implied Volatility	N	Y	Y	Y	Y	Y
2. Historical Volatility	Y	Y	Y	Y	Y	Y
Preferred forecast						
1. Implied Volatility	Y	Y	Y	Y	N	Y
2. Naïve model	Y	Y	Y	Y	Y	Y
Preferred forecast						
1.Historical Volatility	Y	Y	Y	Y	N	Y
2. Naïve model	N	Y	Y	Y	Y	Y

*Y= The forecast encompasses the information contained in the alternative forecast.
*N= The forecast does not encompass the information contained in the alternative forecast.
*From equation 8.

Table A.7.4. Test for forecast change in regime 4

Time Change	Corn	Wheat	Soybeans	Live Cattle	Feeder Cattle	Lean Hogs
1. IV model	N	N	N	N	N	N
2. HV model	N	N	N	N	N	N
3. Composite model	N	N	N	N	N	N
4. Naïve model	N	N	N	N	N	N

*Y^+= The forecast errors are getting bigger overtime.
*Y^- = The forecast errors are getting smaller overtime.
*N= The forecast does not show systematic change over time.
*From equation 9.

Table A.4.5. Test for forecast bias in regime 5

Forecast bias	Corn	Wheat	Soybeans	Live Cattle	Feeder Cattle	Lean Hogs
1. IV model		Y	Y	Y	Y	Y
2. HV model		Y	Y	Y	Y	Y
3. Composite model		Y	Y	Y	Y	Y
4. Naïve model		Y	Y	Y	Y	Y

*Y= The forecast method is unbiased.
*N= The forecast method is biased.
* From equation 5.

Table A.5.5. Test for forecast efficiency in regime 5

Forecast efficiency	Corn	Wheat	Soybeans	Live Cattle	Feeder Cattle	Lean Hogs
***Beta efficiency**						
1. IV model		Y	Y	Y	Y	Y
2. HV model		Y	Y	Y	Y	Y
3. Composite model		Y	Y	Y	Y	Y
4. Naïve model		Y	Y	Y	Y	Y
***Rho efficiency**						
1. IV model		N	Y	Y	Y	Y
2. HV model		Y	Y	Y	Y	Y
3. Composite model		Y	Y	Y	Y	Y
4. Naïve model		Y	Y	Y	Y	Y

*Y= The forecast passes the beta efficiency/rho efficiency test for weak efficiency.
*N= The forecast fails the beta efficiency/rho efficiency test for weak efficiency.
*From equations 6 and 7.

Table A.6.5. Test for forecast encompassing in regime 5

Forecasting encompassing	Corn	Wheat	Soybeans	Live Cattle	Feeder Cattle	Lean Hogs
Preferred forecast						
1. Implied Volatility		Y	Y	Y	Y	Y
2. Historical Volatility		Y	Y	Y	N	Y
Preferred forecast						
1. Implied Volatility		Y	Y	Y	Y	Y
2. Naïve model		Y	Y	Y	N	Y
Preferred forecast						

1.Historical Volatility		Y	Y	Y	Y	Y
2. Naïve model		Y	N	Y	Y	Y

*Y= The forecast encompasses the information contained in the alternative forecast.
*N= The forecast does not encompass the information contained in the alternative forecast.
*From equation 8.

Table A.7.5. Test for forecast change in regime 5

Time Change	Corn	Wheat	Soybeans	Live Cattle	Feeder Cattle	Lean Hogs
1. IV model		N	N	N	N	N
2. HV model		N	N	N	N	N
3. Composite model		N	N	N	N	N
4. Naïve model		N	N	N	N	N

*Y^+= The forecast errors are getting bigger overtime.
*Y^- = The forecast errors are getting smaller overtime.
*N= The forecast does not show systematic change over time.
*From equation 9.

Table A.4.6. Test for forecast bias in regime 6

Forecast bias	Corn	Wheat	Soybeans	Live Cattle	Feeder Cattle	Lean Hogs
1. IV model		Y		Y	Y	Y
2. HV model		Y		Y	Y	Y
3. Composite model		Y		Y	Y	Y
4. Naïve model		Y		Y	Y	Y

*Y= The forecast method is unbiased.
*N= The forecast method is biased.
* From equation 5.

Table A.5.6. Test for forecast efficiency in regime 6

Forecast efficiency	Corn	Wheat	Soybeans	Live Cattle	Feeder Cattle	Lean Hogs
***Beta efficiency**						
1. IV model		Y		Y	Y	Y
2. HV model		Y		Y	Y	Y
3. Composite model		Y		Y	Y	Y
4. Naïve model		Y		Y	Y	Y
***Rho efficiency**						
1. IV model		Y		Y	Y	Y
2. HV model		Y		Y	Y	Y
3. Composite model		Y		Y	Y	Y
4. Naïve model		Y		Y	Y	Y

*Y= The forecast passes the beta efficiency/rho efficiency test for weak efficiency.
*N= The forecast fails the beta efficiency/rho efficiency test for weak efficiency.
*From equations 6 and 7.

Table A.6.6. Test for forecast encompassing in regime 6

Forecasting encompassing	Corn	Wheat	Soybeans	Live Cattle	Feeder Cattle	Lean Hogs
Preferred forecast						
1. Implied Volatility		Y		Y	Y	Y
2. Historical Volatility		Y		Y	Y	Y
Preferred forecast						
1. Implied Volatility		Y		Y	Y	Y
2. Naïve model		Y		Y	Y	Y
Preferred forecast						
1.Historical Volatility		Y		Y	Y	Y
2. Naïve model		Y		Y	N	Y

*Y= The forecast encompasses the information contained in the alternative forecast.
*N= The forecast does not encompass the information contained in the alternative forecast.
*From equation 8.

Table A.7.6. Test for forecast change in regime 6

Time Change	Corn	Wheat	Soybeans	Live Cattle	Feeder Cattle	Lean Hogs
1. IV model		Y^+		N	N	N
2. HV model		Y^+		N	N	N
3. Composite model		Y^+		N	N	N
4. Naïve model		N		N	N	N

*Y^+= The forecast errors are getting bigger overtime.
*Y^- = The forecast errors are getting smaller overtime.
*N= The forecast does not show systematic change over time.
*From equation 9.

Table A.4.7. Test for forecast bias in regime 7

Forecast bias	Corn	Wheat	Soybeans	Live Cattle	Feeder Cattle	Lean Hogs
1. IV model		Y		Y	Y	Y
2. HV model		Y		Y	Y	Y
3. Composite model		Y		Y	Y	Y
4. Naïve model		Y		Y	Y	Y

*Y= The forecast method is unbiased.
*N= The forecast method is biased.
* From equation 5.

Table A.5.7. Test for forecast efficiency in regime 7

Forecast efficiency	Corn	Wheat	Soybeans	Live Cattle	Feeder Cattle	Lean Hogs
***Beta efficiency**						
1. IV model		Y		Y	Y	Y
2. HV model		Y		Y	Y	Y
3. Composite model		Y		Y	Y	Y
4. Naïve model		Y		Y	Y	Y
***Rho efficiency**						
1. IV model		Y		Y	Y	Y
2. HV model		Y		Y	Y	Y
3. Composite model		Y		Y	Y	Y
4. Naïve model		Y		Y	Y	Y

*Y= The forecast passes the beta efficiency/rho efficiency test for weak efficiency.
*N= The forecast fails the beta efficiency/rho efficiency test for weak efficiency.
*From equations 6 and 7.

Table A.6.7. Test for forecast encompassing in regime 7

Forecasting encompassing	Corn	Wheat	Soybeans	Live Cattle	Feeder Cattle	Lean Hogs
Preferred forecast						
1. Implied Volatility		Y		Y	Y	Y
2. Historical Volatility		Y		N	Y	Y
Preferred forecast						
1. Implied Volatility		Y		Y	Y	Y
2. Naïve model		N		N	Y	Y
Preferred forecast						
1.Historical Volatility		Y		Y	Y	Y
2. Naïve model		N		Y	Y	Y

*Y= The forecast encompasses the information contained in the alternative forecast.
*N= The forecast does not encompass the information contained in the alternative forecast.
*From equation 8.

Table A.7.7. Test for forecast change in regime 7

Time Change	Corn	Wheat	Soybeans	Live Cattle	Feeder Cattle	Lean Hogs
1. IV model		Y^-		N	N	N
2. HV model		Y^-		N	N	N
3. Composite model		Y^-		N	N	N
4. Naïve model		Y^-		N	N	N

*Y^+= The forecast errors are getting bigger overtime.
*Y^- = The forecast errors are getting smaller overtime.
*N= The forecast does not show systematic change over time.
*From equation 9.

Table A.4.8. Test for forecast bias in regime 8

Forecast bias	Corn	Wheat	Soybeans	Live Cattle	Feeder Cattle	Lean Hogs
1. IV model				Y	Y	Y
2. HV model				Y	Y	Y
3. Composite model				Y	Y	Y
4. Naïve model				Y	Y	Y

*Y= The forecast method is unbiased.
*N= The forecast method is biased.
* From equation 5.

Table A.5.8. Test for forecast efficiency in regime 8

Forecast efficiency	Corn	Wheat	Soybeans	Live Cattle	Feeder Cattle	Lean Hogs
***Beta efficiency**						
1. IV model				Y	Y	Y
2. HV model				Y	Y	Y
3. Composite model				Y	Y	Y
4. Naïve model				Y	Y	Y
***Rho efficiency**						
1. IV model				Y	Y	Y
2. HV model				Y	Y	Y
3. Composite model				Y	Y	Y
4. Naïve model				Y	Y	Y

*Y= The forecast passes the beta efficiency/rho efficiency test for weak efficiency.
*N= The forecast fails the beta efficiency/rho efficiency test for weak efficiency.
*From equations 6 and 7.

Table A.6.8. Test for forecast encompassing in regime 8

Forecasting encompassing	Corn	Wheat	Soybeans	Live Cattle	Feeder Cattle	Lean Hogs
Preferred forecast						
1. Implied Volatility				Y	Y	Y
2. Historical Volatility				N	Y	Y
Preferred forecast						
1. Implied Volatility				Y	Y	Y
2. Naïve model				N	Y	N
Preferred forecast						
1.Historical Volatility				Y	Y	Y
2. Naïve model				Y	Y	Y

*Y= The forecast encompasses the information contained in the alternative forecast.
*N= The forecast does not encompass the information contained in the alternative forecast.
*From equation 8.

Table A.7.8. Test for forecast change in regime 8

Time Change	Corn	Wheat	Soybeans	Live Cattle	Feeder Cattle	Lean Hogs
1. IV model				N	N	N
2. HV model				N	N	N
3. Composite model				N	N	N
4. Naïve model				N	N	N

*Y^+= The forecast errors are getting bigger overtime.
*Y^- = The forecast errors are getting smaller overtime.
*N= The forecast does not show systematic change over time.
*From equation 9.

Table A.4.9. Test for forecast bias in regime 9

Forecast bias	Corn	Wheat	Soybeans	Live Cattle	Feeder Cattle	Lean Hogs
1. IV model				Y		
2. HV model				Y		
3. Composite model				Y		
4. Naïve model				Y		

*Y= The forecast method is unbiased.
*N= The forecast method is biased.
* From equation 5.

Table A.5.9. Test for forecast efficiency in regime 9

Forecast efficiency	Corn	Wheat	Soybeans	Live Cattle	Feeder Cattle	Lean Hogs
***Beta efficiency**						
1. IV model				Y		
2. HV model				Y		
3. Composite model				Y		
4. Naïve model				Y		
***Rho efficiency**						
1. IV model				Y		
2. HV model				Y		
3. Composite model				Y		
4. Naïve model				Y		

*Y= The forecast passes the beta efficiency/rho efficiency test for weak efficiency.
*N= The forecast fails the beta efficiency/rho efficiency test for weak efficiency.
*From equations 6 and 7.

Table A.6.9. Test for forecast encompassing in regime 9

Forecasting encompassing	Corn	Wheat	Soybeans	Live Cattle	Feeder Cattle	Lean Hogs
Preferred forecast						
1. Implied Volatility				Y		
2. Historical Volatility				N		
Preferred forecast						
1. Implied Volatility				Y		
2. Naïve model				N		
Preferred forecast						
1.Historical Volatility				Y		
2. Naïve model				Y		

*Y= The forecast encompasses the information contained in the alternative forecast.
*N= The forecast does not encompass the information contained in the alternative forecast.
*From equation 8.

Table A.7.9. Test for forecast change in regime 9

Time Change	Corn	Wheat	Soybeans	Live Cattle	Feeder Cattle	Lean Hogs
1. IV model				N		
2. HV model				N		
3. Composite model				N		
4. Naïve model				N		

*Y^+= The forecast errors are getting bigger overtime.
*Y^- = The forecast errors are getting smaller overtime.
*N= The forecast does not show systematic change over time.
*From equation 9.

Table A.8.1. Mean Absolute Errors (MAE), Root Mean Square Errors (RMSE) and Mean Absolute Percentage Errors (MAPES) in regime 1

MAE	Corn[abc]	Wheat	Soybeans	Live Cattle[b]	Feeder Cattle	Lean Hogs[a]
Date	1/13/95-4/25/14	1/13/95-4/5/96	1/13/95-8/22/03	1/13/95-4/5/96	1/13/95-5/29/98	1/13/95-11/1/96
Implied Volatility	0.12543	0.10226	0.09529	0.06924	0.07464	0.13684
Historical Volatility	0.12954	0.10234	0.09749	0.07343	0.07600	0.14332
Composite Approach	0.12532	0.10058	0.09531	0.06907	0.07469	0.13660
Naïve Approach	0.13328	0.10440	0.09751	0.07473	0.07751	0.13913
RMSE	**Corn[abc]**	**Wheat**	**Soybeans[abc]**	**Live Cattle**	**Feeder Cattle**	**Lean Hogs**
Implied Volatility	0.16327	0.13493	0.12932	0.08956	0.09916	0.19674
Historical Volatility	0.16983	0.13403	0.12532	0.09269	0.10396	0.19843
Composite	0.16326	0.13215	0.12931	0.08936	0.09915	0.19650

Approach						
Naïve Approach	0.17356	0.14112	0.13387	0.09314	0.10422	0.19264
MAPE	**Corn[abc]**	**Wheat[c]**	**Soybeans**	**Live Cattle**	**Feeder Cattle**	**Lean Hogs**
Implied Volatility	2.03492	1.83262	2.53409	1.09024	2.59598	2.69718
Historical Volatility	2.21358	1.96705	2.47391	1.20551	2.59019	2.69892
Composite Approach	2.03405	1.79565	2.53250	1.06510	2.60007	2.71796
Naïve Approach	2.32608	2.37075	2.49254	1.19469	2.56693	2.43635

a: Implied volatility and historical volatility point estimates are statistically different at p<0.1.
b: Implied volatility and the naïve approach point estimates are statistically different at p<0.1.
c: Historical volatility and the naïve approach point estimates are statistically different at p<0.1.

Table A.8.2 Mean Absolute Errors (MAE), Root Mean Square Errors (RMSE) and Mean Absolute Percentage Errors (MAPES) in regime 2

MAE	**Corn**	**Wheat**	**Soybeans**	**Live Cattle**	**Feeder Cattle[c]**	**Lean Hogs**
Date	1/18/08-12/12/08	4/12/96-4/18/97	8/29/03-7/1/05	4/12/96-10/11/96	6/5/98-5/14/99	11/8/96-1/16/98
Implied Volatility	0.27831	0.15389	0.15445	0.11403	0.08652	0.10590
Historical Volatility	0.27028	0.16844	0.16052	0.12171	0.08326	0.10352
Composite Approach	0.27027	0.15469	0.15354	0.09963	0.07695	0.10583
Naïve Approach	0.28354	0.14816	0.16017	0.12023	0.08761	0.10440
RMSE	**Corn**	**Wheat**	**Soybeans**	**Live Cattle**	**Feeder Cattle**	**Lean Hogs**
Implied Volatility	0.34698	0.20033	0.19521	0.15676	0.10525	0.15422
Historical Volatility	0.33685	0.23507	0.20638	0.16207	0.10422	0.15676
Composite Approach	0.33685	0.19499	0.19499	0.13922	0.10117	0.15422
Naïve Approach	0.34378	0.20223	0.21328	0.16047	0.10557	0.15613
MAPE	**Corn**	**Wheat[c]**	**Soybeans**	**Live Cattle**	**Feeder Cattle**	**Lean Hogs**
Implied Volatility	4.05031	1.11675	3.20972	2.61275	1.21323	3.43673
Historical Volatility	4.11104	1.22512	2.99093	2.70818	1.16607	3.39181
Composite Approach	4.10588	1.17354	3.24576	1.78385	1.09649	3.43387
Naïve Approach	4.03484	1.00215	3.10379	2.68563	1.21734	3.48536

a: Implied volatility and historical volatility point estimates are statistically different at p<0.1.
b: Implied volatility and the naïve approach point estimates are statistically different at p<0.1.
c: Historical volatility and the naïve approach point estimates are statistically different at p<0.1.

Table A.8.3 Mean Absolute Errors (MAE), Root Mean Square Errors (RMSE) and Mean Absolute Percentage Errors (MAPES) in regime 3

MAE	**Corn[ab]**	**Wheat[bc]**	**Soybeans**	**Live Cattle[bc]**	**Feeder Cattle**	**Lean Hogs**
Date	12/19/08-6/21/13	4/25/97-11/16/07	7/8/05-11/9/07	10/18/96-7/17/98	5/21/99-1/26/01	1/23/98-11/5/99
Implied Volatility	0.16110	0.12873	0.11122	0.06590	0.03408	0.22895
Historical Volatility	0.16501	0.12942	0.11319	0.06569	0.03448	0.23293
Composite Approach	0.16073	0.12874	0.11108	0.06566	0.03408	0.22890
Naïve Approach	0.16536	0.13057	0.11595	0.06325	0.03495	0.23340
RMSE	**Corn[a]**	**Wheat**	**Soybeans**	**Live Cattle**	**Feeder Cattle**	**Lean Hogs**
Implied Volatility	0.20395	0.16530	0.13064	0.07986	0.04055	0.33867
Historical Volatility	0.20742	0.16668	0.13296	0.07993	0.04078	0.34983
Composite Approach	0.20354	0.16530	0.13053	0.07979	0.04055	0.33864
Naïve Approach	0.20747	0.16728	0.13690	0.07863	0.04110	0.34142
MAPE	**Corn**	**Wheat**	**Soybeans[c]**	**Live Cattle**	**Feeder Cattle**	**Lean Hogs**
Implied Volatility	3.13289	2.26262	3.37871	2.33522	1.96838	2.25007
Historical Volatility	3.16322	2.26722	3.23432	2.35540	1.99805	2.62081
Composite Approach	3.13160	2.26259	3.33516	2.35775	1.96808	2.23049
Naïve Approach	3.12821	2.26957	3.47295	2.30902	2.05749	2.32173

a: Implied volatility and historical volatility point estimates are statistically different at $p<0.1$.

b: Implied volatility and the naïve approach point estimates are statistically different at $p<0.1$.

c: Historical volatility and the naïve approach point estimates are statistically different at $p<0.1$.

Table A.8.4 Mean Absolute Errors (MAE), Root Mean Square Errors (RMSE) and Mean Absolute Percentage Errors (MAPES) in regime 4

MAE	**Corn**	**Wheat**	**Soybeans**	**Live Cattle**	**Feeder Cattle**	**Lean Hogs**
Date	7/5/13-4/25/14	11/23/07-1/16/09	11/16/07-9/4/09	7/24/98-6/18/99	2/2/01-2/7/03	11/12/99-9/7/01
Implied Volatility	0.07678	0.23504	0.20146	0.10467	0.06166	0.14335
Historical Volatility	0.07448	0.23265	0.19971	0.10113	0.06269	0.14377
Composite Approach	0.07444	0.23424	0.20145	0.10293	0.06171	0.14341
Naïve Approach	0.07840	0.23651	0.20031	0.10334	0.06108	0.14499
RMSE	**Corn**	**Wheat**	**Soybeans**	**Live Cattle**	**Feeder Cattle**	**Lean Hogs**
Implied Volatility	0.11932	0.29098	0.26775	0.13507	0.08339	0.23141
Historical Volatility	0.10864	0.29255	0.26749	0.13469	0.08412	0.22963
Composite Approach	0.10864	0.29088	0.26666	0.13356	0.08317	0.22900
Naïve Approach	0.12238	0.29472	0.26771	0.13516	0.08175	0.23042
MAPE	**Corn**	**Wheat**	**Soybeans**	**Live Cattle**	**Feeder Cattle**	**Lean Hogs**
Implied Volatility	2.10179	2.64093	1.58787	2.99833	2.09369	2.99389
Historical Volatility	1.90859	2.68471	1.61784	3.14049	2.11364	3.05591
Composite Approach	1.90864	2.66207	1.63602	3.02339	2.03390	2.98930
Naïve Approach	2.14658	2.63494	1.59841	2.99405	1.90093	3.13137

a: Implied volatility and historical volatility point estimates are statistically different at p<0.1.
b: Implied volatility and the naïve approach point estimates are statistically different at p<0.1.
c: Historical volatility and the naïve approach point estimates are statistically different at p<0.1.

Table A.8.5. Mean Absolute Errors (MAE), Root Mean Square Errors (RMSE) and Mean Absolute Percentage Errors (MAPES) in regime 5

MAE	Corn	Wheat	Soybeans	Live Cattle	Feeder Cattle	Lean Hogs
Date		1/23/09-1/1/10	9/11/09-4/25/14	6/25/99-4/6/01	2/14/03-5/16/08	9/14/01-8/8/03
Implied Volatility		0.16114	0.10914	0.05249	0.08071	0.22864
Historical Volatility		0.16081	0.10922	0.05213	0.08401	0.22858
Composite Approach		0.16045	0.10915	0.05156	0.08037	0.22754
Naïve Approach		0.15708	0.11048	0.05257	0.08377	0.23028
RMSE	**Corn**	**Wheat**	**Soybeans**	**Live Cattle**	**Feeder Cattle**	**Lean Hogs**
Implied Volatility		0.19354	0.14046	0.07063	0.10625	0.31218
Historical Volatility		0.19313	0.13965	0.07041	0.11395	0.31256
Composite Approach		0.19266	0.13942	0.06994	0.10527	0.31167
Naïve Approach		0.18901	0.14098	0.07055	0.11348	0.31433
MAPE	**Corn**	**Wheat**	**Soybeans**[ab]	**Live Cattle**	**Feeder Cattle**[b]	**Lean Hogs**
Implied Volatility		1.47640	3.00936	2.07982	2.42407	1.89440
Historical Volatility		1.49210	3.03417	2.11666	2.53857	1.89835
Composite Approach		1.49099	3.01294	2.14524	2.40971	1.88719
Naïve Approach		1.54967	3.07630	2.09290	2.63145	1.92122

a: Implied volatility and historical volatility point estimates are statistically different at $p<0.1$.

b: Implied volatility and the naïve approach point estimates are statistically different at $p<0.1$.

c: Historical volatility and the naïve approach point estimates are statistically different at $p<0.1$.

Table A.8.6. Mean Absolute Errors (MAE), Root Mean Square Errors (RMSE) and Mean Absolute Percentage Errors (MAPES) in regime 6

MAE	Corn	Wheat	Soybeans	Live Cattle	Feeder Cattle	Lean Hogs
Date		1/8/10-12/3/10		4/13/01-2/14/03	5/23/08-6/5/09	8/15/03-5/18/07
Implied Volatility		0.22206		0.09926	0.10605	0.14221
Historical Volatility		0.22197		0.10180	0.10799	0.14334
Composite Approach		0.22155		0.09480	0.10688	0.14336
Naïve Approach		0.21668		0.10197	0.11133	0.14228
RMSE	**Corn**	**Wheat**	**Soybeans**	**Live Cattle**	**Feeder Cattle**	**Lean Hogs**
Implied Volatility		0.27299		0.13430	0.13097	0.20317
Historical Volatility		0.27587		0.13623	0.13038	0.20286
Composite Approach		0.27235		0.12882	0.12979	0.20285
Naïve Approach		0.27363		0.13669	0.13546	0.20319
MAPE	**Corn**	**Wheat**	**Soybeans**	**Live Cattle**	**Feeder Cattle**[b]	**Lean Hogs**
Implied Volatility		2.96660		2.78107	4.50130	3.75775
Historical Volatility		3.12749		2.70229	4.06460	3.82079
Composite Approach		2.91501		2.71767	4.11953	3.81796
Naïve Approach		3.00618		2.71072	5.02285	3.77033

a: Implied volatility and historical volatility point estimates are statistically different at $p<0.1$.

b: Implied volatility and the naïve approach point estimates are statistically different at $p<0.1$.

c: Historical volatility and the naïve approach point estimates are statistically different at $p<0.1$.

Table A.8.7. Mean Absolute Errors (MAE), Root Mean Square Errors (RMSE) and Mean Absolute Percentage Errors (MAPES) in regime 7

MAE	Corn	Wheat[bc]	Soybeans	Live Cattle	Feeder Cattle	Lean Hogs
Date		12/10/10-4/25/14		2/21/03-1/21/05	6/12/09-5/17/13	5/25/07-4/2/10
Implied Volatility		0.14081		0.11523	0.07452	0.18721
Historical Volatility		0.14366		0.12234	0.07481	0.18876
Composite Approach		0.14110		0.11730	0.07458	0.18844
Naïve Approach		0.14666		0.12057	0.07493	0.18570
RMSE	**Corn**	**Wheat[b]**	**Soybeans**	**Live Cattle**	**Feeder Cattle**	**Lean Hogs**
Implied Volatility		0.18944		0.16059	0.09310	0.27356
Historical Volatility		0.19073		0.17130	0.09329	0.27132
Composite Approach		0.18935		0.15649	0.09306	0.27051
Naïve Approach		0.19534		0.17209	0.09344	0.27308
MAPE	**Corn**	**Wheat**	**Soybeans**	**Live Cattle**	**Feeder Cattle**	**Lean Hogs**
Implied Volatility		2.06892		1.75844	2.27508	1.57410
Historical Volatility		2.01819		1.83176	2.25272	1.58974
Composite Approach		2.05705		1.78218	2.26851	1.58155
Naïve Approach		2.09537		1.81891	2.24510	1.55911

a: Implied volatility and historical volatility point estimates are statistically different at $p<0.1$.

b: Implied volatility and the naïve approach point estimates are statistically different at $p<0.1$.

c: Historical volatility and the naïve approach point estimates are statistically different at $p<0.1$.

Table A.8.8. Mean Absolute Errors (MAE), Root Mean Square Errors (RMSE) and Mean Absolute Percentage Errors (MAPES) in regime 8

MAE	Corn	Wheat	Soybeans	Live Cattle	Feeder Cattle	Lean Hogs
Date				1/28/05-10/21/11	5/31/13-4/25/14	4/7/10-4/25/14
Implied Volatility				0.08921	0.04625	0.12950
Historical Volatility				0.09032	0.04706	0.12749
Composite Approach				0.08950	0.04551	0.12943
Naïve Approach				0.09046	0.04556	0.12715
RMSE	**Corn**	**Wheat**	**Soybeans**	**Live Cattle**	**Feeder Cattle**	**Lean Hogs**
Implied Volatility				0.11442	0.05527	0.20165
Historical Volatility				0.11632	0.05572	0.20341
Composite Approach				0.11422	0.05501	0.20164
Naïve Approach				0.11644	0.05511	0.20371
MAPE	**Corn**	**Wheat**	**Soybeans**	**Live Cattle**	**Feeder Cattle**	**Lean Hogs**
Implied Volatility				3.22371	3.37715	2.84271
Historical Volatility				3.29325	3.55030	2.95890
Composite Approach				3.20589	3.29476	2.84700
Naïve Approach				3.29388	3.32017	2.94090

a: Implied volatility and historical volatility point estimates are statistically different at $p<0.1$.

b: Implied volatility and the naïve approach point estimates are statistically different at $p<0.1$.

c: Historical volatility and the naïve approach point estimates are statistically different at $p<0.1$.

Table A.8.9. Mean Absolute Errors (MAE), Root Mean Square Errors (RMSE) and Mean Absolute Percentage Errors (MAPES) in regime 9

MAE	Corn	Wheat	Soybeans	Live Cattle	Feeder Cattle	Lean Hogs
Date				10/28/11-4/25/14		
Implied Volatility				0.06964		
Historical Volatility				0.07157		
Composite Approach				0.06948		
Naïve Approach				0.07178		
RMSE	**Corn**	**Wheat**	**Soybeans**	**Live Cattle**	**Feeder Cattle**	**Lean Hogs**
Implied Volatility				0.09281		
Historical Volatility				0.09469		
Composite Approach				0.09229		
Naïve Approach				0.09468		
MAPE	**Corn**	**Wheat**	**Soybeans**	**Live Cattle**	**Feeder Cattle**	**Lean Hogs**
Implied Volatility				2.29026		
Historical Volatility				2.34584		
Composite Approach				2.29182		
Naïve Approach				2.37637		

a: Implied volatility and historical volatility point estimates are statistically different at p<0.1.

b: Implied volatility and the naïve approach point estimates are statistically different at p<0.1.

c: Historical volatility and the naïve approach point estimates are statistically different at p<0.1.

Table A.9. Coefficients in estimating the composite approach in all commodities

	Corn		Wheat		Soybeans	
	IV	HV	IV	HV	IV	HV
Full Period	0.7865	0.0662	0.6500	0.0621	0.6670	0.1260
Regime 1	0.8542	0.0247	0.4350	0.5530	0.6870	0.0284
Regime 2	0.0243	0.8769	3.0680	-0.4710	1.5070	-0.1250
Regime 3	0.7438	-0.1630	0.5247	-0.0026	0.7280	0.1150
Regime 4	0.0125	0.3523	0.6490	0.0815	-0.4130	0.2750
Regime 5			0.2700	0.2660	0.2000	0.2690
Regime 6			1.0600	-0.2380		
Regime 7			0.5570	0.0897		
	Live Cattle		**Feeder Cattle**		**Lean Hogs**	
	IV	**HV**	**IV**	**HV**	**IV**	**HV**
Full Period	1.1450	-0.2610	0.9510	-0.0617	0.7960	-0.0239
Regime 1	1.1100	-0.0992	1.2530	-0.0576	1.1630	-0.0988
Regime 2	3.3019	-2.1610	-1.4110	0.9770	1.8490	0.0104
Regime 3	0.3150	-0.0604	0.3030	0.0063	0.8800	-0.0211
Regime 4	0.5860	-0.4630	0.5810	-0.2060	0.4570	-0.2630
Regime 5	0.3890	-0.2660	1.1130	-0.2960	0.3730	0.1280
Regime 6	1.7780	-0.7320	0.4460	0.4750	-0.0321	-0.0928
Regime 7	1.1480	-0.3820	0.2970	0.0817	0.3850	-0.3400
Regime 8	0.9440	-0.1590	1.0090	-0.1220	-0.8450	-0.0144
Regime 9	0.9140	-0.2830				

*The coefficients come from a regression to estimate the composite approach as follows: $RV_t = \alpha + IV_{t-1} + HV_{t-1}$