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Abstract

Recent national and international regulatory reforms (e.g. U.S. FAIR and other GATT compliance reforms) in agricultural markets has led some observers to wonder whether the private sector is able to produce a level of price volatility that is socially acceptable. In this paper, we examine the post reform track record of price volatility and its transmission across vertically linked and geographically linked markets. Livestock, grain, and dairy market data (monthly) are considered across the U.S. and E.C. The standard commodity-pricing model supports the hypothesis that competitive storage acts to reduce the volatility of cash prices. Further, speculative attacks and stock outs have been shown to induce increased volatility. This motivates a scope of consideration that includes prices as well as stock levels to assess their contribution to price volatility.

The paper considers evidence based on three decades of monthly data and advanced time series techniques. First, univariate volatility estimates based on the autoregressive conditional heteroskedasticity (GARCH) model are evaluated and compared to historical temporal variation to highlight the importance of well grounded estimation of volatility. Next, the relationships between stocks and the conditional mean, as well as the conditional and unconditional variances of the price series, are assessed for dairy and grain products. Finally, reform associated changes in the structure of the transmission of volatility through vertical markets are considered for dairy products and across geographic markets is considered for grains.

Background.

Extensive literature over the past fifty years has considered the relationship between inventory levels and price volatility. On the basis of such a relationship, a rationale for a role for public sector management of commodity price volatility was developed showing that governments could stabilize prices by managing stocks. However, the feasibility and efficacy of such buffer schemes was later questioned when private sector intertemporal arbitrage and government budget constraints were recognized, see Helmberger, et al. These results were further strengthened as international trade and gaming among market coordinating intermediaries (grain traders) were added to models. During the same period, two other types of changes have influenced commodity markets: 1) expansion of the scope of forward contracting mechanisms such as futures and options markets as well as the use of forward contracting, and 2) liberalization of international trade. Over the past decades, reforms in trade policy as well as government budget constraints has led to reduction of government managed stocks. At the same time, private sector stocks have not expanded, resulting in significant decreases in stock-to-use ratios for many commodities. These changes in the government role in farm markets were most dramatically announced by the F.A.I.R. Act in 1996. Extensive farm press and extension coverage (e.g. AgriFinance, 1997; Yonkers and Dunn, 1996) has suggested that volatility would or has dramatically increased as a result of F.A.I.R. However, the actual impacts of F.A.I.R. are unclear. First it was passed after a substantial period of evolution in the role of government in farm markets. This is highlighted in Figure 1 from which it is apparent that stocks-to-use ratios began to decline sharply in 1986 to a new equilibrium level that was found in about 1989. From this perspective, F.A.I.R. appears to have simply formalized an adjustment already accomplished. Second, during the same period, substantial changes also occurred in trade policy and volume. This setting motivates an examination of volatility in commodity prices over the past several decades.

Of interest in this paper is the impact of changes in market conditions on the volatility of commodity prices. Agricultural markets in the U.S. have been impacted by at least four important types of policies that may have impacted price volatility: U.S. government farm programs, and U.S. macro, trade and tax policy. The implications of each of these types of policy for price volatility has received some attention in the literature. However, the joint implications of changes in these policies has not been considered. Miranda and Helmberger simulated the implications of government storage programs on competitive price stability showing that it is feasible for public storage to stabilize market prices beyond the level associated with perfectly competitive private storage. More broadly, the U.S. farm programs have attempted to stabilize farm level prices through a combination of instruments and actions including: setting of limit prices, price management through public storage and trade transactions, subsidies for private on-farm storage, a variety of supply control instruments, and trade policies. While a detailed modeling and simulation approach might be taken to characterize and analyze each of the associated policy regimes, such an approach is complicated by the jointness of the implementation of these programs as well as by implementation that varied both temporally and spatially.

In very general terms, Crain and Lee identified three eras of post-World War II farm programs: quota dominated, mandatory programs (January 1950- April 1964); acreage control, voluntary programs (April 1964-December 1985); and increasingly market oriented programs (December 1985 - 1997). Considering natural volatility of spot and futures wheat prices across these programs Crain and Lee assumed volatility to constant across daily observations within program regimes and found evidence that volatility had changed significantly across program regimes. Further results suggest that different price volatility was associated with each of the three regimes noted above. Crain and Lee conclude wheat price volatility was higher in the 1964-85 policy regime then the 1985-93 regime. Using dummy variables to characterize salient features of the policy regimes, they found that mandatory and long-term land diversion programs are associated with low volatility in prices. In contrast, they found low loan rates are associated with high levels of volatility. These results provide support for press and extension observations concerning changes in volatility that would be associated with F.A.I.R.

While these past studies are suggestive of a role of government programs in altering the volatility of prices, the market setting for agricultural commodities is complicated simultaneously by farm, tax, macro, and trade policies of both the U.S. and its trading partners. Further, changes in government programs analyzed by Crain and Lee involved numerous changes impacting incentives and constraints affecting private sector production, storage, trade, and utilization decisions. The confluence of these policies and their differential implementations suggest that a less structured approach to assessing changes in price volatility is of interest. In this paper, we re-examine volatility within the most recent of Crain and Lee regimes using less restrictive time series methods. We retain focus on the particular regimes identified by Crain and Lee, however, we do so based on the interpretation that the regimes reflect periods of common underlying political orientation toward interventionist policy, rather than simple changes in farm policy.

Approach

To proceed, we evaluate volatility both over time and across commodities exposed to different levels of policy intervention. We consider the past several decades of experience for two commodities that have been the target of U.S. interventionist government programs: wheat and corn. Further, we consider a substitute commodity, soybeans, which has not been targeted directly by U.S. farm programs, yet is influenced by similar feed grain market fundamentals as well as by competition for land. Finally, to allow for consideration of a commodity that is much less influenced by U.S. policy, we consider cocoa. For each commodity we analyze daily data to allow for consideration of volatility within trading periods. Details on data are summarized in Table 1.

To analyze price volatility, define the price series as $\{P_t\}$. A natural estimator of the volatility of prices has been based on measures of the variation within fixed marketing intervals, see e.g. Poterba and Summers, Brunetti and Gilbert, Park, or Cho and Frees, Peterson, et al.:

1)

$$S_i = \sqrt{\frac{\left[w_i \sum_{\tau_i=1}^{w_i} P^2_{t_i-\tau_i} - \left(\sum_{\tau_i=1}^{w_i} P_{t_i-\tau_i} \right)^2 \right]}{w_i(w_i-1)}} \quad i=1,\ldots I$$

where,
i=market interval
w_i=interval width
t_i=time of occurrence of the i^{th} interval

The market interval has varied over studies, however, the utility of this measure relies upon its consistency with the underlying data generating mechanism. Where the series $\{P_t\}$ follows a random walk in levels, and where the trading interval index *i* is set equal to the sampling index (t) that indicates the observation date, then S_i is estimated for each observation date and 1) provides an estimator of the conditional variance h_t of $\{P_t\}$. Alternatively, where $\{P_t\}$ follows a random walk in logarithms of levels, 1) would not measure conditional variance. In practice, trading interval width (w_i) is defined based on market activity. In this study, daily data is used and the trading interval is defined as the business week. Based on 1), the market interval is allowed to vary to accommodate variation in the number of business days in trading periods (e.g. due to holidays). To relate estimates of S_i based on overlapping intervals requires the additional assumption that prices generated within the interval (e.g. five days of prices) follow from the same underlying distribution.

An alternative approach is to draw an estimate of conditional variance from a more general model of the data generation process. Here, we allow for such a general form by using a GARCH(1,1):

2)

$$\Delta P_t=\beta_0 + \beta_1\Delta P_{t-1} + \mu_t$$

where $\mu_t \sim N(0,h_t)$ and $h_t=\alpha_0 + \alpha_1\mu^2_{t-1} + \phi_1 h_{t-1} + \nu_t$. Furthermore, ν_t is assumed to be Gaussian. By comparison to the natural estimator 1), an estimate of h_t drawn from 2) provides an estimate that varies over each observation without concern for specification of trading intervals. In contrast, the natural volatility estimator provides only an estimate for each trading interval, implicitly assuming the underlying stochastic process within that interval has a constant variance. Further, the specification 2) allows for an autoregressive form in differences, and an error that evolves according to a GARCH(1,1). When the observed price series follows the process 2) with $\beta_0 = \beta_1 = 0$, the natural estimator provides a sample estimate of h_t for each observation. However, the small sample size within these market intervals, and the likelihood that $\{P_t\}$ does not follow a simple random walk, motivates a strong interest in GARCH based estimates of conditional variance. To implement 2), we impose the *a priori* restriction $\beta_0 = 0$.

In order to identify the properties of the data generating process of P_t, we first examine the characteristics of μ_t in equation 2) using Jarque-Bera test for normality as well as direct tests of several alternative heteroscedastic forms. Results presented in Table 2 indicate that the null hypothesis of normality is rejected for each commodity. The heteroscedasticity tests were conducted to determine if the conditional variance of the series varies over the sample period. A simple ARCH(q) form was examined by using a LaGrange Multiplier approach (ARCH LM) to testing the hypothesis

H_o: $c_1=c_2=...=c_q=0$
H_a: not H_o

as a restriction on:

3)

$$\mu^2_t=a + c_1\mu^2_{t-1} + c_2\mu^2_{t-2} + ... + c_p\mu^2_{t-q} + e_t$$

When the GARCH term is introduced, Lee (1991) shows the LM test for GARCH(p,q) errors is identical to the LM test for ARCH(q) provided $p \leq q$. In addition to the ARCH LM test, two additional forms of heteroscedasticity were examined as noted in Table (2). Each test regresses the squared residuals on a measure of the magnitude of the dependent variable, the estimated price change and the squared estimated price change, respectively. In both cases, these specific forms of heteroscedasticity are rejected. In summary, the tests find strong evidence for non-normal residuals and motivates the use of a GARCH specification.

In the financial literature, ARCH and GARCH processes have been extensively used to estimate the conditional variance of price series and examine its evolution across a changing economic environment, see Najand and Yung, Antoniou and Holmes, Baldauf and Santoni. Baldauf and Santoni consider the impact of programmed trading on price volatility by allowing the ARCH model of variance to change across two periods defined based on existence of programmed trading. Antoniou and Holmes considered the impact of the commencement of futures trading in the FTSE-100 Index on spot market volatility by considering changes in an estimated GARCH process. Najand and Yung considered the impact of changes in trading volume on the mean of a GARCH process.

GARCH and ARCH models have also been employed in the commodity market literature with a wide array of applications, see for example Aradhyula and Holt; Han, Jansen, and Penson; and Chavas and Holt. Aradhyula and Holt applied a GARCH model to retail meat prices to determine whether the conditional variances of the series varied over the sample period. The results suggest the constant conditional variance assumption can be rejected for the period and consequently the GARCH specification provided more information about the precision of mean forecasts. Hans, et al. investigated the relationship between the money supply and agricultural and industrial prices within a multivariate ARCH and GARCH framework. Specifically, a vector autoregression (VAR) (G)ARCH model was applied to the farm product price index, industrial product price index, and the money supply (M1). The authors conclude the conditional mean and variance of agricultural prices are more sensitive to changes in the money supply than are industrial prices. Moreover, the results suggest the conditional mean and variance of the three variables exhibit a high degree of correlation. Finally, Chavas and Holt evaluated the hog-corn price ratio and find evidence that the process generating the pork cycle is nonlinear. Based on this finding the authors apply a GARCH model to quarterly observations of the hog-corn price ratio and conclude the model can account for some but not all of the nonlinearity.

The GARCH model provides a basis for interpretation of the nature of price adjustment. Note the conditional variance from equation 2) can be written as,

(4)

$$h_t=\alpha_0 + \alpha_1(\mu^2_{t-1} - h_{t-1}) +(\alpha_1+\phi_1)h_{t-1} + \nu_t$$

With this specification the term $(\mu^2_{t-1} - h_{t-1})$ can be viewed as the shock to volatility while the parameter α_1 indicates the impact of recent innovations in price. Furthermore, ϕ_1 indicates change in volatility induced by the accumulation of past innovations. Interpreting innovations as news allows us to interpret these coefficients in terms of transient vs. long-term impacts of news. Together, the sum $\alpha_1+ \phi_1$ provides an indication of persistence of the impacts of innovations.

Stationarity of a GARCH(p,q) process requires that,

(5)

$$\sum_{i=1}^{q}\alpha_i + \sum_{j=1}^{p}\phi_j < 1$$

Therefore, a GARCH(1,1) model is stationary if $\alpha_1 + \phi_1 < 1$. In the special case when the parameters sum to unity, the GARCH model has a unit root and Engle and Bollerslev (1986) refer to such a model as an IGARCH.[1] That is, if $(\alpha_1 + \phi_1) < 1$ then shocks will dissipate or vanish while shocks will accumulate or persist if $(\alpha_1 + \phi_1) \geq 1$. The GARCH specification provides a basis for examining market efficiency.represents a measure of efficiency. Under an IGARCH process, shocks to volatility persist infinitely suggesting that arbitrage fails to adjust the level of volatility to a long run equilibrium. Further, whenever $\phi_1 > 0$, finite memory persistence exists suggesting markets are slow to react.

The issue of volatility persistence has been addressed by a number of authors in the financial literature, e.g. Lock and Sayers, Poterba and Summers, and Chou. Locke and Sayers investigate the relations between the arrival of information and the persistence of volatility in the S&P 500 index futures market. The authors utilize a number of variables to represent the flow of information such as contract volume, floor transactions, the number of price changes, and executed order imbalance. They conclude that all of the variables explain a significant portion of returns variance but even after information adjustment the S&P 500 returns continued to exhibit volatility persistence.

Another study which investigated the persistence of volatility in the equity markets was conducted by Poterba and Summers (P-S). Here the authors examine the relationship

[1] If the error term follows an IGARCH process, the unconditional variance of μ_t is infinite implying that any shock to the conditional variance has a permanent impact the unconditional variance. The unconditional variance of μ_t is expressed as,

$$\sigma^2=\alpha_0/(1-\alpha_1-\phi_1)$$

As the sum of α_1 and ϕ_1 tends to unity, σ^2 tends to infinity and consequently, neither μ_t or μ_t^2 satisfy the definition of covariance-stationary (Hamilton 1994). However, Nelson (1990) shows that σ^2 is strictly stationary if $\alpha_0>0$ and the error term of the GARCH process is such that between price volatility and price levels for the S&P 500 index during the period 1928-1984 and the results suggest shocks to the market appear not to persist. Finally, Chou utilized a GARCH model to investigate volatility persistence and changing risk premium in equity markets and comes to an entirely different conclusion from P-S. That is, Chou finds a high degree of volatility persistence in stock returns. He concludes the discrepancy between his findings and P-S's is the result data frequency. P-S utilized monthly observations while Chou utilized weekly data.

The price series analyzed are reported graphically in Figure 2. Several features of price variation are apparent from these figures. First, substantial autocorrelation in direction of change appears to exist for each of the commodities. Second, the variation of corn and wheat appear to follow similar patterns and those patterns are distinct from those of soybeans and cocoa. Stationarity of the underlying price series was examined using augmented Dickey-Fuller tests and the results strongly support the conclusion that each price series is I(1) in levels. This supports the interpretability of the natural volatility measure and motivates the use of first differences in 2).

Natural volatility estimates based on a business week marketing interval are presented graphically in Figure 3. Again, corn and wheat appear to follow similar processes which are distinct from that followed by soybeans or cocoa. Further, the graphics suggest that some autocorrelation in volatility exists. That is, high levels of volatility are followed by subsequent periods of high volatility. This is strongest for corn and wheat, and weakest for cocoa. A substantial shock to volatility is apparent for corn and wheat in late 1996, a period associated with the introduction of the F.A.I.R. Act. The observed autocorrelation in volatility further motivates the use of GARCH. Graphically, a further feature of importance to note is that evidence of systematic increases in volatility are not apparent. This observation

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ν_t~(0,1).

was further supported by testing each volatility series for stationarity which resulted in the hypothesis of unit root being rejected in every case.[2] These findings of stationarity provide evidence that supports the inference that a persistent data generating mechanism exists for each price series over the sample period. Based on this inference, it is of interest to consider the descriptive statistics that characterize these series. As noted in Table 1, the units for corn, wheat, and soybeans are comparable, though their scales are not. As reported in Table 3, the mean level of volatility for the sample period was 29.652 for corn, 26.214 for cotton, 41.222 for wheat, and 80.383 for soybeans suggesting that average volatility was highest for the crop not managed by farm programs. Similar ordering of the commodities follows from a comparison of the standard deviations of volatility – soybeans were found to have the highest volatility. These results lend support to the conclusion of Miranda and Helmberger that government storage programs can reduce price volatility. However, these results may be misleading given that sample kurtosis and skewness values suggest each series is represented by a non-normal distribution. Together the results further motivate the utility of GARCH.

Next, consider the GARCH results. The random walk hypothesis necessary for interpretability of the natural estimates is rejected by the GARCH results. As is apparent from Table 4, the coefficient of the lagged difference is statistically significant for each of the commodities. This result implies that the use of natural volatility measures will be inefficient (Mills). ARCH and GARCH coefficients estimated in the GARCH(1,1) are statistically significant and nonnegative with the exception of the GARCH coefficient for soybeans. Results for the coefficient of the lagged innovation (α_1) indicate comparable estimates in

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[2] The augmented Dickey-Fuller test was performed by estimating the following equation,

$$\Delta P_t = \beta_1 P_{t-1} + \beta_2 \Delta P_{t-1} + \ldots + \beta_\rho \Delta P_{t-\rho} + \mu_t$$

where ρ is chosen such that μ_t is white noise. The default lag width utilized was ρ = [cn^r], where c = 5 and r = .25. The test for unit root is analogous to conducting the following test: H_0: $\beta_1 = 0 \longrightarrow$ Unit Root and H_A: $\beta_1 < 0 \longrightarrow$ Stationary. The exclusion of an intercept and trend term was based on a the observance that the volatility series exhibited neither long term drift or trend.

magnitude for corn and wheat, both suggesting a small response to recent shocks. In contrast, the results for soybeans indicate a more substantial response to recent shocks. The GARCH coefficient ϕ_1 indicates autocorrelation in conditional variance suggesting that some persistence in volatility for corn, wheat, and cocoa (see Table 4). In fact, estimates are consistent with IGARCH processes for corn and wheat. No significant persistence is found for soybeans.

The unconditional variance estimates for each commodity during the entire sample period and along within each regime is presented in Table 5. The unconditional variance has also been normalized by the mean price change in each subperiod to allow for comparisons. The results indicate corn and wheat are characterized by an IGARCH process during the first regime while no such evidence is found during regimes 2 and 3. Alternatively. the unconditional variance for soybeans and cocoa suggest a stationary GARCH process.

Comparing the normalized unconditional variance for each commodity indicates soybeans experienced the highest level of volatility over the entire sample period. Notice that the unconditional variance increased across regimes for both wheat and corn while decreasing for soybeans and cocoa. Moreover, it appears that as public involvement was reduced in the corn and wheat markets, price volatility became uniformly disbursed across commodities.

The possibility of a systematic shift in volatility due to changes in market orientation through changes in U.S. and trading partner farm, trade, macro, and tax policies can now be investigated. First, we must recall that the estimated volatility series across the sample appear to reflect no obvious structural breaks (see Figure 4). To proceed, we adopt three policy regimes based on Crain and Lee's argument: acreage control, voluntary programs (January 1970-December 1985), increasingly market oriented programs of (December 1985 -

1993), and a period of substantial market reform (January 1994 – June 1997). While structural breaks could be examined parametrically, in this paper, we limit our consideration to these regimes.

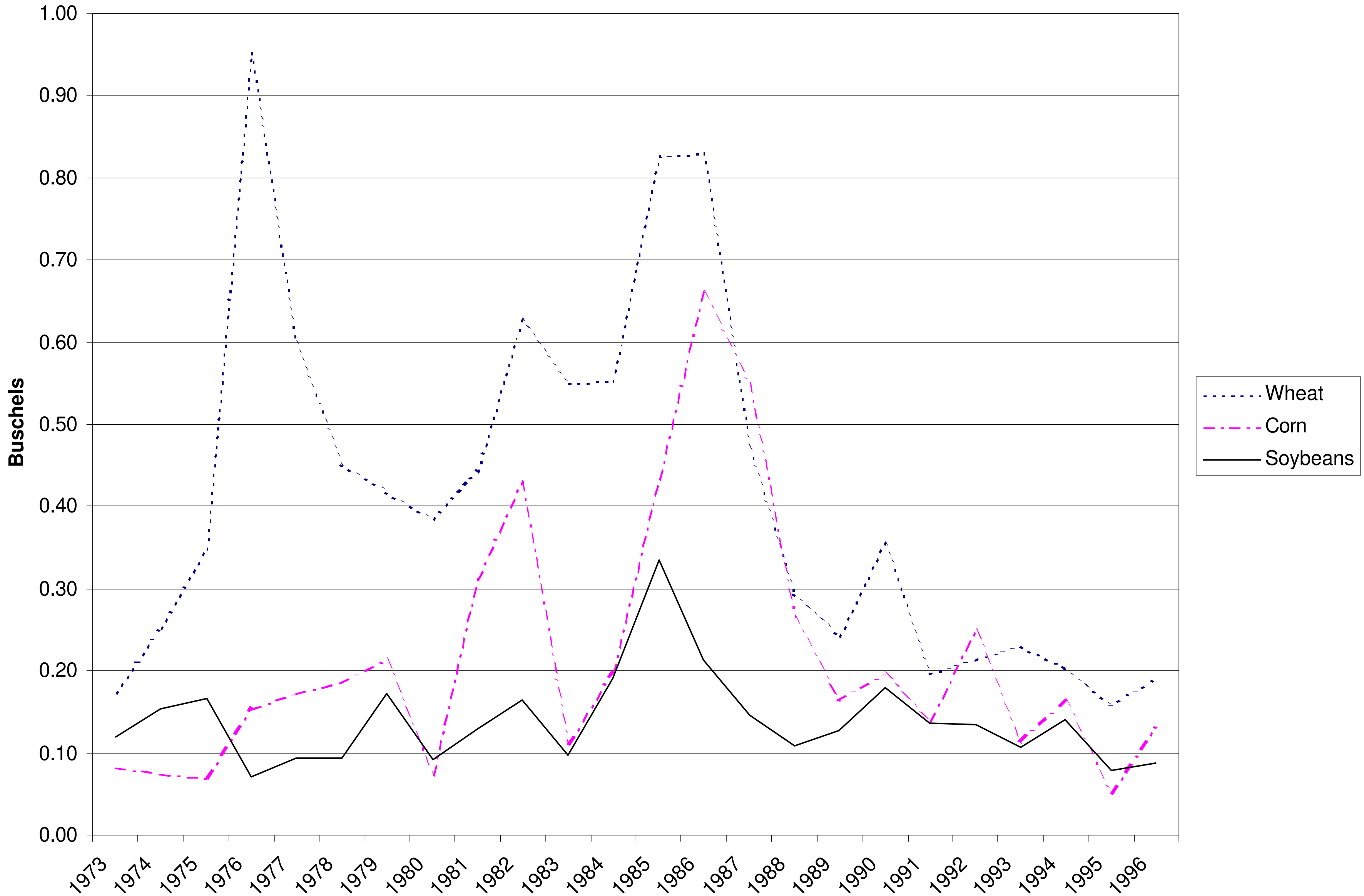
Two approaches are taken. First, the natural volatility series are reexamined within these regimes. Tables 6a – 6d present descriptive statistics. Unit roots of the natural volatility measures within regimes were rejected in each subperiod except for soybeans during the period of January, 1994 to June, 1997. Although the volatility series appeared stationary across the entire sample (1970-1997), the results in Tables 6a – 6d suggest that the characteristics of volatility in each subperiod changed for each commodity. For example, the mean level of volatility for cocoa decreased from 37.749 in the first period to 16.677 in the final. Similarly, the standard deviation also decreased for cocoa in each period. That within each regime except for the period 1/94 - 5/97 when the volatility of corn increased. A common characteristic of all four commodities is that the mean level of volatility decreased from the first period to the second period. And with the exception of cocoa the mean level increased from the second to third periods.

Next, the GARCH models were re-estimated within the policy regimes. Results reported in Tables 7a – 7c provide the basis for several interesting inferences. First, it has already been noted that policies impacting wheat and corn were progressively relaxed in a definite movement toward stronger market orientation as regimes 1-3 are considered. As is apparent from Table 7a – 7c, the persistence of volatility in corn and wheat decreases from regime 1 through to regime 3 where no significant GARCH persistence is found. The absence of persistence is found consistently across regimes for soybeans. These results suggest that as market orientation in corn and wheat markets increased price volatility became a contemporaneous phenomenon and persistence was not found. Furthermore, results for cocoa vary across regimes. In regime 1, no ARCH or GARCH process is identified with results supporting a random walk. In regime 2, a significant ARCH and GARCH process is found with a strong persistence in volatility indicated. In regime 3, no persistence is found, though a lagged impact of innovations is found.

Conclusion

The results from analyzing the prices of corn, wheat, soybeans, and cocoa for the period January, 1970 – June, 1997 suggest a number of noteworthy characteristics. First, price levels for each commodity appear to be I(1) while the volatility series is I(0). Next, the natural volatility estimator suggests the level of volatility increased from 1970 to 1997 for corn and wheat while the GARCH results suggest the persistence of volatility decreased. The diminution of volatility persistence suggests these markets became increasingly efficient for the period. Contrary to the corn and wheat markets, the mean level of volatility for soybeans decreased over the sample period. Moreover for soybeans, no significant persistence was found in any regime.

Figure 1. Stock-to-Use Ratio: Corn, Wheat, and Soybeans



Tables

Table 1. Heteroscedasticity Test Results[3]

	Corn	Wheat	Soybeans	Cocoa
Jarque-Bera*	744.98	14384.63	76741.60	1301.82
ARCH LM	559.24	405.21	1058.48	167.17
ε^2_t on y(hat)	.00	.00	.00	.00
$\varepsilon^2 t$ on $y(hat)^2$	.30	1.43	.02	10.24

*5% critical value=5.99
5% critical value=5.99
5% critical value=3.84

Table 2. Daily Price Data Analyzed

Commodity	Spot Location	Start Date	End Date	Units Obs	Units Analyzed	Representative Price Analyzed
Corn/ #2 Yellow	Chicago	1/5/70	5/30/97	cents/bu.	10^{th}s cent /bu	3024
Wheat/#2 Hard Winter	Kansas City	1/5/70	5/30/97	cents/bu.	10^{th}s cent /bu	4586
Soybeans/ #1 Yellow	Central Illinois	1/5/70	5/30/97	cents/bu.	10^{th}s cent /bu	8150
Cocoa/ Cote d'Ivoire	New York	10/20/80	5/30/97	USD/ton	USD/ton	1610

Table 3. Distributional Statistics of Natural Volatility Estimates (Weekly)

	Corn 1/70 - 5/97	**Wheat 1/70 - 5/97**	**Soybeans 1/70 - 5/97**	**Cocoa 10/80 - 5/97**
Sample Size	1430	1430	1430	867
Mean	29.652	41.222	80.383	26.214
Std. Dev.	26.832	38.046	93.712	18.870
Kurtosis	14.910	19.807	60.078	5.517
Skewness	3.056	3.199	5.952	1.982
Unit Root	Unit Root Test Value=-0.331	Unit Root Test Value=-0.068	Unit Root Test Value=-0.402	Unit Root Test Value= -0.956

Table 4: GARCH(1,1) Summary Statistics

	Corn	**Wheat**	**Soybeans**	**Cocoa**
β_1	0.022348 1.771	-0.023693 -2.005	0.085530 19.941	0.104694 6.473

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[3] 1. Jarque-Bera: Test: $(T-K)/6\ [S^2 + 1/4(K-3)^2] \sim \chi^2_2$
where T= number of observations
K= kurtosis
S= skewness

2. $\varepsilon^2_t = \beta_0 + \beta_1\varepsilon^2_{t-1} + \beta_2\varepsilon^2_{t-2}$
where the test statistic is: $(T-2)R^2 \sim \chi^2_2$

3. $\varepsilon^2_t = \beta_0 + \beta_1 y(hat)$
where the test statistic is: $TR^2 \sim \chi^2_1$

4. $\varepsilon^2_t = \beta_0 + \beta_1 y(hat)^2$
where the test statistic is: $TR^2 \sim \chi^2_1$

α_0	11.103924 12.992	5.871791 8.864	14745 43.873	3.667696 4.598
α_1	0.122241 27.443	0.139187 28.599	0.367983 29.256	0.041037 15.977
ϕ_1	0.881215 251.696	0.878281 250.466	4.150461E-20 0.002	0.956916 382.394

Table 5. Unconditional Variance

		Corn	Wheat	Soybeans	Cocoa
Entire Sample	Unconditional Variance	-3,185.88	-336.15	23,330.10	1,791.74
	Normalized	*-115.44*	*-9.09*	*312.76*	*75.90*
Regime 1	Unconditional Variance	-512.33	-266.68	31,553.90	2048.34
	Normalized	*-18.66*	*-7.35*	*367.44*	*66.46*
Regime 2	Unconditional Variance	1,275.49	2,629.36	12,599.90	968.56
	Normalized	*50.89*	*82.16*	*217.81*	*43.83*
Regime 3	Unconditional Variance	5,463.51	7,124.54	9,107.00	497.41
	Normalized	*159.85*	*137.06*	*148.74*	*30.40*

Table 6a. Subperiod Distributional Statistics of Natural Volatility Estimates (Weekly) for Corn.

	Subperiods		
	1/70 – 12/85	**1/86 – 12/93**	**1/94 – 5/97**
Sample Size	834	418	178
Mean	29.487	26.521	37.777
Std. Dev	25.293	22.348	39.185
Kurtosis	8.747	20.904	16.647
Skewness	2.054	3.475	3.345
Unit Root	Stationary Test Value=-3.474	Stationary Test Value=-2.910	Stationary Test Value=-2.042

*5% critical value is –1.95

Table 6b. Subperiod Distributional Statistics of Natural Volatility Estimates (Weekly) for Cocoa.

	Subperiods		
	10/80 – 12/85	**1/86 – 12/93**	**1/94 – 5/97**
Sample Size	267	418	178
Mean	37.749	22.985	16.677
Std. Dev.	22.862	15.421	8.733
Kurtosis	5.754	8.422	4.220
Skewness	1.503	1.896	1.144
Unit Root	Stationary* Test Value=-6.054	Stationary Test Value-5.107	Stationary Test Value=-4.459

*5% critical value is –1.95

Table 6c. Subperiod Distributional Statistics of Natural Volatility Estimates (Weekly) for Wheat.

	Subperiods		
	1/70 – 12/85	**1/86 – 12/93**	**1/94 – 5/97**
Sample Size	834	418	178
Mean	39.448	36.637	60.299
Std. Dev.	38.541	26.240	51.412
Kurtosis	12.949	7.626	28.541
Skewness	2.607	1.941	3.919
Unit Root	Stationary* Test Value=-3.407	Stationary Test Value=-2.052	Stationary Test Value=-2.193

*5% critical value is –1.95

Table 6d. Subperiod Distributional Statistics of Natural Volatility Estimates (Weekly) for Soybeans.

	Subperiods		
	1/70 – 12/85	**1/86 – 12/93**	**1/94 – 5/97**
Sample Size	834	418	178
Mean	94.087	60.373	63.163
Std. Dev.	112.081	55.916	47.804
Kurtosis	49.164	25.990	9.827
Skewness	5.394	3.869	2.250
Unit Root	Stationary* Test Value=-3.844	Stationary Test Value=-3.104	Non-Stationary Test Value=-1.484

*5% critical value is –1.95

Table 7a. GARCH(1,1) Parameter Estimates for the Period January 5, 1970 – December 22, 1985

	Corn	Wheat	Soybeans	Cocoa
β_1	.006 .343*	-.006 -.385	.068 5.689	.065 2.167
α_0	4.661 5.636	5.067 7.903	19311 30.218	2044.248 39.409
α_1	.131 17.677	.151 23.403	.384 19.405	.002 .202
ϕ_1	.878 154.552	.868 195.066	.004 1.042	4.332-23 0.000

* T-statistics

Table 7b. GARCH(1,1) Parameter Estimates for the Period December 23, 1985 – December 30, 1993

	Corn	Wheat	Soybeans	Cocoa
β_1	.042 1.623	-.067 -3.818	.119 7.359	.108 4.913
α_0	161.987 10.979	57.846 7.014	8530.115 25.454	8.717 3.987
α_1	.207 11.425	.113 12.596	.323 12.740	.052 8.824
ϕ_1	.666 27.483	.865 94.615	8.685-24 0.000	.939 134.200

Table 7c. GARCH(1,1) Parameter Estimates for the Period December 31, 1993 – June 2, 1997

	Corn	Wheat	Soybeans	Cocoa
β_1	.017 .440	-.051 -1.219	-.001 -.015	.125 3.247
α_0	3070.493 15.712	5913.366 61.647	7677.202 20.998	441.701 29.675
α_1	.438 8.279	.170 4.326	.157 3.823	.112 4.557
ϕ_1	6.421-23 0.000	4.446-24 0.000	-6.772-23 0.000	-5.617-20 0.000

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