Reducing price volatility via future markets

Carlos Martins-Filho[1], Maximo Torero[2] and Feng Yao[3]

[1]University of Colorado - Boulder and IFPRI, [2]IFPRI

[3]West Virginia University

OECD - Paris

A simple model for producers' profit maximization

- Producers of agricultural commodities do not have market power. As a result, output decisions are made taking market price as given.
- Let $c(y; w)$ be the producer cost function, where y denotes output and w denote input prices and let marginal cost be denoted by $c'(y; w)$.
- P is a *random* variable that denotes market price.
- P has distribution given by F_P with expected value $\mu_P = \int p \, dF_P(p)$ and variance $\sigma_P^2 = \int (p - \mu_P)^2 \, dF_P(p)$.
- Profit maximization requires $\mu_P = c'(y^*; w)$.

Source: Martins-Filho, & Torero ,(2010)

A simple model for producers' profit maximization

- Producer output cannot be adjusted with the speed at which prices change, producers attain suboptimal profits (L) whenever $P \neq \mu_P$.
- Now, assume without loss of generality that the optimal level of output for price P is $y > y^*$. Then lack of output adjustment produces a loss in profit given by

$$L = -Pdy + \int_{y^*}^{y} c'(\alpha; w)d\alpha \text{ where } dy = y - y^*. \quad (1)$$

Source: Martins-Filho, & Torero ,(2010)

A simple model for producers' profit maximization

- If $c'(y;w) = b(w) + 2c(w)y$ where $b(w)$ and $c(w)$ are constants, then

$$L = -\frac{1}{4c(w)}(P - \mu_P)^2.$$

- Expected loss in profits is

$$E(L) = \frac{1}{4c(w)}E(P - \mu_P)^2 = \frac{1}{4c(w)}\sigma_P^2. \qquad (2)$$

- There is, consequently, a monotonically increasing relationship between volatility (σ_P) and expected losses.

Source: Martins-Filho, & Torero ,(2010)

A simple model for producers' profit maximization

1. Smaller price volatility reduces losses. In fact, if it were possible to attain $\sigma_P^2 = 0$ there would be no loss in profits.
2. Since choosing output to maximize profit equates marginal cost to price, there is optimal allocation of inputs into the agricultural sector. Hence, misallocation is reduced by reducing price volatility. Large values of σ_P^2 produce increased misallocation of resources.
3. Increased price volatility through time generates the possibility of larger net returns $R_t = P_t/P_{t-1} - 1$, where t indexes time. Potential larger returns create the possibility of constructing investment portfolios that previously did not contain agricultural commodities. As such increased price volatility may lead to increased (potentially speculative) trading.

Source: Martins-Filho, & Torero ,(2010)

Proposals to reduce price volatility using future markets

- **Regulation of futures market**
  - Problem 1: non binding regulation
  - Problem 2: Inter-linkages between exchanges
- **Virtual reserves**
  - Problem 1: Granger causality from futures to spot
  - Problem 2: Institutional design
  - Problem 3: Identifying unusually high returns in commodity price series

Regulation of Future exchanges

Should we reform commodity exchanges by:

- limiting the volume of speculation relative to hedging through regulation;
- making delivery on contracts or portions of contracts compulsory; and/or
- imposing additional capital deposit requirements on futures transactions.

Answer: Requires several conditions to be effective

Problem 1: not binding regulation - we have seen triggers were not activated and also not clear incentives

Problem 2: Inter-linkages between exchanges

Methodology: We use three MGARCH models: the interrelations between markets are captured through a conditional variance matrix *H*, whose specification may result in a tradeoff between flexibility and parsimony. We use three different specifications for robustness checks:

- Full T-BEKK models (BEKK stands for Baba, Engle, Kraft and Kroner), are flexible but require many parameters for more than four series.
- Diagonal T-BEKK models are much more parsimonious but very restrictive for the cross-dynamics.
- Constant Conditional Correlation Model (CCC) models allow, in turn, to separately specify variances and correlations but imposing a time-invariant correlation matrix across markets.

Data:

- In the case of corn, we examine market interdependence and volatility transmission between USA (CBOT), Europe/France (MATIF) and China (Dalian-DCE);
- for wheat, between USA, Europe/London (LIFFE) and China (Zhengzhou-ZCE); and for soybeans, between USA, China (DCE) and Japan (Tokyo-TGE).
- We focus on the nearby futures contract in each market and account for the potential impact of exchange rates on the futures returns and for the difference in trading hours across markets.

Source: Hernandez, Ibarra and Trupkin (2011)

Problem 2: Inter-linkages between exchanges

Results – Diagonal T-BEKK model

- The results clearly indicate that there are interactions, at least indirect (via the covariance), between the three exchanges analyzed for each agricultural commodity.
- This model, however, does not provide further insights about the dynamics of volatility transmission across exchanges since it assumes that the degree of innovation from a market to another is zero as well as the persistence in volatility between markets

Results – Full T-BEKK model

- In general, the results indicate that t there are spill-over effects of price and information shocks between the exchanges analyzed for these agricultural commodities.

Constant Conditional Correlation (CCC) model

- The results show that the correlations between exchanges are positive and clearly significant for the three agricultural commodities, which implies that there is volatility transmission across markets.
- In general, we observe that the interaction between USA (CBOT) and the rest of the markets considered (Europe and Asia) is higher compared with the interaction within the latter.
- In particular, the results show that the interaction between CBOT and the European markets is the highest among the exchanges considered for corn and wheat. Similarly, the results indicate that China's wheat market is barely connected with the other markets.
- However, in the case of soybeans, China has a relatively high association with the other markets, particularly with CBOT.

Source: Hernandez, Ibarra and Trupkin (2011)

Safeguard mechanism – Virtual reserve

A safeguard mechanism to manage risk through the implementation of **a virtual reserve** backed up by a financial fund to calm markets under speculative situations

Answer: Requires several conditions to be effective

Problem 1: Links between futures and spot market
Problem 2: Institutional design
Problem 3: An early Warning mechanism to define "volatility" and abnormalities in changes in returns (extreme values) - $R_t=(\ln P_t-\ln P_{t-1})$

Safeguard mechanism – Virtual reserve

- A coordinated commitment by the group of participating countries. Each of the countries would commit to supplying funds if needed for intervention in grain markets

- Determining the size of this fund will require further analysis as commodity futures markets allow for high levels of leverage.

- These resources would be promissory, or virtual, not actual budget expenditures.

- It requires a global market analysis unit (GMAU)

Safeguard mechanism – Virtual reserve

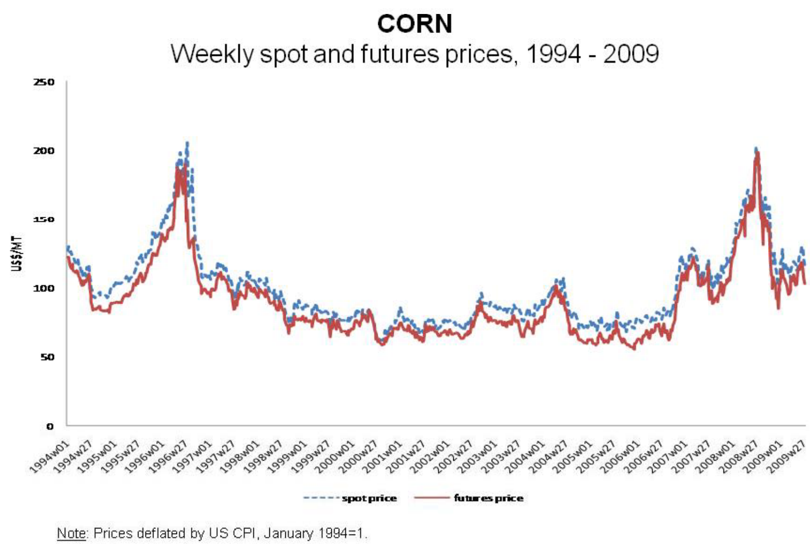
- The intervention will take place in the futures market **=> A signal of a potential intervention will be announced**
- Intervention will happen when the GMAU triggers the alarm that changes in returns are significantly above (95th percentile of its conditional value at risk) based on market fundamentals
- The potential intervention would consist of executing a number of short sells over a specific period of time in futures markets around the world at a price lower than the current future price.
- The global intelligence unit would recommend the price or series of prices to be offered in the short sales

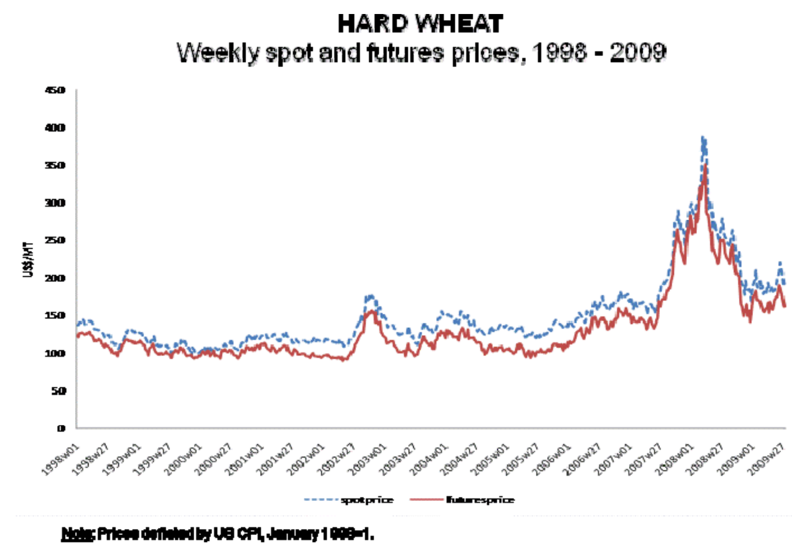
Safeguard mechanism – Virtual reserve

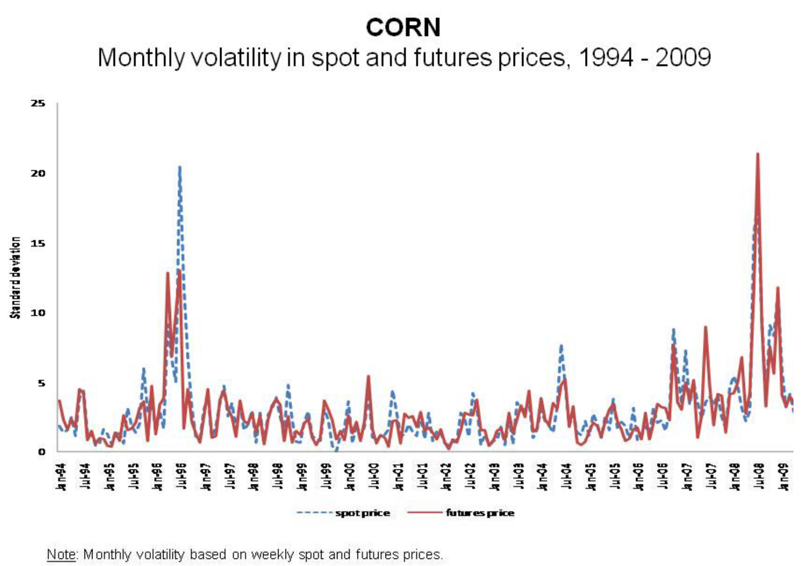
The key advantages of the VR with respect to a physical reserve and regulation concepts are:

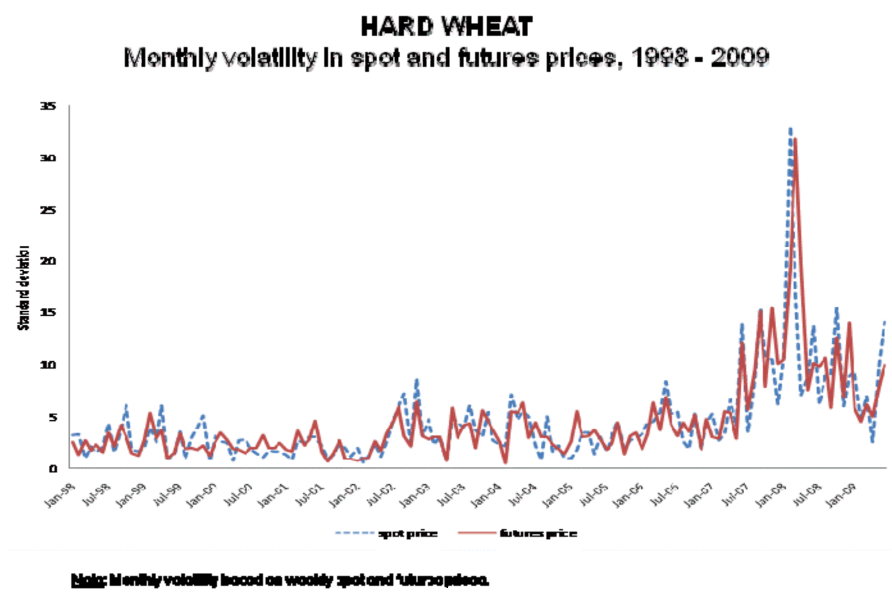
- it is just a signalling mechanism;
- it does not put more stress on the commodity market;
- it does not incur in the significant storage and opportunity cost of a physical reserve;
- it resolves the problem of the inter-linkage between the financial and the commodity market; and
- given that it is a signal, its effect over markets should be minimal.

Problem 1: Spots and future move together









Source: Hernandez & Torero (2009)

Problem 1: Spots and future move together

- Granger causality tests were performed to formally examine the dynamic relation between spot and futures markets.
- The following regression model is estimated to test if the return in the spot market (*RS*) at time *t* is related to past returns in the futures market (*RF*), conditional on past spot returns,

$$RS_t = a_0 + \sum_{k=1}^{p} a_{1k} RS_{t-k} + \sum_{k=1}^{p} a_{2k} RF_{t-k} + e_t$$

where H_0: $a_{2k} = 0 \ \forall \ k = 1, \dots, p$ (i.e. *RF* does not Granger-cause *RS*).

- Conversely, RF_t is the dependent variable to evaluate the null hypothesis that spot returns (*RS*) does not Granger-cause futures returns (*RF*).

- Similar tests are performed to examine causal links in the volatility of spot and futures returns.

Source: Hernandez & Torero (2009)

Problem 1: Spots and future move together

Granger causality test of weekly returns in spot and futures markets, 1994 - 2009

# lags	H_0: Futures returns does not Granger-cause spot returns				H_0: Spot returns does not Granger-cause futures returns			
	Corn	Hard Wheat	Soft Wheat	Soybeans	Corn	Hard Wheat	Soft Wheat	Soybeans
1	167.47***	263.03***	169.85***	15.44***	6.10***	2.20	0.40	0.55
2	116.20***	186.92***	106.61***	21.24***	2.09	0.02	0.01	0.47
3	77.58***	135.27***	75.33***	20.74***	2.24*	0.11	0.27	1.75
4	58.56***	100.84***	57.92***	16.93***	2.08*	0.97	1.50	1.41
5	48.65***	79.91***	46.38***	14.57***	1.66	1.32	1.59	1.28
6	40.63***	65.92***	38.36***	12.41***	1.59	1.21	1.64	1.06
7	34.76***	56.21***	32.90***	11.51***	2.12**	1.45	1.76*	0.96
8	30.95***	49.91***	29.37***	10.35***	1.97**	1.21	1.46	1.06
9	27.62***	44.64***	26.09***	9.38***	1.58	1.10	1.25	1.04
10	24.80***	40.89***	23.44***	9.05***	1.45	1.21	1.21	1.03

*10%, **5%, ***1% significance. F statistic reported.

Note: The Schwartz Bayesian Criterion (SBC) suggests lag structures of 2, 3, 2 and 3 for corn, hard wheat, soft wheat and soybeans, respectively. The Akaike Information Criterion (AIC) suggests lag structures of 8, 3, 4 and 5, respectively. Period of analysis January 1994 - July 2009 for corn and soybeans, and January 1998 - July 2009 for hard and soft wheat.

It appears that futures prices Granger-cause spot prices.

Source: Hernandez & Torero (2009)

Problem 1: Spots and future move together

Tests were also performed on sample sub periods to analyze if the dynamic relation between spot and futures markets has changed across time.

1. Causality tests for separate 2-year periods.

2. Causality tests for each sample sub period corresponding to a different farm program (1990, 1996, 2002 & 2008 Farm Bills).

3. Rolling causality tests: repeated tests over 104-week periods by rolling the subsample period one week ahead until the available data is exhausted.

4. Nonparametric causality tests were performed to uncover potential nonlinear dynamic relations between spot and futures markets.
   The test proposed by Diks and Panchenko (2006) is implemented.

Overall, it appears that futures markets have generally dominated spot markets in the past years.

Source: Hernandez & Torero (2009)

Problem 2: Institutional design

Clearly, agreement on the arrangements for the VR will not be easy and may require a high-level United Nations task force to analyse the way forward. Yet similar institutional arrangements have been made in the past; examples are:

- The International Fund for Agricultural Development (IFAD): IFAD, for example, was established as an international financial institution in 1977 as a major outcome of the 1974 World Food Conference in response to the food crisis of the early 1970s.
- The Food Aid Convention (FAC): first signed in 1967 and renewed five times, is the only treaty under which signatories have a legal obligation to provide international development assistance.
- The IMF Cereal Import Facility and the IEA.

Problem 3: An early Warning mechanism to define volatility and abnormalities in changes in returns

Important questions

- How can we construct a statistical model for the stochastic behavior of prices that includes volatility?
- How should we model such volatility?
- Should our interest be on price levels at a particular point in time, say P_t or on (log) returns $log(\frac{P_t}{P_{t-1}})$?
- How do we decide what constitutes "large" price variations?

The statistical model

We assume that:

1.$r_t = m(r_{t-1}, r_{t-2}, \cdots, r_{t-H}, w_{t.}) + h^{1/2}(r_{t-1}, r_{t-2}, \cdots, r_{t-H}, w_{t.})\varepsilon_t$

2. $w_{t.}$ is a $1 \times K$ dimensional vector of random variables
3. ε_t are iid with marginal distribution given by F_ϵ, $E(\epsilon_t) = 0$ and $V(\epsilon_t) = 1$.
4. For simplicity, we put $X'_{t.} = (r_{t-1}, r_{t-2}, \cdots, r_{t-H}, w_{t.})'$ a $d = H + K$-dimensional vector and assume that

$$m(X_{t.}) = m_0 + \sum_{a=1}^{d} m_a(X_{ta}), \quad \text{and } h(X_{t.}) = h_0 + \sum_{a=1}^{d} h_a(X_{ta}) \quad (4)$$

The α-quantile for the conditional distribution of r_t given $X_{t.}$, denoted by $q(\alpha|X_{t.})$ is given by

$$q(\alpha|X_{t.}) \equiv F^{-1}(\alpha|X_{t.}) = m(X_{t.}) + (h(X_{t.}))^{1/2} q(\alpha). \qquad (5)$$

- This conditional quantile is the value for returns that is exceeded with probability $1 - \alpha$ given past returns (down to period $t - H$) and other economic or market variables ($w_{t.}$)
- Large (positive) log-returns indicate large changes in prices from periods $t - 1$ to t and by considering α to be sufficiently large we can identify a threshold $q(\alpha|X_{t.})$ that is exceeded only with a small probability α.
- Realizations of r_t that are greater than $q(\alpha|X_{t.})$ are indicative of unusual price variations given the conditioning variables.

Estimation

- First, m and h are estimated by $\hat{m}(X_{t\cdot})$ and $\hat{h}(X_{t\cdot})$ given the sample $\{(r_t, X_{t1}, \cdots, X_{td})\}_{t=1}^{n}$
- Second, standardized residuals $\hat{\varepsilon}_t = \frac{r_t - \hat{m}(X_{t\cdot})}{\hat{h}(X_{t\cdot})^{1/2}}$ are used in conjunction with extreme value theory to estimate $q(\alpha)$.

The exceedances of any random variable (ϵ) over a specified nonstochastic threshhold u, i.e, $Z = \epsilon - u$ can be suitably approximated by a generalized pareto distribution - GPD (with location parameter equal to zero) given by,

$$G(x; \beta, \psi) = 1 - \left(1 + \psi \frac{x}{\beta}\right)^{-1/\psi}, x \in D \qquad (6)$$

where $D = [0, \infty)$ if $\psi \geq 0$ and $D = [0, -\beta/\psi]$ if $\psi < 0$.

Estimation

1. Using $\hat{\varepsilon}_{1:n} \geq \hat{\varepsilon}_{2:n} \geq ... \geq \hat{\varepsilon}_{n:n}$ and obtain $k < n$ excesses over $\hat{\varepsilon}_{k+1:n}$ given by $\{\hat{\varepsilon}_{j:n} - \hat{\varepsilon}_{k+1:n}\}_{j=1}^{k}$
2. It is easy to show that for $\alpha > 1 - k/n$ and estimates $\hat{\beta}$ and $\hat{\psi}$, $q(\alpha)$ can be estimated by,

$$\widehat{q(\alpha)} = \hat{\varepsilon}_{k+1:n} + \frac{\hat{\beta}}{\hat{\psi}} \left(\left(\frac{1-\alpha}{k/n} \right)^{-\hat{\psi}} - 1 \right). \tag{7}$$

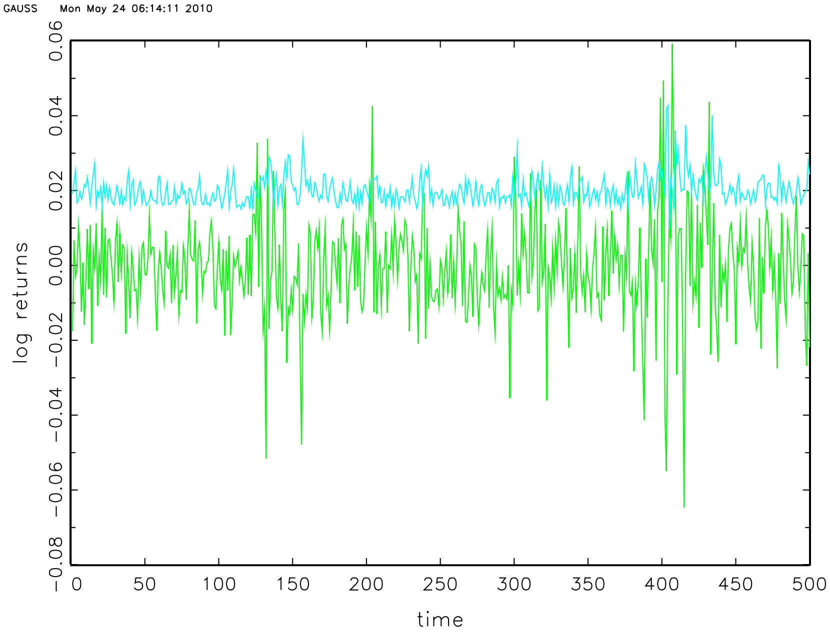
Empirical exercise

For this empirical exercise we use the following model

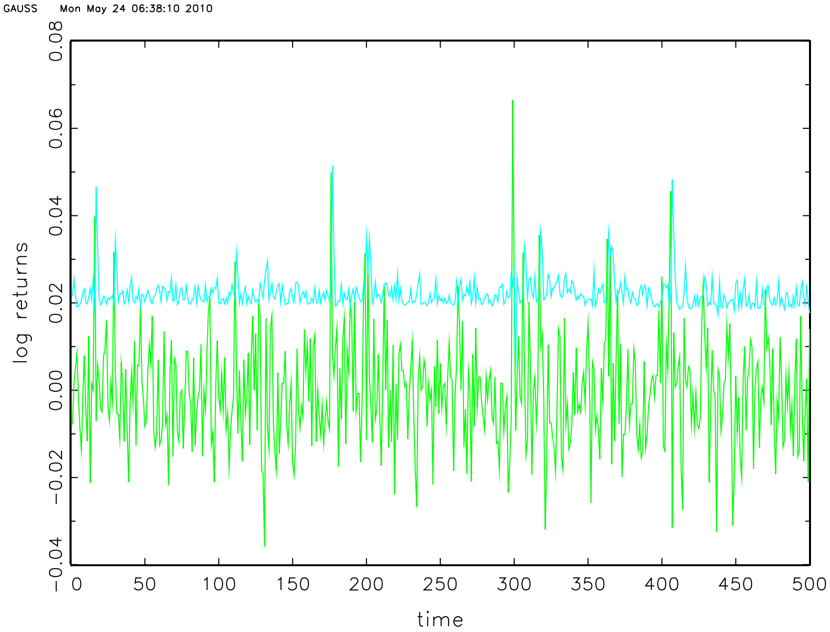
$$r_t = m_0 + m_1(r_{t-1}) + m_2(r_{t-2}) + (h_0 + h_1(r_{t-1}) + h_2(r_{t-2}))^{1/2}\,\varepsilon_t. \tag{8}$$

- For each of the series of log returns we select the first $n = 1000$ realizations (starting January 3, 1994) and forecast the 95% conditional quantile for the log return on the following day. This value is then compared to realized log return.
- This is repeated for the next 500 days with forecasts always based on the previous 1000 daily log returns. We expect to observe 25 returns that exceed the 95% estimated quantile

Soybeans: We expect 25 violations, i.e., values of the returns that exceed the estimated quantiles. The actual number of forecasted violations is 21 and the the p-value is 0.41, significantly larger than 5 percent, therefore providing evidence of the adequacy of the model.


GAUSS Mon May 24 06:14:11 2010
log returns
0.06
0.04
0.02
0.00
−0.02
−0.04
−0.06
−0.08
0
50
100
150
200
250
300
350
400
450
500
time

Hard wheat: We expect 25 violations, i.e., values of the returns that exceed the estimated quantiles. The actual number of forecasted violations is 21 and the the p-value is 0.41, significantly larger than 5 percent, therefore providing evidence of the adequacy of the model.


GAUSS Mon May 24 06:38:10 2010
log returns
time
0.08
0.06
0.04
0.02
0.00
−0.02
−0.04
0
50
100
150
200
250
300
350
400
450
500

Daily results are available at:

- http://www.foodsecurityportal.org/

In particular:

- Policy Analysis Tools