Agricultural liberalization policy and commodity price volatility: a GARCH application

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This study examines the effect of the recent radical agricultural liberalization policy, i.e. the 1996 FAIR Act, on agricultural commodity price volatility using Generalized Autoregressive Conditional Heteroscedasticity (GARCH) models. Results of the study indicate that the agricultural liberalization policy has caused an increase in the price volatility for three major grain commodities (corn, soybeans and wheat) and little change for oats, but a decrease for cotton. These findings stand in sharp contrast to Crain and Lee's observations in 1996 based on wheat markets that market-oriented measures in government farm policies tend to reduce agricultural price volatility.

I. INTRODUCTION

The most recent major agricultural legislation, the Federal Agricultural Improvement and Reform (FAIR) Act of 1996, signed into law in April 1996, fundamentally liberalized US farm commodity programmes. The new law, although only in effect until 2002, has been widely portrayed as a radical departure from the heavy governmental intervention in US agricultural policy over the last 60 years, signalling a new market-orientated direction for US farm policy. The core of the FAIR Act is to grant virtual production flexibility and reduce governmental support of crop production. In particular, this is the first time that (annually fixed and declining) government support, renamed 'production flexibility contract payments', is not related to commodity market prices or current commodity production. Thus, US agriculture production is expected to be market oriented during the period specified in the FAIR Act.

The agricultural liberalization policy has been controversial. Many people share concerns about how the FAIR Act and the greatly increased planting flexibility will affect agricultural commodity price volatility. Knowledge of price volatility under market-oriented agricultural policy is important. Output price volatility is an indispensable input for farmers' and agribusiness' decision-making (e.g., Maynard *et al.*, 1997). It also may affect the enactment of successive farm policies, because Congress pays attention to the loss and risk borne by farmers and their satisfaction with the new law. It has been widely argued that planting flexibility under the new law would generally result in greater commodity price volatility (Ray *et al.*, 1998; Shertz and Johnston, 1997; Knutson *et al.*, 1996). The greater price volatility would increase a farmer's income risk already incurred by receipt of only fixed and declining government subsidies (Young and Shields, 1996). Others have argued that the overall effect of increased planting flexibility on crop price risks is uncertain and may not necessarily increase price volatility (Harwood *et al.*, 1996; Young and Westcott, 1996; Smith and Glauber, 1998). If year-to-year planting adjustments are significantly greater than in the past, prices may be more volatile. However, price volatility may be reduced if farmers can more readily respond to market signals without the planting

restrictions that may have constrained acreage shifts in the past (Harwood *et al.*, 1996). All of these arguments relied on some economic intuition and are not yet subject to empirical verification.

Until recently, the direct impact of government farm policies on price volatility has received surprisingly limited attention in the empirical literature, although price stabilization was the primary goal for farm programmes (Crain and Lee, 1996). *A priori*, the hypothesis of this study is that the FAIR Act *per se* can only decrease or at least cannot increase agricultural price volatility, which is motivated by Crain and Lee (1996). They studied wheat price volatility across various farm programmes, and found that the market-driven measures introduced in US farm programmes have helped reduce price volatility in the wheat market. Our study extends their work by considering price volatility changes associated with a clearly market-oriented measure (i.e. production flexibility) for five major crops directly under farm programmes. Specifically, corn, oat, wheat and cotton may be directly affected by the policy change of the production flexibility in the FAIR Act. Soybeans may be affected indirectly because soybeans, corn and wheat are grown together in a relatively concentrated geographical area and may compete with each other for the planting acreage.

The rest of the paper is organized as follows. First, US agricultural laws are briefly reviewed with a focus on planting flexibility. Second, the empirical methodology is discussed. Third, the data and the empirical results are presented. The final section offers concluding remarks.

II. PLANTING FLEXIBILITY AND THE US FARM POLICY

Farm programme policy dates back to President Franklin D. Roosevelt's New Deal, when protective federal intervention was deemed essential to stabilize farm income. The Agricultural Adjustment Act of 1938 was the first to establish the basic price support and production control system for non-perishable agricultural commodities and it remained in existence more than 50 years. By the mid-1980s, farm programme policies faced increasing pressure for reform, largely due to rapidly growing implementation costs. The following paragraphs briefly review planting flexibility under four recent major farm laws.

Planting flexibility affected US crop production in the following way: only acreage planted with specific programme crops qualified to receive government deficiency payments. This requirement was further compounded by two additional factors: (1) using the average qualified crop acreage in proceeding or following several years; and (2) limiting total acreage. The former factor meant that production control covered a longer time horizon. An individual farmer with more total qualified acreage could receive more deficiency or loan rate payments under certain limitations. Both payments aimed to cover the difference between target prices and (lower) market prices and were potentially a substantial subsidy.

The Agriculture and Food Act of 1981 kept almost the same restrictions on production flexibility. In this act, the base acreage for four programme commodities (wheat, feed grains, upland cotton and rice) was calculated separately, implying that shifting from a crop within one group to a crop in another group would affect the farmer's acreage eligible for deficiency payments. The total acreage planted to designated programme crops was also limited to an individual farmer. The next major agricultural law, the Food Security Act of 1985, brought new formulas for computing acreage bases and partially broke the link between production and receipt of government payments (Dicks *et al.*, 1986). Also, soybean-use acres and conservation-use acres were included for the first time in calculating the farm acreage base. The sum of programme crop acreage bases was used to determine the government payment. Farmers had more discretion to switch production among the five programme crops. The required percentage for crop acreage in each year was also reduced. If farmers planted between 50% and 92% of the permitted acreage, programme acreage would be counted as equal to 92%. However, flexibility was limited because many constraints, such as the use of average calculation of qualified crop acreage over several years, remained. For example, any year of zero planting of cotton and rice during 1981–1983 meant that the acreage could not be counted in the calculation of programme crop acreage.

In 1990, the Food, Agriculture, Conservation and Trade Act continued the spark of market-orientated farm policy started in the 1985 Act. The planting flexibility provision was modified so that farmers enrolled in programmes could plant any crop except fruits and vegetables up to 25% of their crop base. Farmers were still eligible for benefits other than deficiency payments if they chose to plant a crop different from their original programme crop. The 1990 Act made significant progress in elimination of production control. However, the 25% limit still obstructed flexible production in response to market demands.

Finally, the 1996 FAIR Act brought virtually full flexibility to crop production, except for fruits and vegetables (Knutson *et al.*, 1996). The limitation of total acreage, the requirement of specific crops to be planted, the 25% limit on flex acreage, and prohibition of programme crops on non-programme acreage were all eliminated. At the same time, the FAIR Act replaced the target price or the deficiency payments provision with a series of seven-year decoupled 'transition' payments, which guaranteed annual fixed but declining payments over the period 1996–2002 and totalled $35.7 billion. The term 'decoupled' means that the size of the payment does not depend on the amount of crop produced or the level of the market

price. Obviously, the 1996 FAIR Act forced US agricultural production to be more fully driven by market forces. The lawmakers also expected that the flexibility would make farmers respond to market signals in their production decisions and hence have an improved opportunity for profit, at least partially offsetting the loss in government subsidies.

III. EMPIRICAL METHODOLOGY

Commodity price volatility or uncertainty has been widely modelled as the conditional variance in the GARCH framework, as originally developed by Engle and generalized by Bollerslev (1986). Many papers have employed this methodology to explore various commodity price volatility issues (Aradhyula and Holt, 1989; Holt, 1993; Jayne and Myers, 1994; Yang and Brorsen, 1992; 1993; Hudson and Coble, 1999). This study extends the use of the GARCH framework to test the hypothesis on agricultural price volatility changes associated with the FAIR Act. There are several advantages to this modelling approach. First, the well-documented time-varying pattern of price volatility or risk can be well described by a GARCH process (Yang and Brorsen, 1992; 1993), compared to more traditional alternatives. Second, the risk in the model is defined as a function of the variance of price forecast errors conditional on available information, and is thus consistent with the notion of unpredictability rather than instability (Jayne and Myers, 1994). Third, price volatility and price forecasts can be determined simultaneously in the GARCH model.

To capture the possible changes in commodity price volatility, an $AR(k)$-$GARCH(p,q)$ model with a dummy variable is specified as follows:

$$y_t = \mu + \sum_{s=1}^{s=k} a_s y_{t-s} + \varepsilon_t \qquad (1a)$$

$$\varepsilon_t | \Omega_t \sim td(0, \sigma_t^2, \nu) \qquad (1b)$$

$$\sigma_t^2 = \omega + \sum_i^p \alpha_i \varepsilon_{t-i}^2 + \sum_j^q \beta_j \sigma_{t-j}^2 + dD_t \qquad (1c)$$

where y_t is the return or the first difference of log price, k is the lag length, $td(0, \sigma_t^2, \nu)$ represents the student's t density with mean zero, variance σ_t^2, and degree of freedom ν, and p and q are lag lengths for the squared residuals and the conditional variance, respectively. Price volatility is accounted for by the conditional variance σ_t^2 in the Equation 1c, which is specified as a linear function of past squared errors, past values of the conditional variance, and a reform dummy variable D_t. Following its use in the literature (Choi and Kim, 1991; Crain and Lee, 1996), the dummy variable D_t was set to equal one after 1 April 1996 when the FAIR act was in effect and to zero otherwise. If

the dummy variable is statistically significant, then market-oriented agricultural policy has had an impact on commodity price risk, and its positive/negative sign indicates the increase/decease in price volatility. Inferences drawn on the basis of GARCH-M models have been found to be highly susceptible to model misspecification (Jones *et al.*, 1998), therefore a GARCH-M model was not estimated to allow for a possible change in the risk premium.

Finally, to determine if the models were correctly specified, a variety of diagnostic tests was conducted on the standardized residuals from $AR(k)$-GARCH model estimation. Ljung–Box Q tests show whether there is autocorrelation in the standardized residuals. Ljung–Box Q^2 tests show whether there is autocorrelation in the squared standardized residuals. ARCH tests show whether there is unexplained ARCH effect in the standardized residuals.

IV. DATA AND EMPIRICAL FINDINGS

The data consisted of daily cash and futures settlement prices for corn, oat, soybeans, wheat (hard winter) and cotton. The year period covered provided a total of 1695 observations from 1 January 1992, to 30 June 1998. All these prices were from actively traded cash and futures markets and were reported daily in the *Wall Street Journal*. Though results based on both cash and futures prices are reported in this session, more attention should be paid to the results based on futures prices. There is no national cash market for agricultural commodities and the cash prices used here only represent the prices from an active cash market in a particular region/location for each commodity. In contrast, a futures market is a central marketplace where the nationwide price information may be aggregated and incorporated into futures prices. Crain and Lee (1996) also observed that the cash market is for immediate delivery and suppliers and buyers on the cash market may not have time to respond to prices. Yang and Leatham (1999) provided the supportive evidence for this argument, highlighting the important difference between commodity cash and futures prices in processing the long-run price information.

GARCH modelling requires a stationary data-generating process. First the non-stationarity of the levels and first differences for each price series was tested, using the augmented Dickey–Fuller test (Dickey and Fuller, 1981). The results indicated that all the prices were stationary in first differences but not non-stationary in levels at the 5% significance level. Thus, we properly used the first difference of the logarithm of prices which equals the daily return ($R_t = \ln(P_t/P_{t-1})$), in GARCH models.

The preliminary analysis was conducted on $AR(k)$-$GARCH(p,q)$-t specifications for $p, q = 1, 2, 3, 4$. It was found that the AR (0)-GARCH (1,1)-t process provided a good approximation of the data generating process

for all cash and futures prices under consideration, with the exception of soybeans cash prices and wheat futures prices, where an AR (1)-GARCH (1,1)-*t* process is a better fit. The results based on cash and futures prices are reported in Tables 1 and 2, respectively. The time-varying pattern of agricultural price variability was confirmed because at least one of the coefficients of GARCH effects (α and β) is significant in all cases. The sum of α and β measures the persistence of the price volatility. In most cases the sum of α and β was close to but less than one, thus implying a persistent volatility effect of an economic shock on these commodity prices. It was especially important to check the significance of the coefficient for the reform dummy (*d*). It was found that for three of the five commodities (corn, soybeans, wheat) the coefficient *d* was positive and significant at least at the 10% level for cash prices and at the 5% level for futures prices, implying an increase in the price volatility for these commodities after the FAIR act. The negative coefficient *d* was statistically significant at the 5% level in the case of cotton for both cash and futures prices, implying a decrease in the price volatility for cotton after

the FAIR act. The coefficient *d* was insignificant from zero in the case of oats for both cash and futures prices even at the 10% level. This suggests little change in the price volatility for oats after the FAIR act. To see the volatility changes more visually, Figs 1 and 2 plot the futures price volatility (as captured by the estimated conditional variance) for one commodity where volatility increased (corn) and one commodity where volatility decreased (cotton). The day 1109 corresponds to 1 April 1996, when the FAIR Act came into effect. These plots of futures price volatility (other figures depicting time-varying volatility of both cash and futures prices for each commodity are available upon request) confirm the previous inferences from Tables 1 and 2. In sum, the findings are in favour of the argument that price volatility increased under the 1996 FAIR Act for most commodities.

Using a simulation method, Ray *et al.* (1998) projected that after the FAIR Act, corn, wheat, and soybean prices were likely to be more variable but cotton prices were not. The results here are quite consistent with the simulation evidence from Ray *et al.* (1998). However, while

Table 1. *Results of GARCH* $(1, 1)$*-t process for cash prices* (*1.1.1992–30.6.1998*)

Coefficient (*t*-ratio)	Corn	Oat	Soybeans	Wheat	Cotton
α	0.07**	0.13	0.06**	0.12**	0.04**
	(4.64)	(0.85)	(4.63)	(4.73)	(3.46)
β	0.90**	0.04**	0.93**	0.78**	0.93**
	(46.38)	(7.00)	(62.39)	(17.78)	(42.46)
d	0.000004*	−0.0007	0.000002*	0.00001*	−0.000004**
	(1.84)	(−0.81)	(1.77)	(1.91)	(−2.12)
$\alpha + \beta$	0.97	0.17	0.99	0.90	0.97
Specification tests (*p*-value reported)					
ARCH(12)	0.98	0.97	0.99	0.89	0.31
LB-Q(12)	0.41	0.11	0.02	0.38	0.12
LB-Q^2(12)	0.91	0.87	0.97	0.68	0.15

Note: **denotes significance at the 5% level, and *denotes significance at the 10% level.

Table 2. *Results of GARCH* $(1, 1)$*-t process for future prices* (*1.1.1992–30.6.1998*)

Coefficient (*t*-ratio)	Corn	Oat	Soybeans	Wheat	Cotton
α	0.07**	0.16**	0.05**	0.07**	0.02**
	(4.42)	(4.75)	(4.38)	(3.46)	(2.58)
β	0.90**	0.81**	0.93**	0.85**	0.96**
	(43.37)	(26.12)	(59.97)	(19.57)	(69.58)
d	0.000005**	0.000007	0.000003**	0.000007**	−0.000003**
	(2.01)	(1.15)	(2.01)	(1.93)	(−4.07)
$\alpha + \beta$	0.97	0.97	0.98	0.92	0.98
Specification tests (*p*-value reported)					
ARCH(12)	0.41	0.75	0.99	0.52	0.99
LB-Q(12)	0.47	0.06	0.09	0.61	0.15
LB-Q2(12)	0.18	0.61	0.95	0.89	0.99

Note: ** denotes significance at the 5% level, and *denotes significance at the 10% level.
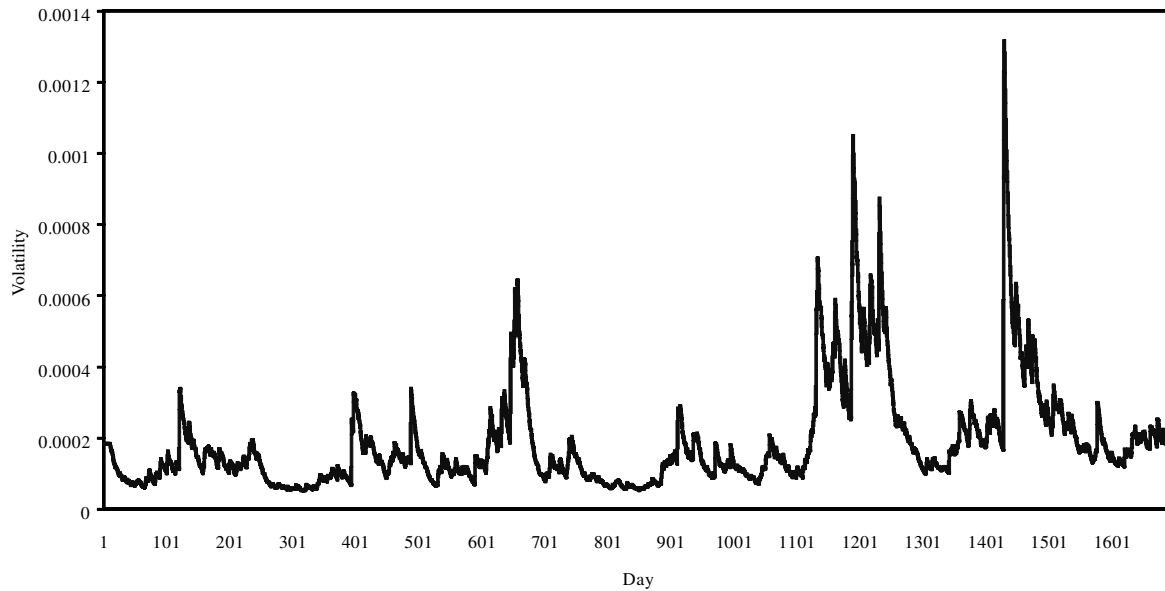
Note: Day 1109 corresponds to 1 April 1996, the first day the FAIR Act was in effect.

Fig. 1. *Daily time-varying volatility for corn futures* (*1/1/1992–30/06/1998*)
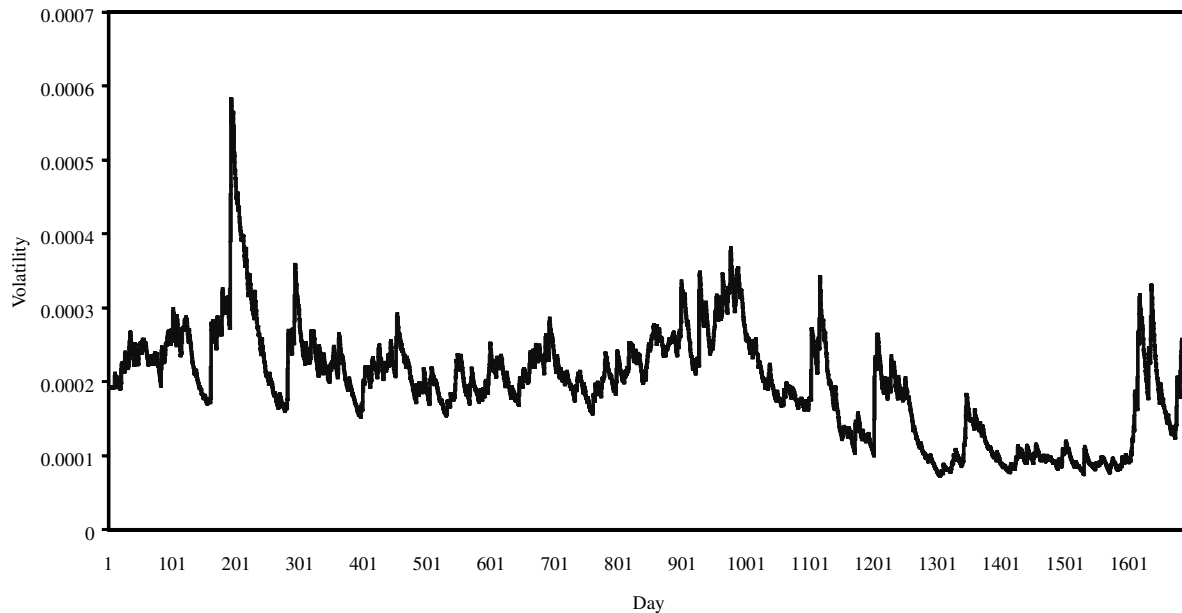
Note: Day 1109 corresponds to 1 April 1996, the first day the FAIR Act was in effect.

Fig. 2. *Daily time-varying volatility for cotton futures prices* (*1/1/1992–30/06/1998*)

the possible price volatility change for each commodity is clearly estimated here, it is not possible to use the data presented to determine precisely what portion of price volatility change can be only attributed to the policy changes instituted in the 1996 FAIR Act alone. This caveat is similar to that of Ray *et al.* (1998, p. 32). Crain and Lee (1996, p. 337) observed that government farm programmes did induce most of the observed changes in spot and futures volatility in the wheat market and that other factors such as weather were not correlated with the dummy variable used to capture the farm policy change. It was also found that including the futures trading volume in the above GARCH models yielded qualitatively similar results (not reported here but available upon request). Thus, the futures trading activity cannot fully account for the price volatility changes associated with the dummy variable.

Finally, the specification test results showed that GARCH models did an adequate job of describing the data-generating process of cash and futures prices for each commodity.

V. CONCLUSIONS

This study investigated the effects of the market-oriented 1996 FAIR Act on agricultural commodity price volatility using GARCH models. The results provide evidence that the agricultural liberalization policy has generally caused an increase in the price volatility of the major grain commodities (corn, soybeans and wheat), little change for oats, but a decrease for cotton. These findings stand in sharp contrast to Crain and Lee's (1996) observations based on wheat markets, that market-oriented measures in government farm policies tend to reduce agricultural price volatility. The results of this study also corroborate the previous empirical findings of Ray *et al.* (1998) although they used a different methodology (simulation).

Interestingly, Yang *et al.* (2001) reported that two of the commodities with increased price volatility in this study, soybeans and hard winter wheat, did not have closely aligned cash and futures prices in the long run (i.e. no cointegration). Yang *et al.* (2001) pointed out that these two commodities were traded largely in international markets. In contrast, oats and corn, which did not have an increase in price volatility after the FAIR Act, were found to have cointegrated cash and futures prices during the same sample period (Yang *et al.*, 2001). On the surface, this suggests the following possibility: if the agricultural liberalization policy can induce more closely aligned cash and futures prices for an individual commodity, it may help to decrease or at least not increase commodity price volatility. It could be true because more information would be processed and transmitted between futures and cash markets. This hypothesis may be worthy of further investigation.

REFERENCES

Aradhyula, S. V. and Holt, M. T. (1989) Risk behavior and rational expectations in the U.S. broiler markets, *American Journal of Agricultural Economics*, **71**, 892–902.

Bollerslev, T. (1986) Generalized autoregressive conditional heteroscedasticity, *Journal of Econometrics*, **31**, 307–27.

Choi, S. and Kim, B. J. C. (1991) Monetary policy regime changes and the risk premium in the foreign exchange markets: a GARCH examination, *Economics Letters*, **37**, 447–52.

Collins, K. J. and Glauber, J. W. (1998) Will policy changes usher in a new era of increased agricultural market variability? *Choices*, Second Quarter, pp. 26–9.

Crain, S. J. and Lee, J. H. (1996) Volatility in wheat spot and futures markets, 1950–1993: government farm programs, seasonality, and causality, *Journal of Finance*, **51**, 325–43.

Dickey, D. A. and Fuller, W. A. (1981) The likelihood ratio statistics for autoregressive time series with a unit root, *Econometrica*, **49**, 1057–72.

Dicks, M. *et al.* (1986) Implications of the 1985 Farm Bill, *Agricultural Outlook (USDA)*, **March**, 23–33.

Engle, R. F. (1982) Autoregressive conditional heteroscedasticity with estimates of the variance of U.K. inflation, *Econometrica*, **50**, 987–1008.

Harwood, J., Heifner, D., Coble, K. and Perry, J. (1996) Strategies for a new risk management environment, *Agricultural Outlook (USDA)*, **October**, 24–30.

Holt, M. T. (1993) Risk response in the beef marketing channel: a multivariate generalized ARCH-M approach, *American Journal of Agricultural Economics*, **75**, 559–71.

Hudson, D. and Coble, K. (1999) Harvest contract price volatility for cotton, *Journal of Futures Markets*, **19**, 717–33.

Jayne, T. S. and Myers, R. J. (1994) The effect of risk on price levels and margins in international wheat markets, *Review of Agricultural Economics*, **16**, 63–73.

Jones, C. M., Lamont, O. and Lumsdaine, R. L. (1998) Macroeconomic news and bond market volatility, *Journal of Financial Economics*, **47**, 315–37.

Knutson, R. D., Smith, E. G., Outlaw, J. L. and Woods, W . F. (1996) New farm bill: watershed change in policy. Texas A&M Agricultural and Food Policy Center.

Maynard, L. J., Harper, J. K. and Hoffman, L. D. (1997) Impact of risk preferences on crop rotation choice, *Agricultural and Resource Economics Review*, **26**, 50–9.

Ray, D. E., Richardson, J. W., De La Torre Ugarate, D. G. and Tiller, K. H. (1998) Estimating price variability in agriculture: implications for decision makers, *Journal of Agricultural and Applied Economics*, **30**, 21–33.

Schertz, L. and Johnston, W. E. (1997) Farm Act '96: managing farm resource in a new environment, *Agricultural Outlook (USDA)*, **August**, 18–21.

Smith, V. H. and Glauber, J. W. (1998) The effect of 1996 farm legislation on feed and food grains, *Contemporary Economic Policy*, **16**, 69–76.

Yang, J. and Leatham, D. J. (1999) Price discovery in wheat futures markets, *Journal of Agricultural and Applied Economics*, **31**, 359–70.

Yang, J., Bessler, D. A. and Leatham, D. J. (2001) Asset storability and price discovery of commodity futures markets: a new look, *Journal Futures Markets*, **21**, 279–300.

Yang, S.-R. and Brorsen, B. W. (1992) Nonlinear dynamics of daily cash prices, *American Journal of Agricultural Economics*, **74**, 706–15.

Yang, S.-R. and Brorsen, B. W. (1993) Nonlinear dynamics of daily futures prices: conditional heteroscedasticity or chaos? *Journal of Futures Markets*, **13**, 175–91.

Young, E. and Shields, D. A. (1996) Overview: FAIR Act frames farm policy for 7 years, *Agricultural Outlook (USDA)*, **April**, 1–4.

Young, E. and Westcott, P. C. (1996) 1996 Farm Act impacts: an early assessment, *Agricultural Outlook (UDA)*, **August**, 22–5.