Measuring commodity price volatility and the welfare consequences of eliminating volatility.*

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Abstract

Commodity price volatility in international markets has been used to justify numerous policy interventions, including the need for buffer stocks and counter-cyclical payments. The common measure of volatility, the standard deviation or coefficient of variation, likely overstates the actual variation faced by economic agents. By making a distinction between its predictable and unpredictable components, volatility is found to be low, suggesting that significant welfare gains may be unattainable with policy interventions designed to stabilize prices. The use of the standard deviation implies price volatility as high as 30 per cent for certain grain markets. Removing the predictable components from this measure decreases volatility to between 0.1 per cent and 15.9%. We find little evidence to suggest that volatility is increasing over time for all commodities. The benefits of eliminating low levels of commodity price volatility are small, less than 1% of consumption for the majority of commodities studied.

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Introduction

Many economists have argued that commodity prices are notoriously volatile creating instability in global commodity markets (Blandford (1983) and Heifner and Kinoshita (1994), PREM notes, World Bank, 2000). Empirical support for this argument typically relies upon the standard deviation of price or the coefficient of variation as a measure of volatility. High price volatility has been used to rationalize commodity stabilization programs, such as price supports, buffer stock programs and producer subsidies. More recently, Sarris (2000), Deaton and Laroque (1992) and the International Task Force on Commodity Risk Management in Developing Countries, (2000) have suggested the use of international hedge funds to manage the risk inherent in the volatility of commodity prices. However, as Sarris notes (2000), such programs require a sizable commitment of resources. In the United States, the recent 2002 Farm Security and Rural Investment Act, continues to implement payments to farmers with the view that agriculture is an inherently variable industry.[1]

We suggest that the commodity price volatility measures' magnitude and time variation has not been properly evaluated in the literature. Moreover, Gardner (1977, page 188) suggests that "[volatility] needs to be put into... [a] welfare framework that will permit us to gauge the importance of efficiency and equity impacts of instability and to evaluate the gains and losses that will be incurred by public policy designed to reduce instability". This paper seeks to determine the magnitude of volatility in international commodity markets, to assess if volatility is uniformly increasing, and to contribute to the debate on the welfare effects of volatility by measuring the benefits of eliminating commodity price volatility.

Some of the factors causing a change in the volatility of prices in international commodity markets are listed in Table 1 . The classic microeconomic argument for increasing volatility is due to the mismatch between demand and supply. Ng and Ruge-Murcia (1997) extend the competitive storage model to show that volatility and the persistence of shocks to prices may increase if (i) there are long gestation lags in production with heteroskedastic supply shocks, (ii) forward multiperiod contracts that overlap provide unanticipated additional sources of supply in every period, or (iii) there is a convenience return to holding inventories.[2] To date, the simulation results from these microeconomic models have failed to show volatility as high as

	Macroeconomic arguments	Microeconomic arguments
Increasing volatility	Macroeconomic policy, terms of trade shocks, trade barriers, and exchange rates.	Large demand and supply mismatches and supply shocks such as weather.
Decreasing volatility	Macroeconomic policy, terms of trade shocks, and government interventions in commodity markets to stabilize prices.	Imperfect competition and institutions to hedge price risk (complete markets).

Table 1: Summary of arguements that explain volatility

that which is implied by volatility computed from data. Aside from obvious weather effects, short-term volatility can also increase in the presence of large-scale entry-and-exit into global markets or from the unpredictable behavior of state traders. This argument suggests that the structure of the market and the degree of government intervention can alter volatility over time.[3] The macroeconomic argument typically asserts that increased trade, capital flows and policy shocks which result in changes in the terms of trade and exchange rates affect agricultural commodity prices (Mitchell, 1987). While there is evidence that exchange rates affect commodity prices for *certain* agricultural commodities and *certain* countries, it is still open to debate whether the magnitude of the effects are small or large (see Cho, Sheldon and McCorriston, 2002 for one perspective and Moledina, 2002 for another).

The general objective of this paper is to assess the magnitude of price volatility of selected commodities traded in world markets. We suggest that the predictable and seasonal components of the price process should not be considered part of price volatility. Removing these components leaves the unpredictable or stochastic component. This, we argue is the appropriate measure of price volatility.

We place this volatility measure within a Lucas-like representative agent model to determine the welfare effects of eliminating volatility. If unpredictable volatility is low, the costs of interventions to diversify risks or to stabilize prices may outweigh the benefits of these efforts. Lucas (1987) showed that the gains in welfare that would accrue to agents from eliminating economic fluctuations would be negligible compared to what could be achieved with more growth.

If volatility by our measure is lower than that of Lucas (1987), it would strengthen the case against those proposing interventions to dampen volatility or otherwise provide compensation to farmers. Our objectives are therefore to (1) obtain insight into whether volatility is as high as the standard deviation implies; (2) ascertain if volatility is increasing over time; and to (3) approximate the benefits of removing commodity price volatility.

Our results show that the use of the standard deviation implies price volatility as high as 30 per cent for certain grain markets. Removing the predictable components from this measure decreases the volatility to between 0.1 per cent and 15.9%. Volatility in commodity markets does not seem to be uniformly increasing or decreasing. The apparent absence of a common trend suggests the need to study factors that influence commodity price volatility for each market separately.[4] The welfare consequences of eliminating the low levels of commodity price volatility implied by our results are approximated to be small and in the order of less than 1% of consumption depending on the commodity. We conduct the analysis on both real and nominal series. Interestingly, the results are similar. We present only the results from the analysis of the real series.[5]

In the next section, we discuss the measurement of volatility and review past studies. Then, we outline the methodology used to measure volatility, comparing and contrasting our approach with the literature. This is followed by a discussion of the results. We also address the question of whether volatility is changing over time followed by a discussion on the welfare implications of volatility. A discussion of broader implications concludes the paper.

On how farmers form expectations and measuring volatility

Measures of uncertainty or volatility are intricately tied to how one thinks farmers form expectations. Previous studies have attempted to obtain insights on how farmers form expectations (see for instance, Fisher and Tanner, 1978; Kenyon, 2000; and Eales et. al., 1990). Eales et al. (1990), using a series of expected producer price from 1987 and 1988, found it to be insignificantly different from futures prices but lower in variance than the volatility implied in the futures market. While this evidence does not suggest that farmers exploit *all* of the information available in forming rational expectations, it nevertheless suggests some rationality in basing the expectation of future outcomes on historical evidence. Thus we proceed with the hypothesis that producers are rational in the sense that their expectations of price levels and volatility reflect some form of adaptive or rational expectations: that at any point in time, the producer's expectation of the distribution of future price is a function of past realizations.

Previous studies have typically measured commodity price uncertainty (volatility) using the unconditional standard deviation or the coefficient of variation.[6] Implicit in this measurement is the idea that past realizations of price and volatility have no bearing on current or future realizations. However, it seems reasonable to expect that producers can distinguish regular features in a price process such as seasonal fluctuations and the ex-ante knowledge of the conditional distribution of commodity prices. On the basis of this information, producers generate probabilistic assessments of *predictable* and *unpredictable* elements in a price process. The unconditional standard deviation of course does not distinguish between these two components of a price series, and thus overstates the degree of uncertainty (Dehn, 2000). Like Dehn (2000), in section 2.1 we derive the *unpredictable* component of a price series using an idea from Ramey and Ramey (1995) and propose the variance of the residuals as a measure of volatility.[7]

Blandford (1983) used the unconditional standard deviation of price as a measure of volatility. Using price data for wheat and coarse grains, and computing the standard deviation of changes in price (from the trend) for two ten-year intervals, he concluded that volatility was high. Using the standard deviation as a measure of volatility, he concluded that from 1971-1981, within one standard deviation, the wheat prices fluctuated 27 percent and for coarse grains the prices fluctuated 17.6 percent. Heifner and Kinoshita (1994) used a longer time series, a wider range of commodities and a slightly different measure of volatility – the standard deviation of the *rates of change* in *real* prices. They conclude that most grains and soybeans exhibited price variabilities below 10 percent between the 1950's and sixties, but rose to the 20 percent range during the eighties and nineties.

Sarris (2000) addresses whether cereal price variability has changed more directly. His first step is to determine if the price series are trend or difference stationary. The argument for this is that if the series is trend stationary, then any shock has a temporary effect and if the series is difference stationary, then any shock will have permanent effects. The usual method to determine whether a series is trend or difference stationary is to perform unit root tests.

Unfortunately these test are of low statistical power especially when it comes to series that may contain structural breaks or when the number of observations is small. Sarris (2000) uses a rather short time series: yearly data from 1970-1996. Further, the year of the first oil shock and the collapse of Bretton Woods was identified by Dehn (2000) as a structural break. Sarris does not first-difference the series. Instead he divides the nominal prices by the Consumer Price Index (CPI) and detrends the real maize, wheat and rice prices. He finds very little *inter*-year variability for wheat, maize and rice. Sarris also constructs an index of *intra*-year variability by dividing the unconditional standard deviation of price for the July-June crop year with the average annual price (calculated using monthly price data). This index is then regressed on a constant and linear time trend which turn out to be insignificant. This leads him to conclude that there are no trends in the *intra*-year variability of prices.

Dehn (2000) constructs a single geometrically weighted index of commodity prices in dollars for 113 developing countries following the methodology of Deaton and Miller (1995). Dehn's commodity index contains both agricultural and non-agricultural commodities. Our approach to measuring volatility is patterned after Dehn in that he distinguishes between *predictable* and *unpredictable* components of the price series to construct measures of volatility. Using the constructed commodity price index he derives Generalized Autoregressive Conditional Heteroskedasticity (GARCH) based measures of volatility or uncertainty and finds that: (1) the unconditional standard deviation of prices substantially overestimates the degree of volatility when compared to the GARCH based measures and (2) that the conditional price volatility is relatively lower for producers of food and lowest for producers of non-agricultural products. In the context of our analysis, the finding about food volatility has significance because it suggests that as more countries open their economies to trade, a multitude of export markets for food may mitigate international volatility. For instance, Diao and Roe (2000) found that the effect of the Asian crisis on US agriculture was small because falling exports in Asia were accompanied by increasing exports to other countries such as Mexico. It seems like as countries diversify their export bases, they are less likely to suffer from increasing volatility overall.

The analysis in the next sub-section follows Dehn (2000) with the major departure being that our focus is commodity specific and not based on an aggregated price index. Any linear aggregation of heterogenous prices into an index would confound the subtleties present in each series and perhaps misestimate the volatility (Hanawa-Peterson and Tomek, 2000). The next sub-section outlines our methodology for measuring volatility.

Methodology

To obtain the *predictable* elements of a price process, we test for the presence of unit root using the Phillips-Perron test (see Figure 1 for a flow chart of the methodology). The Phillips-Perron test is robust to the presence of serial correlation in the residuals. If we fail to reject the null hypothesis of unit root, we first difference the price series. Similarly, if there is sufficient evidence to reject the unit-root-hypothesis then the series remains in levels. Because of the low power of this test, especially when we have small samples and structural breaks, Sarris (2000) and Dehn (2000) have opted to first-difference series regardless of whether they reject the null hypothesis of unit-root. Our data set contains monthly prices from 1960 to at least 1999 or 2001 for some series. Thus, we only first difference the price series when we fail to reject the null hypothesis.[8]

Once we have performed the unit root tests and tested for the presence of trend and drift terms, the Box-Jenkins approach along with the Akaike and Schwartz information criteria are applied to the differenced (respectively undifferenced) series in order to select $k_{\max}$, $m_{\max}$, and $n_{\max}$ the time series process that best fits the data. Most generally, for any commodity j in market l we estimate,

$$p_{jt}^{l} = \alpha_0 + \alpha_1 t + \sum_{k=1}^{k_{\max}} c_k p_{j(t-k)}^{l} + \sum_{m=1}^{m_{\max}} \beta_m \varepsilon_{j(t-m)}^{l} + \sum_{n=1}^{n_{\max}} \eta_n D_t^l \ + \varepsilon_{jt}^{l} \forall t = 1, ..., T \qquad (1)$$

where p_{jt}^{l} is the (respectively first difference of) logarithm of commodity price j at time period t for market l and D_t^l is a dummy variable capturing seasonal effects. The α's , c's β's, η's and ε's are coefficient estimates and the error term respectively.[9] The standard error of regression (1) is taken as the measure of unconditional volatility.[10] This approach treats as *predictable* the past values and trends of the series (including seasonal components captured in the dummies) as being accumulated information or knowledge by agents. The principle being applied is that any estimate of uncertainty must purge these known priors.

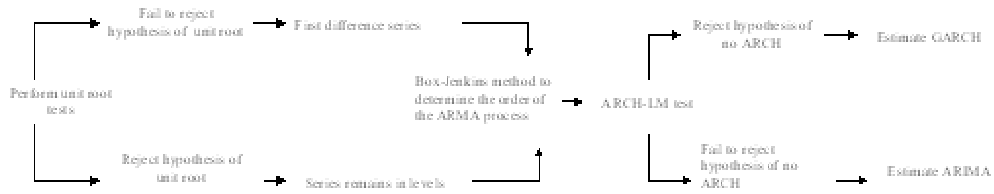

Figure 1: Flowchart of methodology to compute conditional volatility

Cashin, Liang and McDermott (1999) challenge the central assumption of the Box-Jenkins approach - that uncertainty is not time varying. They argue that commodity prices experienced higher volatility in the seventies as a result of the oil crisis. In order to relax the assumption of homoskedasticity on the residuals, we test for its presence using the Autoregressive Conditional Heteroskedasticity-Lagrange Multiplier (ARCH-LM) test suggested by Engle (1982). This test is performed by estimating a regression of the squared residuals on a constant and lagged residuals up to the order q. The ARCH-LM test statistic is the number of observations multiplied by the R^2 from the test regression. It is asymptotically distributed $\chi^2(q)$.

For those commodities that reject the null hypothesis of no ARCH using the ARCH-LM test, we estimate a GARCH model for each market's commodity price. Using a univariate GARCH(1,1) we estimate for each of these j commodities in market l,

$$\begin{aligned} p_t &= \alpha_0 + \alpha_1 t + \sum_{k=1}^{k_{\max}} c_k p^l_{j(t-k)} + \sum_{m=1}^{m_{\max}} \beta_m \varepsilon^l_{j(t-m)} + \sum_{n=1}^{n_{\max}} \eta_n D^l_t + \varepsilon_t \\ \sigma^2_t &= \gamma_0 + \gamma_1 \varepsilon^2_{(t-1)} + \gamma_2 \sigma^2_{(t-1)}, \ \forall t = 1, 2, ..., T \end{aligned} \tag{2}$$

where σ^2_t denotes the variance of ε_t conditional upon information up to period t. The fitted values of σ^2_t are the conditional variance whose square root is our reference measure of uncertainty or volatility.

Hanawa-Peterson and Tomek (2000) show that annual prices of corn and soybeans appear to vary around a constant mean; however, when deflated by the Consumer Price Index (CPI), the deflated prices are autocorrelated around a declining deterministic or stochastic trend. Not only can deflating a series "change the properties of the time-series process but data transformations can, in some cases, generate spurious cycles that do not exist in the original data resulting in

Study	Commodities price series analyzed	Type of price
Blandford (1983)	Wheat and coarse grains	Nominal dollars
Heifner and Kinoshita (1999)	30 agricultural commodities, 4 agricultural commodity indexes	Nominal and real prices from USDA (Major statistical series).
Leon and Soto (1997)	24 most traded commodities including agricultural and non agricultural commodities	Real dollars
Cashin, Liang and McDermott (June, 1999)	Agricultural, non agricultural goods and oil	IMF reference international commodity prices in dollars deflated by manufacturing unit value index.
Cashin, McDermott and Scott (November, 1999)	Agricultural, non agricultural goods and oil	IMF reference international commodity prices in dollars deflated by manufacturing unit value index
Cashin, McDermott and Scott (December, 1999)	Agricultural, non agricultural goods and oil	IMF reference international commodity prices in dollars deflated by manufacturing unit value index
Sarris (2000)	Wheat, maize, and rice	IMF reference international prices in real dollars
Dehn (2000)	The commodity export price of 113 developing countries constructed into an index for each country	Constructed index of CIF prices in dollars
Cashin and McDermott (2001)	Economist's industrial commodity price index	Nominal commodity price index weighted by imports and deflated by CPI

Table 2: Summary of previous studies on commodity price uncertainty

biased estimates of price risk or supply response." (Hanawa-Peterson and Tomek, 2000, page 1) In our work we apply the methodology just described to both real and nominal prices, with this finding in mind. All but one of the studies reviewed above deflated the nominal price series in some manner (see Table 2).

We use monthly price data for selected agricultural commodities from the International Monetary Fund's *International Financial Statistics* CD-ROM (2000). Consumer Price Index (CPI) data used to deflate each commodity price series comes from the Bureau of Labor Statistics.

Results

The results for the real prices are displayed in Tables 3 and 4. With two exceptions to be discussed later, what appears to be the true for real prices is also true for nominal prices except for the fact that the magnitude of volatility found in real prices is of a lower magnitude than nominal prices.[11] Column four reports the standard deviation and column five reports a deviation from a trend line computed using a Hodrick-Prescott Filter. Column six reports the standard error of the residuals from (1). Column seven reports the median fitted values of σ_{jt} from (2) as the conditional standard deviation.[12] We also report the time series model used to estimate the conditional and unconditional standard deviation in the column entitled process.

For all commodities, our measure of conditional volatility is substantially lower than the unconditional volatility. For instance, the volatility implied by the standard deviation for U.S. wheat prices is as high as 39% within a one standard deviation band. Removing the predictable component drops the volatility of that series to 0.2%. This result is consistent with Dehn (2000). The removal of a time-varying predictable component from a series is bound to decrease the variance. What is surprising, however, is the change in ranking of the most volatile commodities.

If we are to use the *standard deviation* as our measure of volatility, from 1957 to 2001, the most volatile commodity is oil, followed by sugar prices (see Table 5). Thirty-four percent of the time since 1957, oil prices increased by 64 percent, while thirty-four percent of the time oil prices decreased by 64 percent. International sugar prices have increased (respectively decreased) by 62 percent, thirty-four percent of the time. The least volatile commodities using the same measure in order of lowest to highest are: tea prices at 31 percent, banana prices, the heavily regulated U.S. and E.E.C. sugar prices and beef prices in the United States. Using this measure of volatility as well as the more sophisticated, deviation from trend, it would be natural to conclude that volatility in agricultural markets is "high".

If we are to use the *unconditional* or *conditional* standard deviation as our measure of volatility, the most volatile commodities in order of highest to lowest are rice prices in Thailand, wheat prices in Argentina and oil (see Table 6). The least volatile commodities using the same measure in order of lowest to highest are: the US sugar price, the price of average medium cotton, US rice prices, and Australian beef prices. Australian beef price volatility is 0.1436 percent while US sugar volatility is as low as .06 percent.

The results are striking. Using the standard deviation as a measure of volatility, commodity markets appear to be volatile, with oil leading the way and coarse grain commodities following close behind. On the other hand, the conditional or unconditional standard deviation suggest that commodity markets are not as volatile as previously expected. Commodities traded in developing countries suffering from long periods of political and economic instability have the greatest volatility. This result is consistent with the finding of Mitchell (1987) who attributes most of the volatility in commodity prices to macroeconomic and political factors.

A close inspection of the conditional volatility shows the distribution for most commodities to be highly leptokurtic - large changes follow even larger changes and small changes follow

Series name: Real Price of	Units	Period	Standard deviation	Deviations from trend†	Unconditional standard deviation	Conditional standard deviation	Process of nominal series	Process of real series
Maize								
Maize United States, Chicago	real dollars per bushel	1965:01-2001:02	0.450	0.133	0.071	0.004	ARIMA(0,1,1) GARCH(1,1)	ARIMA(0,1,4) GARCH(1,1)
Maize US#2 Yellow Gulf	real dollars per bushel	1957:02-2000:02	0.427	0.107	0.046	-	ARIMA(0,1,1) GARCH(1,1)	ARIMA(0,1,1) GARCH(1,1)
Rice								
Rice New Orleans	real dollars per metric tonne	1964:04-2001:02	0.397	0.125	0.049	0.001	ARIMA(2,1,1) GARCH(1,1)	ARIMA(1,1,0) GARCH(1,1)
Rice Thailand, Bangkok	real dollars per metric tonne	1967:01-2000:11	0.519	0.192	0.159	-	ARIMA(1,0,1)	ARIMA(0,1,1)
Rice Thailand, Bangkok (Index)	real dollars per metric tonne	1957:01-2001:02	0.461	0.128	0.054	0.003	ARIMA(0,1,1) GARCH(1,1)	ARIMA(0,1,1) GARCH(1,1)
Rice Myanmar	real dollars per metric tonne	1960:01-1998:12	0.464	0.203	0.162	0.018	ARIMA(1,0,1) GARCH(1,1)	ARIMA(0,1,1) GARCH(1,1)
Wheat								
Wheat Australia	real dollars per bushel	1964:01-1999:10	0.350	0.112	0.044	0.002	ARIMA(0,1,1) GARCH(1,1)	ARIMA(0,1,1) GARCH(1,1)
Wheat Australia (unit value)	real dollars per bushell	1965:05-2001:01	0.392	0.139	0.103	0.006	ARIMA(0,1,1) GARCH(1,1)	ARIMA(0,1,1) GARCH(1,1)
Wheat U.S. Gulf	real dollars per bushel	1960:01-1999:11	0.399	0.106	0.048	0.002	ARIMA(0,1,1) GARCH(1,1)	ARIMA(0,1,1) GARCH(1,1)
Wheat Argentina (unit value)	real dollars per bushel	1960:01-1999:09	0.429	0.129	0.100	-	ARIMA(1,0,1)	ARIMA(1,1,0)
Beef								
Beef Australia	real dollars per pound	1960:01-1999:11	0.365	0.086	0.048	0.001	ARIMA(1,1,1) GARCH(1,1)	ARIMA(1-12,1,1) GARCH(1,1)
Beef United States	real dollars per pound	1964:01-1998:08	0.272	0.080	0.046	0.002	ARIMA(1,1,1) GARCH(1,1)	ARIMA(0,1,0) GARCH(1,1)
Beef Argentina	real dollars per pound	1960:01-1999:09	0.373	0.151	0.109	0.009	ARIMA(1,0,1) GARCH(1,1)	ARIMA(0,1,1) GARCH(1,1)
Coffee								
Coffee Santos (Brazil)	real dollars per pound	1957:01-2001:02	0.521	0.172	0.076	0.003	ARIMA(1,1,1) GARCH(1,1)	ARIMA(1,1,0) GARCH(1,1)
Coffee Central America (index)	real dollars per pound	1957:02-2001:02	0.462	0.163	0.069	0.004	ARIMA(0,1,1) GARCH(1,1)	ARIMA(1,1,0) GARCH(1,1)
Coffee Brazil	real dollars per pound	1964:01-1999:11	0.534	0.204	0.121	0.009	ARIMA(1,1,1)	ARIMA(6,1,0)
Coffee Africa	real dollars per pound	1960:01-1999:11	0.569	0.150	0.063	0.003	ARIMA(0,1,1) GARCH(1,1)	ARIMA(1,1,1) GARCH(1,1)
Bananas								
Bananas Ecuador (FOB US Ports)	real cents per pound	1957:01-2000:02	0.309	0.143	0.120	0.012	ARIMA(1,0,1) GARCH(1,1)	ARIMA(0,1,1-3-4-12) GARCH(1,1)
Sorghum								
Sorghum US #2 Yellow	real dollars per pound	1967:01-2001:02	0.440	0.107	0.055	-	ARIMA(0,1,1)	ARIMA(0,1,1)

Table 3: Estimates of commodity price volatility using IMF price data.

Series name: Real Price of	Units	Period	Standard deviation	Deviations from trend+	Unconditional standard deviation	Conditional standard deviation	Process of nominal series	Process of real series
Soybeans								
Soybeanmeal CIF Rotterdam	real dollars per pound	1957:01 - 2001:02	0.404	0.139	0.063	0.002	ARIMA(0,1,1) GARCH(1,1)	ARIMA(0,1,1) GARCH(1,1)
Soybean oil	real dollars per pound	1957:01 - 2001:02	0.485	0.148	0.060	0.003	ARIMA(0,1,1) GARCH(1,1)	ARIMA(0,1,1) GARCH(1,1)
Soybeans #2 Bulk	real dollars per pound	1957:01 - 2001:02	0.397	0.109	0.054	0.002	ARIMA(0,1,1) GARCH(1,1)	ARIMA(0,1,1) GARCH(1,1)
Sugar								
Sugar US Import price	real dollars per pound	1957:01 - 2001:02	0.294	0.140	0.049	0.001	ARIMA(1,1,1) GARCH(1,1)	ARIMA(4-10,1,0) GARCH(1,1)
Sugar ISA FOB	real dollars per pound	1957:01 - 2001:02	0.627	0.245	0.103	0.009	ARIMA(0,1,1) GARCH(1,1)	ARIMA(0,1,1) GARCH(1,1)
Sugar EEC FOB	real dollars per pound	1957:01 - 2001:02	0.218	0.106	0.060	0.001	ARIMA(0,1,1) GARCH(1,1)	ARIMA(1,1,1) GARCH(1,1)
Sugar Phillipines	real dollars per pound	1962:01 - 2000:09	0.372	0.182	0.142	0.010	ARIMA(1,0,1) GARCH(1,1)	ARIMA(1,1,0) GARCH(1,1)
Sugar Brazil	real dollars per pound	1963:01 - 2000:12	0.581	0.257	0.207	0.032	ARIMA(1,0,1) GARCH(1,1)	ARIMA(0,1,1) GARCH(1,1)
Tea								
Tea United Kingdom	real dollars per pound	1957:01 - 2001:02	0.485	0.132	0.076	0.004	ARIMA(1,0,1) GARCH(1,1)	ARIMA(1-2,1,0) GARCH(1,1)
Tea Sri Lanka	real dollars per pound	1975:01 - 2000:10	0.313	0.127	0.070	0.004	ARIMA(1,0,1) GARCH(1,1)	ARIMA(0,1,0) GARCH(1,1)
Cotton								
Cotton Arr Med	real dollars per pound	1957:01 - 2001:02	0.388	0.119	0.035	0.001	ARIMA(1,1,1) GARCH(1,1)	ARIMA(1,1,1) GARCH(1,1)
Cotton Long Med	real dollars per pound	1968:01 - 1997:03	0.504	0.228	0.182	0.037	ARIMA(0,1,1) GARCH(1,1)	ARIMA(0,1,1) GARCH(1,1)
Cotton Long Stap	real dollars per pound	1968:01 - 1997:03	0.464	0.206	0.167	0.016	ARIMA(1,0,1) GARCH(1,1)	ARIMA(1,1,0) GARCH(1,1)
Cotton Twelve markets	real dollars per pound	1970:01 - 2001:02	0.383	0.145	0.076	-	ARIMA(1,1,1)	ARIMA(1,1,1)
Oil								
Oil Alaska	real dollars per barrell	1957:01 - 1996:04	0.581	0.160	0.090	-	ARIMA(0,1,1)	ARIMA(0,1,1)
Oil Dubai	real dollars per barrell	1957:01 - 2001:02	0.649	0.163	0.090	-	ARIMA(0,1,1)	ARIMA(0,1,1)
Oil Spot Price	real dollars per barrell	1957:01 - 2001:02	0.605	0.153	0.083	-	ARIMA(0,1,1)	ARIMA(0,1,1)
Oil Texas	real dollars per barrell	1983:01 - 2001:02	0.338	0.154	0.077	0.004	ARIMA(1,1,1) GARCH(1,1)	ARIMA(0,1,1) GARCH(1,1)
Oil UK Brent	real dollars per barrell	1957:01 - 2001:02	0.601	0.151	0.082	-	ARIMA(0,1,1)	ARIMA(0,1,1)

Notes
These series are in natural logs.
† Deviation from trend is the standard deviation of a differenced series. The differenced series is computed by taking the difference between a series and its trend estimated with the Hodrick Prescott Filter.

Table 4: Estimates of commodity price volatility using IMF price data continued.

Rank		Series: Real Price of	Standard Deviation
Top quintile	1	Oil Dubai *(3)*	0.649
	2	Sugar ISA FOB *(18)*	0.627
	3	Oil Spot *(5)*	0.605
	4	Oil UK Brent *(6)*	0.601
	5	Sugar Brazil *(11)*	0.581
Bottom quintile	34	Sugar EEC FOB *(36)*	0.218
	35	Beef United States *(33)*	0.272
	36	Sugar US Import price *(38)*	0.294
	37	Bananas Ecuador (FOB US Ports) *(14)*	0.309
	38	Tea Sri Lanka *(23)*	0.313

Numbers in brackets denote rank using the conditional standard deviation

Table 5: Volatility ranking using standard deviation.

Rank		Series: Real Price of	Conditional standard deviation
Top quintile	1	Rice Thailand, Bangkok *(10)*	0.159
	2	Wheat Argentina (unit value) *(20)*	0.100
	3	Oil Dubai *(1)*	0.090
	4	Oil Alaska *(6)*	0.090
	5	Oil Spot Price *(3)*	0.083
Bottom quintile	34	Beef Australia *(31)*	0.001
	35	Rice New Orleans *(25)*	0.001
	36	Sugar EEC FOB *(34)*	0.001
	37	Cotton Av Med *(27)*	0.001
	38	Sugar US Import price *(36)*	0.001

Numbers in brackets denote rank using the standard deviation

Table 6: Volatility ranking using conditional standard deviation.

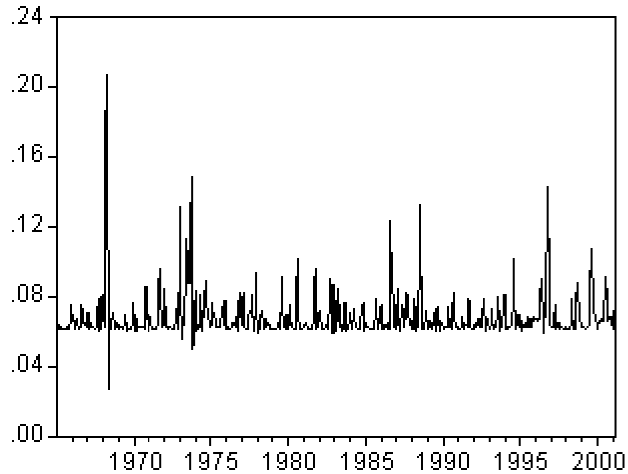

Figure 2: Cond. std. deviation (in percent) of US Maize Chicago

smaller changes (see Figure 2 for an example). Clearly this persistence can affect the cost of commodity price stabilization programs as implied by Cashin, Liang and McDermott (June, 1999). Figure 2 also illustrates the low volatility in Maize prices before the first oil shock in 1973 and greater volatility after the oil shock. An interesting question then is to ascertain if volatility has indeed increased.

Volatility over time

Our goal in this section is to determine if there is a statistically significant linear time trend in the conditional volatility series from equation 2. First, to compare the changes over time, we simply compare the medians of our estimates of time-varying variance in each epoch. The epochs chosen coincide with those of Dehn (2000). Then we reestimate equation 2 with a time trend in the variance equation.

Results

The median volatility over time for all commodity groups does not show consistent increases or decreases (see Table 7). Three commodity groups, namely bananas, coffee, and wheat show increasing volatility, while one, soybeans shows decreasing volatility. We find mixed results for cotton, oil, rice, tea, sugar and beef. These results hold regardless of whether we are looking at real or nominal prices except for the case of U.S. maize prices for #2 yellow and sorghum prices. Both U.S. maize prices for #2 yellow and sorghum prices show increasing volatility if one is to look at real prices but decreasing volatility if one is to look at nominal prices. However, an *F-test* on both the real and nominal maize price as well as sorghum prices suggests that the variance of the real and nominal series are statistically indistinguishable. Hence, while we cannot conclude that volatility is increasing or decreasing for these two sets of commodities, we have reason to believe that deflating the nominal series may have altered the time-series properties of the original series. The issue that one has to bear in mind and what is striking about Table 7 is that, while there is no consistent pattern to the volatility over time, the volatility is consistently low.

The results are broadly consistent when we compare a time trend in the variance equation of 2 (See Table 8) with Table 7 . Again the coefficients on the time trend are of a very low magnitude. There seems to be no uniform pattern to volatility over time, what's more, the lack of significance in some markets suggest that there may be no linear time trend in volatility at all!

Can we conclude that volatility has unambiguously increased? The results presented so far are mixed. Production variations do get transmitted to world prices, as Sarris (2000) and Mitchell (1987) have shown. But their results suggest that these production variations can only account for between 15 to 23 percent of the volatility. Most of the volatility seems to come from unpredictable events such as the oil shock or macroeconomic and political disturbances. Volatility would seem to only increase then if macroeconomic and political disturbances have increased. We are not aware of any study that tries to show increasing macroeconomic or political *instability*.

The welfare effects of volatility

To obtain insights into the approximate welfare benefits from the stabilization of commodity prices with the volatility parameters obtained here, we draw upon a relatively simple approach developed by Lucas (1987). This approach focuses on a single source of uncertainty, with all other markets complete. Others have since employed more complex models. For example,

Real prices	Mean			Median			Standard Deviation		
	1957:01 - 1973:08	1973:09 - 1985:08	1985:09 - 2001:02	1957:01- 1973:08	1973:09 - 1985:08	1985:09 - 2001:02	1957:01 - 1973:08	1973:09 - 1985:08	1985:09 - 2001:02
Bananas (Ecuador FOB US Ports)	0.0100	0.0108	0.0220	0.0097	0.0102	0.0195	0.0032	0.0035	0.0121
Beef Argentina	0.0079	0.0247	0.0244	0.0068	0.0085	0.0175	0.0058	0.0345	0.0239
Beef Australia	0.0033	0.0025	0.0012	0.0019	0.0024	0.0012	0.0028	0.0013	0.0003
Beef United States	0.0019	0.0033	0.0013	0.0020	0.0033	0.0012	0.0005	0.0008	0.0002
Coffee Africa	0.0024	0.0068	0.0077	0.0011	0.0049	0.0053	0.0042	0.0062	0.0072
Coffee Brazil	0.0108	0.0093	0.0277	0.0056	0.0085	0.0153	0.0117	0.0039	0.0414
Coffee Central America (Index)	0.0016	0.0059	0.0096	0.0010	0.0052	0.0073	0.0014	0.0042	0.0082
Coffee Santos Brazil	0.0021	0.0112	0.0248	0.0007	0.0029	0.0141	0.0047	0.0217	0.0354
Cotton Average Medium	0.0005	0.0018	0.0022	0.0003	0.0013	0.0017	0.0006	0.0014	0.0015
Cotton Long Medium	0.0380	0.0402	0.0493	0.0369	0.0369	0.0369	0.0044	0.0132	0.0742
Cotton Long Staple	0.0122	0.0360	0.0791	0.0091	0.0169	0.0217	0.0099	0.0603	0.1380
Maize US #2 Yellow Gulf *				0.0331	0.0515	0.0526			
Maize US Chicago	0.0050	0.0045	0.0047	0.0039	0.0039	0.0041	0.0048	0.0017	0.0020
Oil Alaska *				0.0092	0.1297	0.0932			
Oil Dubai *				0.0222	0.1288	0.0901			
Oil Spot price *				0.0144	0.1194	0.0861			
Oil Texas	-	0.0015	0.0079	-	0.0014	0.0049	-	0.0005	0.0089
Oil U.K. Brent *				0.0861	0.1078	0.0922			
Rice Myanmar	0.0120	0.0603	0.0726	0.0086	0.0264	0.0427	0.0106	0.1179	0.0849
Rice New Orleans	0.0010	0.0046	0.0020	0.0007	0.0045	0.0013	0.0010	0.0027	0.0016
Rice Thai Index	0.0027	0.0026	0.0033	0.0023	0.0023	0.0028	0.0012	0.0010	0.0018
Rice Thailand Bangkok *				0.1053	0.0705	0.2066	-		
Sorghum U.S. #2 Yellow *				0.0461	0.0560	0.0575			
Soybean meal CIF Rotterdam	0.0024	0.0076	0.0028	0.0013	0.0038	0.0024	0.0034	0.0118	0.0014
Soybean oil	0.0030	0.0053	0.0031	0.0025	0.0048	0.0025	0.0015	0.0029	0.0015
Soybeans #2 Bulk	0.0022	0.0047	0.0023	0.0013	0.0032	0.0018	0.0044	0.0051	0.0014
Sugar Brazil	0.0566	0.0349	0.0471	0.0488	0.0282	0.0295	0.0381	0.0212	0.0408
Sugar EEC	0.0007	0.0071	0.0013	0.0004	0.0043	0.0013	0.0007	0.0065	0.0004
Sugar ISA FOB	0.0113	0.0146	0.0086	0.0085	0.0119	0.0074	0.0079	0.0083	0.0050
Sugar Phillipines	0.0085	0.0577	0.0162	0.0040	0.0418	0.0003	0.0103	0.0433	0.0258
Sugar United States	0.0031	0.0113	0.0006	0.0007	0.0049	0.0003	0.0092	0.0152	0.0009
Tea Sri Lanka	-	0.0075	0.0038	-	0.0042	0.0035	-	0.0117	0.0013
Tea United Kingdom	0.0057	0.0071	0.0056	0.0041	0.0036	0.0045	0.0042	0.0101	0.0030
Wheat Argentina	0.0071	0.0414	0.0307	0.0032	0.0039	0.0052	0.0113	0.2588	0.1175
Wheat Australia	0.0009	0.0032	0.0024	0.0005	0.0019	0.0022	0.0013	0.0029	0.0009
Wheat Australia (unit value)	0.0094	0.1756	0.0135	0.0045	0.0049	0.0096	0.0107	0.0342	0.0135
Wheat U.S. Gulf	0.0017	0.0039	0.0026	0.0012	0.0021	0.0024	0.0011	0.0049	0.0008

* Unconditional standard deviation

Table 7: Descriptive statistics: Volatility and persistence over time.

Realprice volatility	Time trend	
	Coefficient	Std. Error
Bananas (Ecuador FOB US Ports)	0.0000021	0.0000016
Beef Argentina	0.0000017 ***	0.0000004
Beef Australia	0.0000000	0.0000001
Beef United States	-0.0000024 ***	0.0000000
Coffee Africa	0.0000014 ***	0.0000002
Coffee Brazil	0.0000007	0.0000009
Coffee Central America (Index)	0.0000019 ***	0.0000004
Coffee Santos Brazil	0.0000027 ***	0.0000003
Cotton Average Medium	0.0000003 **	0.0000001
Cotton Long Medium	0.0001070 ***	0.0000107
Cotton Long Staple	0.0000585 ***	0.0000086
Maize US #2 Yellow Gulf †	0.0000008	0.0000066
Maize US Chicago	-0.0000061 ***	0.0000000
Oil Alaska †	-0.0000012	0.0000152
Oil Dubai †	-0.0000011	0.0000128
Oil Spot price †	-0.0000013	0.0000118
Oil Texas	0.0000068	0.0000042
Oil U.K. Brent †	-0.0000016	0.0000116
Rice Myanmar	0.0000140 ***	0.0000020
Rice New Orleans	0.0000003 ***	0.0000001
Rice Thai Index	-0.0000034 ***	0.0000000
Rice Thailand Bangkok †	-0.0002552	0.0002916
Sorghum U.S. #2 Yellow †	-0.0000007	0.0000079
Soybean meal CIF Rotterdam	0.0000013 ***	0.0000004
Soybean oil	-0.0000001	0.0000002
Soybeans #2 Bulk	-0.0000035 ***	0.0000000
Sugar Brazil	-0.0000565 ***	0.0000000
Sugar EEC	-0.0000043 ***	0.0000000
Sugar ISA FOB	-0.0000008	0.0000005
Sugar Phillipines	0.0000003 ***	0.0000003
Sugar United States	-0.0000045 ***	0.0000000
Tea Sri Lanka	-0.0000095 ***	0.0000000
Tea United Kingdom	-0.0000069 ***	0.0000000
Wheat Argentina	0.0000036 ***	0.0000008
Wheat Australia	0.0000005 ***	0.0000002
Wheat Australia (unit value)	0.0000011 ***	0.0000003
Wheat U.S. Gulf	0.0000000	0.0000001

Notes
† Unconditional standard deviation
*** Indicates 99% level of significance
** Indicates 95% level of significance

Table 8: Coeff. est. of the time trend in conditional variance equation

Atketson and Phelan (1994) measured the welfare costs of fluctuations for heterogenous agents in the absence of an imperfect insurance market. More recently, Otrock (1999) employed a complete business cycle model in which consumption is endogenous. Otrock concludes from his work and others in this literature that the welfare cost of volatility is not much larger than the Lucas estimate which was obtained by a far more direct method.[13]

Hence, we apply the Lucas method to our estimate of median maize price volatility in the Gulf Port from the period 1985-2001. Table 7 shows the point estimate to be 0.0526 percent. Let the demand for maize be

$$\ln y = \ln a - b \ln p \tag{3}$$

where y is output and p is the price of maize assumed to be a random variable with mean μ_p and variance σ_p^2. Here a and b are coefficients and b can be interpreted as the price elasticity of demand. The variance of y is then $b^2\sigma_p^2$. If the price elasticity of demand is less than unit elastic for agricultural goods, which it is, a one percent increase in the variance of Maize prices, σ_p^2, could increase output variance σ_y^2 by less than one percent.[14] To keep our argument simple, suppose instead that the median volatility of maize prices translated into a standard deviation of maize output of the same magnitude, although we could argue that the volatility in output would be lower especially given the low price elasticity of demand for cereals (See Regmi, Deepak et al., 2001).

Now assume a representative consumer, endowed with a stochastic consumption stream who is risk averse. The consumption stream is stochastic because prices are stochastic. Hence, as in Lucas (1987), the stochastic consumption stream is,

$$c_t = Ae^{\mu t}e^{-(1/2)\sigma_y^2}\varepsilon_t,$$

where $\log(\varepsilon_t)$ is a normally distributed random variable with mean 0 and variance, σ_y^2. Preferences over such consumption paths are assumed to be,

$$E\left\{\sum_{t=0}^{\infty}\left(\frac{1}{1+\rho}\right)^t \frac{c_t^{1-\gamma}}{1-\gamma}\right\},$$

where ρ is a discount rate, γ is the coefficient of risk aversion, and the expectation is taken with respect to the common distribution of shocks, ε_0, ε_1, and so on. This risk averse consumer prefers a deterministic consumption stream over a risky stream with the same mean. Define λ as the amount that the consumer must be compensated to be indifferent between the risky and deterministic stream. Lucas obtains,

$$\lambda \cong \frac{1}{2}\gamma\sigma_y^2$$

where "the compensation parameter λ - the welfare gain from eliminating consumption risk - depends naturally enough, on the amount of risk that is present, σ_y^2 and the aversion people have for risk, γ." (Lucas, 2003, page 4). Using our estimates of volatility through (3) and estimates of the parameter, γ that run from 1 to 4, we can obtain an estimate of the benefits of eliminating commodity price volatility. The results are displayed in Table 9 column 7 for $\gamma = 4$. In the presence of perfect insurance markets in developed countries, the benefits of eliminating such low levels of volatility are negligible. For developing countries the benefits of eliminating volatility are likely higher but not by a large order of magnitude. Furthermore, since the source of the volatility comes more from macroeconomic and political factors, reduced volatility may come more from stable macroeconomic policies and a stable political environment, rather than a commodity price stabilization program. The results point to the need of comparing the costs and benefits of commodity price stabilization programs to those programs that seek to improve productivity.

Conclusions

If the appropriate measure of commodity price uncertainty is the conditional standard deviation, volatility in commodity markets is much lower than previous estimates. We have also shown that the measure used challenges the conventional wisdom on the ranking of the most volatile commodities. If we were to use the standard deviation as our measure of volatility, oil markets are the most volatile of the markets studied. Using the *conditional* standard deviation as a measure of volatility, the price of rice in Thailand is the most volatile. This change in ranking is most likely attributed to the fact that most of the volatility in prices are due to macroeconomic and political factors as shown by Mitchell (1987). We also reaffirm Dehn's (2000) conclusion that from the perspective of a country as a whole, commodity exporters that export a diversity

Series name: Conditional standard deviation of real	Median Variance			Welfare Stabilization increases consumption by		
	1957:01 - 1973:08	1973:09 - 1985:08	1985:09 - 2001:02	1957:01 - 1973:08	1973:09 - 1985:08	1985:09 - 2001:02
Bananas (Ecuador FOB US Ports)	0.0001	0.0001	0.0004	0.0189%	0.0209%	0.0763%
Beef Argentina	0.0000	0.0001	0.0003	0.0091%	0.0143%	0.0615%
Beef Australia	0.0000	0.0000	0.0000	0.0007%	0.0011%	0.0003%
Beef United States	0.0000	0.0000	0.0000	0.0008%	0.0021%	0.0003%
Coffee Africa	0.0000	0.0000	0.0000	0.0002%	0.0048%	0.0057%
Coffee Brazil †	0.0000	0.0001	0.0002	0.0063%	0.0144%	0.0468%
Coffee Central America (Index)	0.0000	0.0000	0.0001	0.0002%	0.0053%	0.0106%
Coffee Santos Brazil	0.0000	0.0000	0.0002	0.0001%	0.0017%	0.0398%
Cotton Average Medium	0.0000	0.0000	0.0000	0.0000%	0.0004%	0.0006%
Cotton Long Medium	0.0014	0.0014	0.0014	0.2724%	0.2720%	0.2719%
Cotton Long Staple	0.0001	0.0003	0.0005	0.0166%	0.0574%	0.0944%
Maize US #2 Yellow Gulf †	0.0011	0.0027	0.0028	0.2194%	0.5314%	0.5534%
Maize US Chicago	0.0000	0.0000	0.0000	0.0030%	0.0030%	0.0033%
Oil Alaska †	0.0001	0.0168	0.0087	0.0171%	3.3657%	1.7390%
Oil Dubai †	0.0005	0.0166	0.0081	0.0984%	3.3167%	1.6232%
Oil Spot price †	0.0002	0.0143	0.0074	0.0413%	2.8523%	1.4829%
Oil Texas	-	0.0000	0.0000	-	0.0004%	0.0048%
Oil U.K. Brent †	0.0074	0.0116	0.0085	1.4829%	2.3243%	1.7015%
Rice Myanmar	0.0001	0.0007	0.0018	0.0148%	0.1389%	0.3652%
Rice New Orleans	0.0000	0.0000	0.0000	0.0001%	0.0041%	0.0004%
Rice Thai Index	0.0000	0.0000	0.0000	0.0011%	0.0011%	0.0016%
Rice Thailand Bangkok †	0.0111	0.0050	0.0427	2.2186%	0.9952%	8.5368%
Sorghum U.S. #2 Yellow †	0.0021	0.0031	0.0033	0.4257%	0.6267%	0.6613%
Soybean meal CIF Rotterdam	0.0000	0.0000	0.0000	0.0003%	0.0029%	0.0012%
Soybean oil	0.0000	0.0000	0.0000	0.0013%	0.0047%	0.0012%
Soybeans #2 Bulk	0.0000	0.0000	0.0000	0.0003%	0.0021%	0.0006%
Sugar Brazil	0.0024	0.0008	0.0009	0.4756%	0.1590%	0.1739%
Sugar EEC	0.0000	0.0000	0.0000	0.0000%	0.0036%	0.0004%
Sugar ISA FOB	0.0001	0.0001	0.0001	0.0146%	0.0284%	0.0111%
Sugar Phillipines	0.0000	0.0018	0.0000	0.0031%	0.3501%	0.0000%
Sugar United States	0.0000	0.0000	0.0000	0.0001%	0.0049%	0.0000%
Tea Sri Lanka	-	0.0000	0.0000	-	0.0035%	0.0024%
Tea United Kingdom	0.0000	0.0000	0.0000	0.0034%	0.0026%	0.0040%
Wheat Argentina	0.0000	0.0000	0.0000	0.0020%	0.0030%	0.0055%
Wheat Australia	0.0000	0.0000	0.0000	0.0000%	0.0007%	0.0009%
Wheat Australia (unit value)	0.0000	0.0000	0.0001	0.0041%	0.0048%	0.0186%
Wheat U.S. Gulf	0.0000	0.0000	0.0000	0.0003%	0.0009%	0.0012%

† Unconditional standard deviation

Table 9: Welfare effects of volatility using conditional variance.

of goods are likely to suffer from less volatility on average because they can hedge their exposure to the risk manifested in commodity price volatility. The main result from our work, however, is that the magnitude of the volatility in commodity markets is small.

A second result is that median volatility for commodity groups over time shows no consistent increase or decrease. Evidence for some increase in volatility can be found in the prices of bananas, coffee, wheat, while soybeans shows decreasing volatility. The remaining commodities, cotton, maize, rice, tea, sugar and beef, show little change. Again, the main result is that while there is no consistent pattern to volatility over time, the magnitude of the volatility continues to be small.

The finding that volatility is low, an approximate welfare calculation using a representative consumer framework as developed by Lucas (1987) and our point estimates lead us to conclude that the benefit of eliminating such fluctuations are on average substantially less than 1 percent of consumption for the overwhelming majority of commodities. Couple this finding with the literature that finds that commodity price stabilization programs are costly and one would conclude that resources committed to eliminating volatility would perhaps be better spent on improving productivity growth in agriculture or even more importantly, improving the poor's access to basic food.[15] Our results further suggest that the reform in U.S. agricultural programs which began in 1986, that took the U.S. government out of holding agricultural commodities, was the right change in policy. It seems difficult to justify policy interventions in agriculture based solely on price volatility.

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Notes

[1] In a report to the President and Congress that was written to inform the 2002 Farm Act, the Comission reports that "support for US agriculture has been sustained, in large part, because of the recognition that production agriculture is an inherently volatile industry." ("Directions for future farm policy: The role of government in support of production agriculture", Page xiv).

[2] Convenience return is defined as a situation when the marginal revenue from holding inventories is greater than the marginal cost.

[3] The existence of imperfect competition allows firms to engage in price competition. In order to preserve market share, firms may choose not to pass-through changes in their marginal costs or other sources of uncertainty to consumer prices. Volatility may also decrease with the growth of market or non-market instruments to hedge price risk.

[4] A modest, but by no means comprehensive analysis was undertaken but not reported here.

[5] Please contact the authors for an analysis of the nominal series.

[6] See Offutt and Blandford (1981) for a list of different single variable measures based on the standard deviation.

[7] For a more eloquent discussion of this issue see Dehn (2000, page 4). In his discussion he delves deeper into the relationship between permanent (respectively transitory) innovations in the price process and predictable (respectively unpredictable) uncertainty.

[8] One might argue if more annual data rather than more frequent observations increase the power of the unit root tests. This is an open question but beyond the scope of this paper.

[9] For notational brevity from here on we supress l and j.

[10] Strictly speaking, this is a conditional volatility because it is computed on past information present in the series. However, because we want to distinguish this measure of volatility from one where the volatility is time-varying, we hope the reader will forgive our lack of precision.

[11] Please contact the authors for results related to nominal prices.

[12] It is important to note that the *median conditional volatility* reported in column seven is calculated simply in order to compare the conditional volatility with unconditional volatility measures. The conditional volatility varies over time.

[13] Assuming a time-separable constant relative risk aversion utility function Lucas estimates that a representative agent would be willing to sacrifice 0.1% of her consumption in order to be ensured a stable consumption stream.

[14] Regmi, Deepak et al. (2001) find price elasticities of demand for cereals from 0.6 for low income countries to 0.2 for high income countries.

[15] See Cashin et al. (1999, 2000) and Deaton and Laroque (1996) for differering views on the costs of commodity stabilization programs.