LONG RUN TRENDS AND FLUCTUATIONS IN COTTON PRICES

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Abstract

Real cotton prices have fallen significantly since 1900, but statistical verification of the presence of a long-run downward trend has proven elusive. Cotton price volatility has varied widely over the last 226 years, with volatility correlated with macroeconomic instability, although its period of greatest instability—during the U.S. Civil War—was primarily driven by cotton-specific trade and production disruptions. One of the periods with the largest cotton price volatility since 1792 occurred over 2009-12, and was in part a consequence of nearly unprecedented macroeconomic instability and. in part due to factors specific to cotton markets at the time. Cotton price volatility over the next decade is likely to be greater than the volatility experienced during the last 2 years.

Introduction

Forecasting the long run direction of cotton prices is addressed in this paper through literature review. The statistical problems involved in the analysis are complex enough that our individual findings can be regarded as tentative. Trends in USDA's published long run real cotton price forecasts are clearly downward trending, but the shifts from year to year in the average mean along which these trends are realized is used as evidence of the importance of understanding the sources and impacts of volatility.

Volatility of individual prices over time is measured, and periods of general price volatility are identified through cross-sectional aggregation of volatility measures across sets of commodity prices. The frequent association of periods of high volatility in cotton prices with periods of general price volatility, and the association in turn of these generally volatile periods with macroeconomic uncertainty and regime shifts are used to draw implications about the roots of the 2010-12 price spike and about the future of cotton price volatility.

Materials and Methods

Volatility Measures

In this paper, individual commodity (n) price series volatility at various times (t) is measured 3 ways, and general commodity price volatility is measured using 2 cross-sectional summarizations of individual price volatility. The measures of individual volatility employed here are 1) the conditional variance ($h_{n,t}$) from a general autoregressive conditional heteroscedasticity (GARCH) model of the price series, 2) the sample standard deviation ($\hat{\delta}_{n\ t}$) for rolling sub-samples centered on t of the log first-differences of the price, and 3) the magnitude of the year-to-year price change at times when that change falls in the 90th percentile of the logged sample's absolute year-to-year changes ($\lambda_{n\ t}$). General commodity volatility is measured as 1) the median at each time (t) of a database's N price series' sub-sample standard deviations (Ψ_{1t}), and 2) the proportion at time t of the N individual commodity prices in a database that have absolute year-to-year changes in the 90th percentile (Ψ_{2t}).

All three individual volatility measures are related to the theoretical properties of commodity price series. If price is represented by y_t, and y_t is stationary, with an autoregressive data generating process (DGP) of order p_m, then:

$$y_t = \delta + \sum_{i=1}^{p_m} \rho_i y_{t-i} + \epsilon_t$$
$$\epsilon_t \sim IID(O, \sigma^2)$$

While the unconditional mean of y_t in this model is constant at $\frac{\delta}{1-\sum_{i=1}^{p}\rho_i}$, the conditional mean—conditional on the information set (Ω_{t-1}) of past realizations of y_t— (E(y_t| Ω_{t-1}) varies over time. The variance of y_t is also fixed, both the unconditional variance, and the conditional variance, the latter of which equals σ_t^2. Engle (1982) and Bollerslev (1986) extended this model to account for the apparent clustering of periods of higher and lower volatility in many financial time series. In this general autoregressive conditional heteroscedasticity (GARCH) model, the unconditional variance again remains constant, but the conditional variance is now a function of the information set (Ω_{t-1}). In the GARCH model,

$$y_t = \delta + \sum_{i=1}^{p_m} \rho_i y_{t-i} + \mu_t$$

$$\mu_t = \epsilon_t \left(\alpha_0 + \sum_{i=1}^{q} \alpha_i \mu_{t-i}^2 + \sum_{j=1}^{p_v} \beta_i h_{t-j} \right)^{1/2}$$

$$\epsilon_t \sim NID(O, 1)$$

In the GARCH(p_v, q) model, the conditional variance is,

$$h_t = \alpha_0 + \sum_{i=1}^{q} \alpha_i \mu_{t-i}^2 + \sum_{j=1}^{p_v} \beta_i h_{t-j}$$

This approach has the benefit of consistently filtering out the impact of the changing conditional mean to produce sound estimates of the volatility. It has the cost of computational complexity and demanding data requirements. The impact of possible errors in specifying and estimating the model must be balanced against the benefits. As an alternative, an approximation of the conditional standard error can be estimated from y_t. A t-centered, rolling-sample, standard deviation ($\hat{\delta}_{n,\,t}$) of the log differences for sub-sets of the T time periods in the dataset is useful when GARCH modeling is not appropriate.

The most indirect measure of volatility ($\lambda_{n\ t}$) is based on the range of a price over a 12-month period, measured as the difference between the price at the end of the period and at the beginning, focusing on the extreme absolute values of these differences in set T dates. This approach is only useful for detecting and measuring episodes of high volatility, and is motivated by the theory of the competitive storage model (Gustofsen, 1958; Cafiero, et al., 2011). With storage, variations in stockholding help smooth consumption across periods with supply and demand shocks, while deviation of prices from long-run expected levels and the marginal cost of production alter the incentives to hold and release stocks, as well as consumption and production. In this model, large deviations from smoothly evolving price trends are inevitably self-correcting (Chen, et al., 2014; Wang and Tomek, 2007), and the large changes ($\lambda_{n\ t}$) will correlate with underlying volatility.

Data

Annual and monthly databases of U.S. commodity prices were assembled, starting from 1791, covering essentially the entire period prices quoted in U.S. dollars are available. A monthly database of U.S. cotton prices covering 1791:12 to 2017:12 was assembled, centered on current USDA/AMS 7-market U.S. average spot quotations for base quality (color 41, leaf 4, staple 34). Consistent with commercial practice and market standards prevailing in different time periods, and the grade of quoted prices and the transaction location of the quotes varies in the earlier years of the dataset. Grading standards, the average characteristics of the fiber produced in the United States and demanded by textile mills around the world has changed substantially over the last 225 years (Quark, 2013), and the first 115 years of our dataset is for New York spot prices of 7/8-inch staple cotton. Overlapping data from various sources (USDA/AMS, 2017; USDA/ERS, 1974; USDA/BAE, 1951; Cole, 1938) are used to derive adjustment factors to maintain a price series that consistently reflects prevailing commercial standards over time, and smoothly transitions between the characteristics of newer and older series of data.

Annual data were also assembled for 12 commodities over 1792-2016: cotton, coffee, copper, sugar, corn, rice, wheat, coal, wool (1850-), petroleum (1859-), rubber (1869-), rayon (1921-), and polyester (1952-). To the greatest extent possible, these prices are for transactions within the United States, with the entire 18th and 19th centuries' data representing U.S.-specific quotes. Since the mid-20th century, as the relative global significance of U.S. commodity production and consumption has declined, market activity has in some cases shifted to non-U.S. locations. As described for the monthly cotton prices above, consistent price series have been developed for each commodity, albeit at a lower frequency than for cotton alone (details available from authors upon request). This dataset was used to detect periods of general commodity volatility over 1792-2016 by calculating the median sample (5-year, centered) standard deviations of the dataset's prices ($\sigma_{n,t}$), the proportion of prices with 90th percentile changes each year (Ψ_{2t}), and the median of the dataset's $\sigma_{n,t}$ (Ψ_{1t})

The World Bank's public monthly commodity price database (World Bank, 2017) for 38 commodities was used to calculate a monthly version of Ψ_{2t} for 1961-2016. In this case, the price changes calculated with respect to 12 months earlier. This allows a finer level of temporal detail than possible with the database of calendar year averages used above, and has a larger number of commodities. The variety of datasets and volatility measures used permits corroboration of observed patterns.

Results

Results of λ_t Calculation

Figures 1 and 2 visually summarize the apparent trends and the occurrences of months of extreme change for cotton prices (λ_t) over the last 226 years, 1791-2017. The apparent downward trend observed in Figure 2 will be addressed in the Discussion portion of this section, after reviewing the volatility results.

In the monthly data used to examine volatility, months with either extreme increases or decreases (λ_t) are largely found to be grouped in episodes of sequential realizations, and we define three types of these episodes. One type is an extreme change in a given direction that is followed within about 12 months sometimes by another episode in the same direction, but more frequently by an episode with the opposite sign—we group these sets of adjacent episodes and term the group a cycle. Thus, one type of episodes are those at the start of a cycle, which occur after a relatively long period following the end of the last preceding cycle, the median gap being 44 months over the 225-year sample. Another type of episode follows these cycle-initiating episodes with a median gap of 10 months, a span of time consistent with the annual production cycle of cotton and other temperate-zone row crops. The cycle-initiating episodes can be broken into two types: those significant enough to trigger subsequent offsetting episodes and those that are not. Table 1 lists all the cycles observed over 1791-2017, and 6 cycles with extreme changes in only one direction are listed. While the median peak absolute value of the price changes in these truncated cycles is only moderately below the median of the initiating-episodes of the 12 bi-directional peacetime cycles listed (48 percent versus 54 percent), they do represent less significant economic disruptions. The longer, bi-directional cycles include periods with macroeconomic shocks in both directions, and/or repeated macroeconomic shocks. Peacetime cycles are shaded grey in Figures 1 and 2 while periods of military conflict are indicated with cross-hatched bars.

The largest disruption to date was of course that associated with the U.S. Civil War, initiated by the prospects for, and subsequent realization of, cotton trade embargos and sharply reduced U.S. cotton production. While the peak price levels of this cycle have been truncated from Figure 1, August 1861 saw the initiation of 22 sequential months in which prices were more than 45.3 percent above those of 12 months earlier. In addition to remaining above the 45.3-percent threshold of the 90th percentile of all such absolute changes in the 225-year sample for the longest stretch of any episode, prices during this episode were as much as λ_t=115 percent higher than 12 months earlier in real terms, the largest such difference observed. April 1865 saw the initiation of an 11-month string of extreme declines—as much as λ_t=133 percent down relative to 12 months earlier, the largest absolute change in this study's sample—clearly representing the operation of an offsetting change in expectations and activity compared with 1861. Given the scale of the disruption to U.S. agriculture, government debt, and money supply, we have grouped the extreme price changes that occurred as late as 1872 with the Civil War cycle in Table 1.

Most peace-time cotton price cycles were much shorter and less severe, and a majority of these cycles clearly coincide with the dates of significant events in the U.S. and/or global macro-economy. While 19th century business cycles are different in many important respects from business cycles as understood in the modern economy—leading to questions about the appropriate measurement of their extent and duration (Davis and Weidenmier, 2016; Romer, 1986; Huffman and Lothian, 1984)—the historical record is clear that significant financial panics occurred in the U.S. and/or the UK in 1819, 1826, 1837, and 1848. While the 1819 event is best understood as part of the transition between war-time and peacetime government finance, the other years are associated with both peace-time economic downturns and downward cotton price extremes. This is evidence of the importance of macroeconomic stability to the level of commodity price volatility.

The largest absolute peace-time price change—and the second largest change in either war or peace—was the -122-percent change realized in April 1922. Friedman and Schwartz (1965) have highlighted how this period represented one of the most extreme declines in money supply and wholesale prices observed in their study of the 1865-1965 U.S. monetary system, and have cite missteps by the relatively new Federal Reserve System in the genesis of this shock. Analogous to the case of the negative 1819 episode, we have included the early 1920s in Table 1 as part of the cycle started by the initiation of World War I, since again it followed from the efforts of combatants that had suspended the specie convertibility of their currencies to later drive down domestic prices.

Two cycles bear particular note, those starting, respectively, in 1973 and 2009. The importance of these cycles stems from their being the largest most-recent cycles—the 2 largest cycles in a time period similar the foreseeable future—and from an aspect of the timing of the start of the 1973 cycle. This cycle started 376 months following the end of the previous cycle (compared with a 44-month median gap for all cycles). The absence of extreme price changes during any month in 1943-1972 is an achievement never approached even remotely during any comparable stretch of time, excepting the end of the 19th century. Between 1872 and 1900, 336 months occurred with no extreme cotton price changes, despite the occurrence of some major economic shocks, including panics in 1873 and 1893. Similarly, the panic 1907 was not associated with an extreme change in cotton prices.

Results of Ψ_{2t} Calculations

Analysis of the monthly World Bank (WB) commodity price data provides a 1960-2017 set of monthly values for Ψ_{2t}. Trends in the monthly Ψ_{2t}—and differentiating between the negative and positive components of the calculated share—also supports the linkage of extreme cotton price changes to macroeconomic disruption. Figure 3 shows the full 1961-2017 series of monthly cotton price changes from 12 months earlier in the WB database, and the monthly level of Ψ_{2t}—the share of the database realizing extreme changes—broken out into increasing and decreasing extreme changes. The pre-1971 lack of price volatility is apparent in both λ_t and Ψ_{2t}, and the pair of maximum values for each measure largely coincide with 1973 and the period around 2010. In 1973-75, the alignment of the cotton and general commodity price volatility is nearly perfect, and while the 2010 cotton price shock is not so clearly parallel with general price trends, the broader 2009-12 cycle shows greater alignment with Ψ_{2t} than general press narratives of the 2010 price spike typically acknowledge.

The two extremes for Ψ_{2t} over 1961-2017—the only 2 times $\Psi_{2t} \geq 50\%$—are 1973 and 2009. In 2009, virtually all the price extremes driving Ψ_{2t} to the 58% sample maximum in March 2009 were negative, as was the cotton price change that same month driving λ_t also to 58%. While the sharp upward spike in cotton price in 2010-11 (Feb. 2011 λ_t = 94 % at its peak) was not matched by a general realization of extreme price changes, in Figure 3 one can see that both 2010 and 2011both realized values for Ψ_{2t} well above the sample median of 8 percent, suggesting a more drawn out, but still significant period of broader volatility.

When we switch to Ψ_{2t} calculations based on calendar year annual averages (Figure 4) we see the same patterns of general commodity price volatility as when analyzing the monthly WB data, and we can extend the analysis back to the end of the 18th century. Aggregating price data from a monthly frequency into January-December averages alters some of the observed year-to-year relationships, and the commodity compositions of the two databases are also different. One consequence of these differences is that with the annually-based data the 2011 value of Ψ_{2t} becomes among the highest of the 226-year sample. By the same token, the 2009 shock apparent in the monthly calculations was too brief to be directly realized in the annual data, but the important information that these two datasets reveal together is that the 2009-11 period was one of general commodity price volatility. The relative positions of the upward and downward values for λ_t are also altered with the transition to annual data: the absolute value of the 2012 decline exceeds the absolute value of either of the preceding years of positive values. The 2011 cotton price increase coincides with Ψ_{2t} =55%, only the fourth time we observe Ψ_{2t} > 50 percent in the post-1900 data.

The annual Ψ_{2t} calculations in Figure 4 also highlight that 1921, in addition to standing out in the Friedman and Schwartz (1965) study of U.S. monetary history, also stands out with its realization of the highest share of extreme commodity price changes in the entire 226-year annual sample (Ψ_{2t} = 82%). Similarly, the annually-based λ_t calculation for cotton matches the monthly-based results in marking 1921 as the year of the most extreme 12-month cotton price change realized outside of the U.S. Civil War. In addition, the onset of the Great Depression and the subsequent devaluation of the U.S. dollar that helped arrest the decline in economic activity can be clearly observed as periods of general commodity price volatility during the early 1930s on the order of that observed in 1973.

The annual Ψ_{2t} data also illustrate that the relatively low volatility of cotton prices during 1873-1913 and 1942-72 corresponds strongly with periods of remarkably low general commodity price volatility, periods with multiple consecutive years when no price realized an extreme change, especially in the 20th century period. The global monetary systems prevailing in each of these two periods revolved around a major large economy, with fixed exchange rates. Note that UK lost its position as the world's largest economy to the United States during the period of 19th century stability, but the system continued to function much as it had earlier through the start of the first World War. The annually-based λ_t cotton calculations show one Gold Standard extreme value—in 1900—and the monthly-based λ_t calculations show several, minor extreme cotton price changes during 1900-11, which may reflect the impact of the UK's declining ability to act as a moderating locus of world monetary affairs towards the end of the gold standard period (Eichengreen, 2004).

Results of $\hat{\delta}_{n,t}$ and Ψ_{1t} Calculations

Since Ψ_{2t} is an unconventional volatility measure, we also calculate standard deviations of log-difference real annual prices ($\hat{\delta}_{n,t}$) over 1791-2017, using 5-year-centered rolling samples, and then calculate the median of the N $\hat{\delta}_{n,t}$ estimates for each year (Ψ_{1t}, in Figure 5). The peaks of $\hat{\delta}_{cotton,\,t}$ coincide virtually exactly with the λ_t peaks throughout the 226-year sample, and starting the 1870s, the path of $\hat{\delta}_{cotton,\,t}$ coincides almost exactly with Ψ_{1t}.

We can observe in Figure 5 that cotton realized a volatility peak in 1921 that was an outlier with respect to the general relationship observable between $\hat{\delta}_{cotton,\,t}$ and Ψ_{1t} prevailing from the 1870s to the 21st century, and that 2012 was even more of an outlier in this respect. The smaller outlier over 1997-98 in the difference between the cotton and general volatility measures likely reflects the impact of the Asian Financial Crisis, which affected income-responsive and Asian-centric commodities more than it affected general commodities.

As with λ_t for cotton, the $\hat{\delta}_{cotton,\,t}$ calculations show the greatest volatility for cotton during the U.S. Civil War, but the entire pre-1860 period also shows relatively high cotton price volatility with respect to general price volatility. The could be a function of the greater role international trade played in determining U.S. cotton prices compared with other commodity prices. But, with Ψ_{1t}—as with Ψ_{1t},—we again observe the highest levels of general commodity price volatility during the 19th century during the War of 1812 and the Civil War. The Ψ_{1t} data also confirm the relatively high general commodity price volatility during 2010-12, coincident with extraordinary volatility in cotton prices.

The rise of global petroleum and grain prices during 2002-06 generated substantial concern and analysis, but by a variety of measures (Ψ_{1t} and Ψ_{2t} based on annual data, and Ψ_{2t} based on monthly data), this was not a period of high volatility. While this period realized higher <u>average</u> grain and energy prices (higher relative to the years immediately preceding the increases), the price changes were relatively smooth. Figure 3 with the monthly-based Ψ_{2t} shows a period over 2002-6 with a greater than median-level of extreme price increases. But, as with the means of the many commodity prices over 2002-06, the general volatility realized over this time only looks high when contrasted with relatively low volatility that immediately preceded it. Both of these periods fell within the Great Moderation (Bernanke, 2004) a period known for its macroeconomic stability, which extended to the start of the Global Financial Crisis.

Figure 6 shows estimated annual growth in world gross domestic product (GDP) from a combination of the Angus Maddison database and the International Monetary Fund's World Economic Outlook database, together spanning the years 1831-2017. This illustrates that the downward global income shock associated with the onset of the 2009 financial crisis stands out as one of the biggest such shocks since the 19th century. Outside of the Great Depression, 2009 was only the second peace-time occurrence of negative global GDP growth. The last previous such occurrence was in 1908, following the Panic of 1907, which, while it did not result in an extreme cotton price shock, was severe enough to trigger the establishment of the U.S. Federal Reserve System.

Figure 6 also indicates that the periods of remarkably low commodity price volatility (under the Gold Standard and Bretton Woods System—see Table 3) were dissimilar with respect to patterns of income growth. They differed both in volatility and in the mean level of growth prevailing. The Bretton Woods period was characterized by the highest average level of GDP growth observed in the nearly 200-year sample for income growth. The 19th century gold standard period included several years with sharp, downward economic shocks, but these shocks did not translate into commodity price volatility. The monetary institutions prevailing during both of these periods assured monetary stability, which translated into commodity price stability despite other economic shocks (see Eichengreen, 2008 and Block, 1977 for an overview of monetary system operation).

Results of GARCH Model

The GARCH modelling effort focused only on cotton prices. We also focused only on 1960-2017, since this is the period with the most relevance to developing expectations of future price behavior. Testing of the real log monthly price series in levels indicated the presence of one unit root, so the estimation proceded using first-differenced data. While the unit root test results in studies examining patterns in the mean of cotton prices (see Table 2) often turn on the role of breaks in the cotton price data series as a source of spurious unit root results, we will abstract from these issues and model the volatility with the data starting with first-differences.

Following Enders (2010), the data generating process (DGP) of the cotton price series' first-difference mean was identified using the traditional Box-Jenkins analysis of the patterns in the estimated auto- and partial auto-correlations. Deterministic variables were introduced to account for the impact of U.S. Farm Legislation in 1966 and 1986, and for the downward shocks associated with the onset of the Global Financial Crisis and the upward shocks associated with the subsequent extraordinary responses by monetary authorities and fiscal activity in the United States, China, Europe, and elsewhere.

The errors of ARMA(0, 3) model showed no evidence of autocorrelation, but did show evidence of auto-regressive conditional heteroscedasticity (ARCH). A GARCH (1,1) process was added, eliminating the ARCH characteristics of the error term, and was superior to other specifications or the error process based on conventional information criteria.

The estimated conditional variances (h_t) (Figure 7) show remarkably low volatility over the last 2 years. Median volatility has been 40-50 percent below median values of the previous 10 and 20 years. The estimates also show volatility peaking in January 1974 and August 2011. The 1961-2017 sample's overall peak is in 2011, and occurs during the start of the rapid descent in cotton prices after the 2010-11 spike. This highlights that although the 2009-12 extreme changes in cotton prices in large part reflected macroeconomic instability at that time, factors peculiar to the cotton market played a more important role in the price volatility than was the case in the 1970s. The discussion section will begin by examining the circumstances of this most recent period of extreme cotton price volatility.

Discussion

With the insight that large commodity prices are typically associated with macroeconomic shifts and uncertainty, we can more deeply examine the market-specific context of the 2009-12 cotton price cycle, its sources and its impacts.

Macroeconomic volatility led to a broad decline in commodity prices after the Northern Hemisphere harvest in 2008/09, and low cotton prices persisted through the 2009 crop's planting season. In March 2009, cotton prices reached a 4-year low, and the IMF's 2010 world GDP forecast fell below 2.0 percent, a growth rate consistent with a decline in world cotton consumption. By October 2010, the IMF was estimating 2010 world GDP growth at an above-average 4.8 percent, and USDA's marketing year 2009/10 consumption forecast was raised 4 million bales between January 2010 and December 2010. Northern Hemisphere cotton area outside of China and Pakistan rose 12.5 percent from a year earlier in the 2010/11 marketing year, and good weather resulted in an unexpected boost to U.S. production, but the combination of low carry-in stocks, surging demand, falling area in China, and flood damage in Pakistan brought a tightening of world cotton supplies.

The absence of a common, relatively extraordinary shock across commodities (Ψ_{1t} and Ψ_{1t}) at that time completely comparable to cotton's volatility (h_t, $\hat{\delta}_{cotton,t}$, and λ_t) highlights the role of market-specific events in the cotton price spike. Two developments specific to cotton included the depletion of cotton for sale from China's National Reserve and the tightening of export controls by India, the world's second largest exporter and producer. China limited world cotton price declines in 2008/09 through purchases of 13 million bales for its Reserve, and then starting in May 2009 it sold 16.6 million bales—equivalent to 14 percent of world consumption—with its final sales in November 2010. In April 2010, India first announced restraints on cotton exports, and during the fall of 2010 India extended its export limitations to the next crop year and added licensing requirements that would have inhibited timely shipment of their previously announced quota. U.S. cotton futures in November 2010 may have experienced one of the 4 most outstanding periods of explosive price behavior identified over 1970-2013 (Etienne, et al. 2014). U.S. Export Sales also showed remarkably high early season sales consistent with precautionary buying in excess of ordinary seasonal demands, indicating a possible role for herding behavior and feedback trading by market participants at some points during the price spike, and prices did not begin falling until April 2011.

The impact of cotton production shocks on supplies was mixed in 2010/11, with unusually and unexpectedly good weather in the United States (third largest producer) and destructive floods in Pakistan (fourth largest). Floods in Australia cut production, but output significantly exceeded early-season expectations and previous-years' production as the country finally emerged from a prolonged El Niño impact. China's crop (then the world's largest) significantly under-shot initial expectations, and the corrections to the forecasts came only in the fall, unusually late. A contributing factor to information problems was the Chinese government's severing of internet access in Xinjiang for nearly a year starting in July 2009 in response to ethnic violence in its largest cotton producing province. In summary, numerous factors affected the cotton price spike in 2010/11 including macroeconomic instability and policy changes in major producing/consuming countries.

Making the leap from noting the association of events with the price spike to assigning a chain of causality for these events is challenging. On one level, the macroeconomic volatility in 2009-10 can be described as an ultimate cause of first the decline in production and then the increase in demand that set the stage for other events. India's trade restrictions, and the rapid expansion of precautionary demand seen in futures markets are akin to events in world soybean markets in 1973 when the U.S. banned soybean exports (USDA/ERS, 1986), and the dynamic of largely self-defeating individual trade policy adjustments in response to global agricultural price increases had already played out in response to higher grain prices in the years before 2009 (Gouel, 2013). Thus, for cotton, these can be regarded as typical responses set in motion by the initial macroeconomic shock. The question of China's large interventions, sudden cut-off of Reserve sales, and transparency issues regarding the actual size of its reserves and developments in its largest cotton-producing province—Xinjiang—also in many respects predated the period of volatility, but take on added meaning given China's outsized role in world cotton markets at that time (MacDonald, et al., 2015). Ultimately, only the shock of the financial crisis seems to warrant a completely independent important causal role.

The impact of the price shock continued to 2017/18 in the form of below-peak global cotton consumption, but more interesting from a forecasting perspective was the impact on expectations of future cotton prices in the years immediately after the shock. Figure 8 shows USDA's long run (10-year) baseline projections for cotton prices published each year for 2007-2017. One can observe that the expectations for average future prices in any given year are highly correlated with the prices prevailing around the year the forecast is published. While all of the USDA projections include periods of declining real prices, the mean of these projections varies substantially .

Both of these characteristics of long run price projections are reflected in the findings in the literature on commodity and cotton price behavior. Reviewing this literature in the light of the impact of the 2010 price spike reveals the importance of understanding the genesis and role of cotton price volatility in the evolution of commodity prices. Large, but ephemeral, shocks are difficult to distinguish from shifts in the mean. This failure to distinguish ephemeral from persistent changes results in forecast error, and presumably sub-optimal policy outcomes like the wide divergences between both U.S. loan rates after 1981 and China's domestic cotton price supports after 2011 relative to the lower market prices that were realized in the years following the implementation of those two policy regimes.

Guidance on Long Run Price Trends in Economics Literature

An intuitively-guided examination of Figure 2 of real U.S. cotton prices over 1900-2017 suggest that there has been a long run decline. A similar pattern has been observed in many commodity prices, and Prebisch (1950) and Singer (1950) presented early post-war analysis hypothesizing there was a generalized commodity price trend (using an 1870-1945 sample). A large literature emerged in subsequent years testing the Prebisch-Singer Hypothesis (PSH), reaching varying conclusions as additional years of data were analyzed and statistical techniques evolved. Analysis of commodity price indexes has given way to analyzing individual prices either with panel techniques (Azerki et al, 2014) or as a set of individual series (e.g. Kellard and Wohar, 2006). Table 3 summarizes the most recent studies that have includes test for the presence of a downward trend in cotton prices, and two generalizations arise from reviewing these studies: 1) making statistically verifiable statements about the presence or absence of trends in cotton prices is difficult, and 2) that studies that account for breaks or mean shifts in cotton prices typically find break points coinciding with the dates of extreme cotton price changes identified through our first volatility measure, the monthly-based λ_t.

One the one hand, a variety of economic studies offer measurements indicating the presence of—and/or sound reasons to expect—a relative productivity-growth differential favoring agriculture versus the general economy over large portions of the years since the start of the 20th century (eg Olmsted and Rhode, 2008 ;Gordon, 2012; O'Donoghue, 2011; Fuglie, 2012). But, on the other hand, it is quite possible that a pattern of real price declines over the long run could be realized at least in part through stepwise shifts, as with the findings of Enders and Holt (2012), for example. It is also possible that some portion of any downward movement in real commodity prices is an artifact of sustained over-estimation of the rate of inflation due to the failure to fully capture the impact of improving product characteristics (Nordhaus, 1998). Grilli and Yang (1988) raise this latter issue, but also note that the characteristics of primary commodities have arguably improved as well, exemplified here by the observation that standard grade of cotton traded on world markets has increased in staple length from 7/8" at the start of the 20th century to 1 3/16" today. Svedberg and Tilton (2006) argue that real copper prices have actually risen in the long run, and Wang and Tomek (2007) forcefully make the point that inappropriate transformations of price data utilizing poorly-measured inflation can introduce spurious findings.

Baffes and Etienne (2015) abstract from the need to confirm a specific statistical property of a commodity price series by encompassing both parts of the PSH in an model that tests the long run relationship between cotton prices and income. They find a negative relationship, and since world income has a positive trend, cotton prices will tend to decline. They note however, the real decline's channel in the model is through inflation.

The variety of conclusions in the literature argues for caution in the interpretation of any study of long run price levels, but the consistency of real long run price data relative to exchange rates across a number of developed countries suggests the methodology of price index estimation, however flawed, is well developed and unlikely to change radically in the next 10 years. Therefore, even if an observed trend is ultimately based on biased data, the bias is likely to continue.

Conclusions

1) It is appropriate for USDA to project declining real agricultural prices over significant portions of its 10-year forecast horizon.
2) Distinguishing even temporary mean shifts from large, ephemeral shocks is difficult but important.
3) The low volatility realized by cotton prices in the last 2 years is not necessarily a good basis for future expectations.

The lowest volatility for cotton prices has occurred in periods when global monetary arrangements were stable and well anchored in the financial markets of the largest economy. The world's current two largest economies—the United States and China—have a very different relationship than that prevailing between the United States and the UK during the latter part of the highly-stable Gold Standard period of the late 19th and early 20th centuries. This would suggest that the typical level of volatility over the next decade would more closely resemble the 1970-2015 median than the 1942-70 or 1870-1913 medians. While we have no basis to predict a disruption as profound as those in 1973 or 2009 in the foreseeable future, we also have little justification in completely ruling out a comparable shock. The historical distribution of commodity and cotton price changes has included some very extreme values, and additional research in several disciplines will be necessary if forecasts of such changes in the future are to improve.

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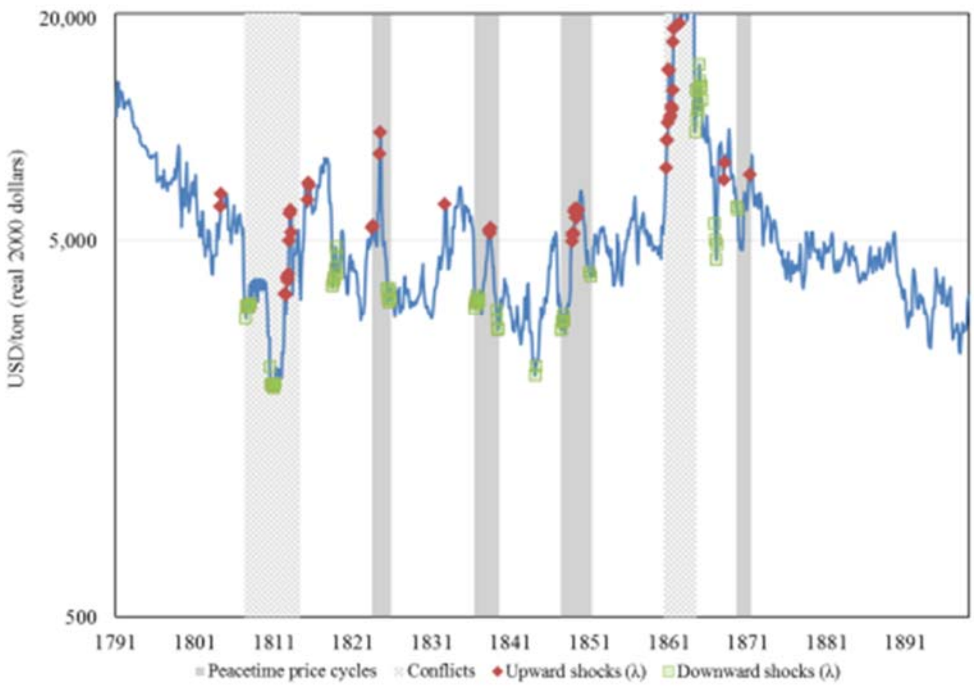

Figure 1. Real U.S. cotton prices and price shocks (λ): 1791-1899.

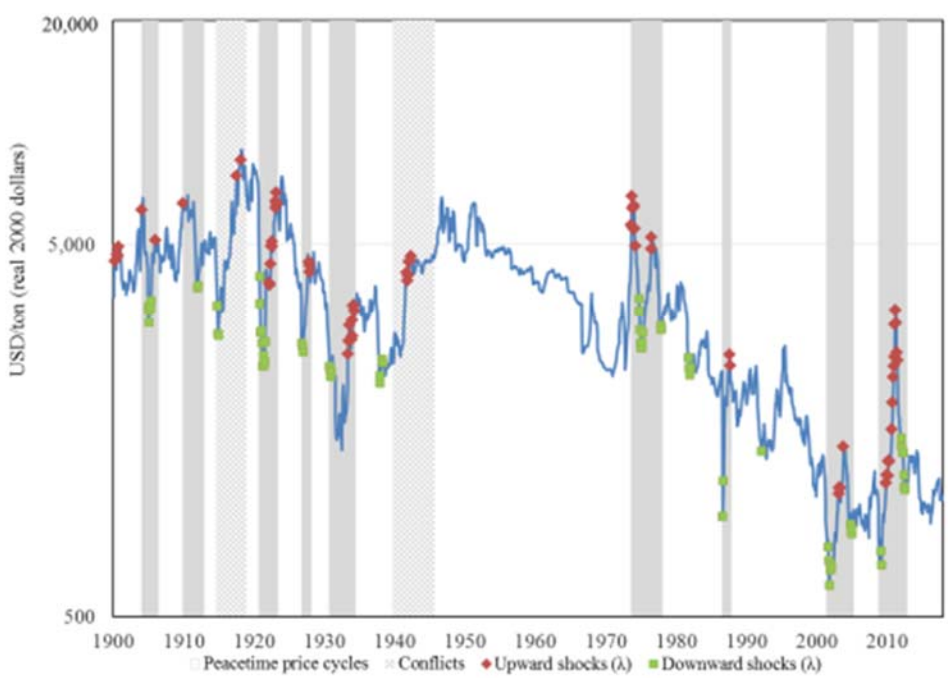

Figure 2. Real U.S. cotton prices and price shocks (λ): 1900-2017.

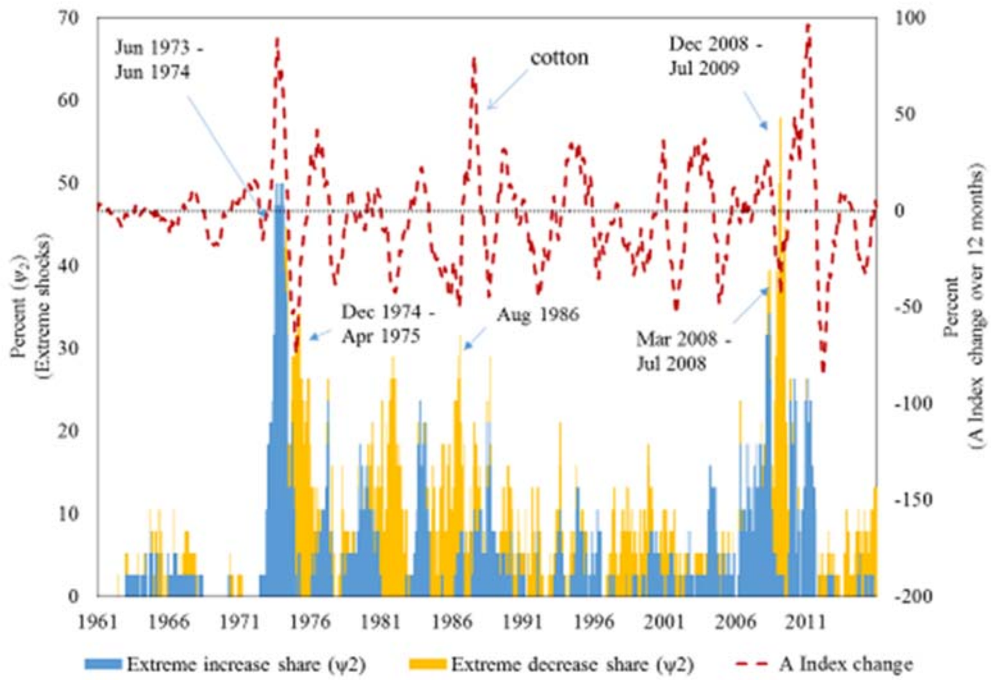

Figure 3. Detecting general commodity price shocks (ψ_2), 1961-2015,
And level of cotton price changes.

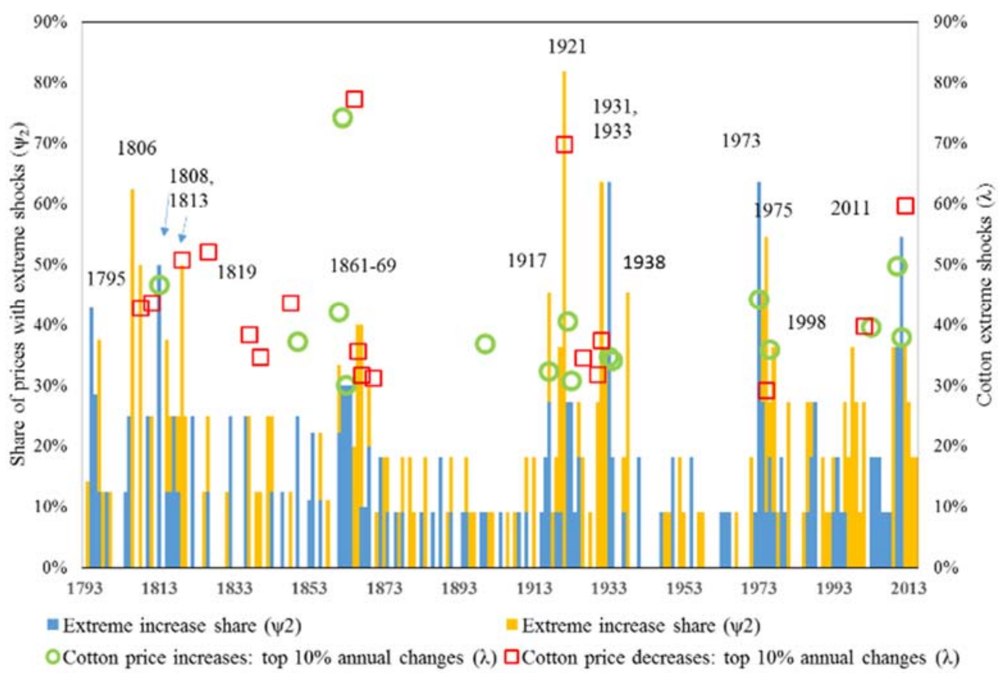

Figure 4. Detecting general commodity price shocks (Ψ_2), 1793-2015,
And level of cotton price shocks (λ).

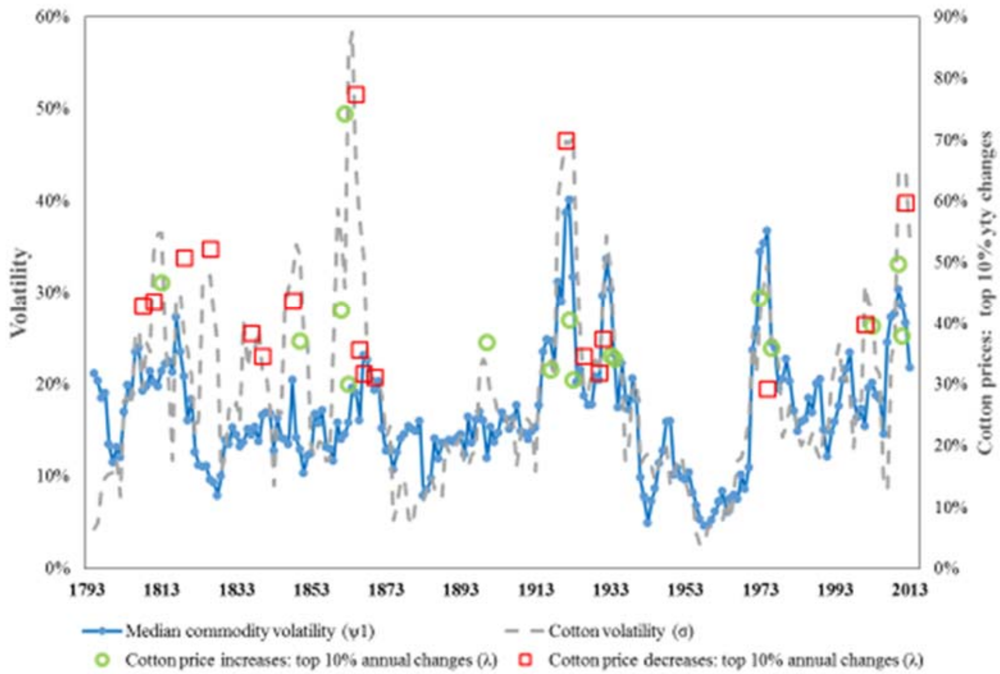

Figure 5. Detecting general commodity price shocks (Ψ_1), 1793-2015,
And levels of cotton price shocks (λ).

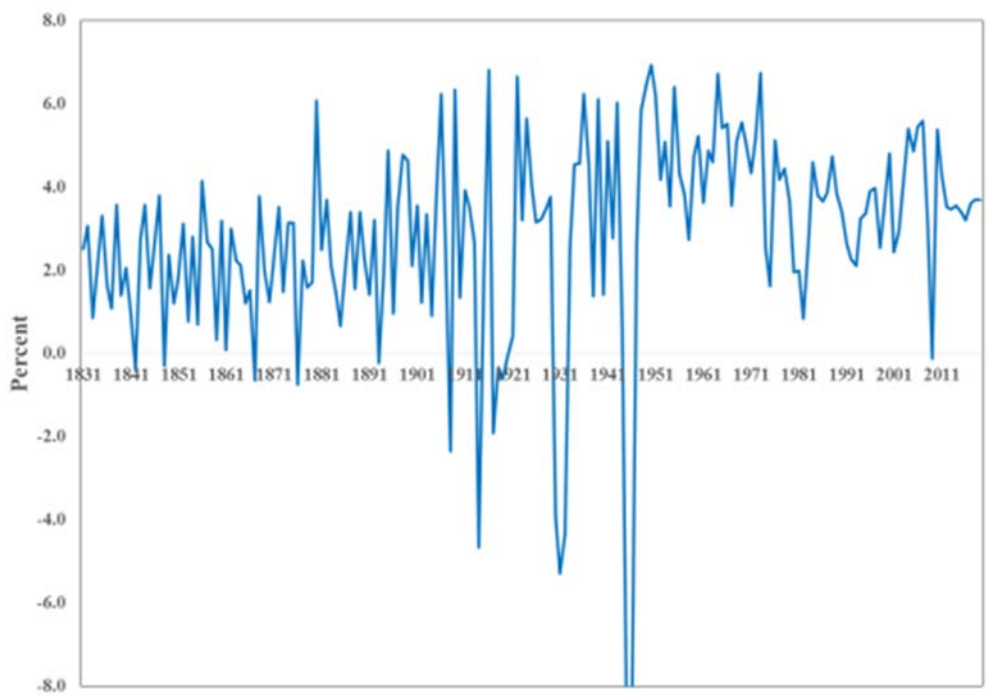

Figure 6. World GDP annual growth, 1831-2019.

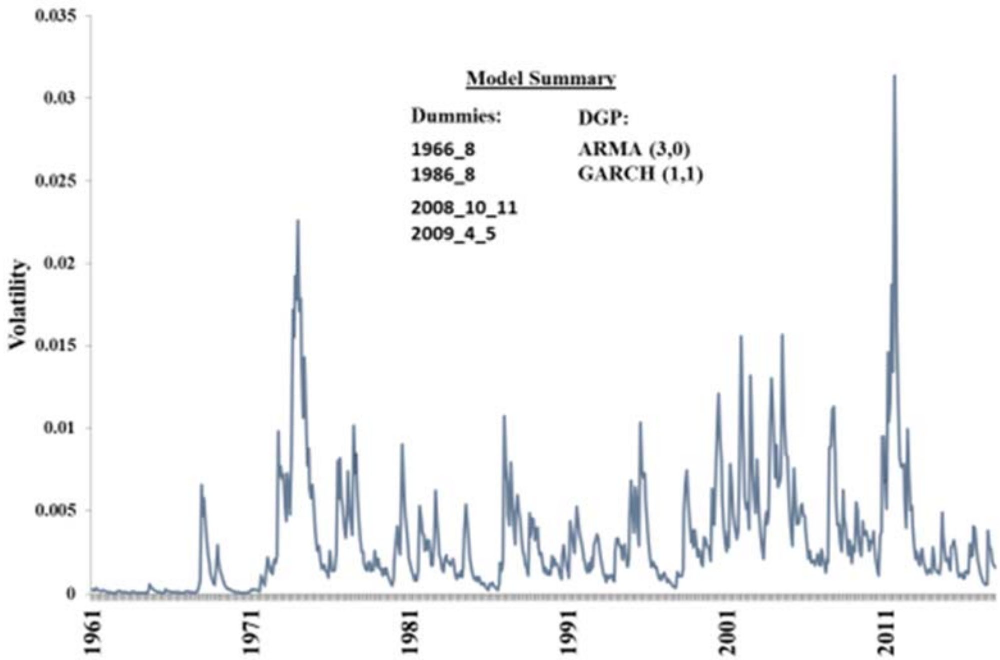

Figure 7. Conditional variance (h_t): U.S. cotton prices monthly, 1961-2017.

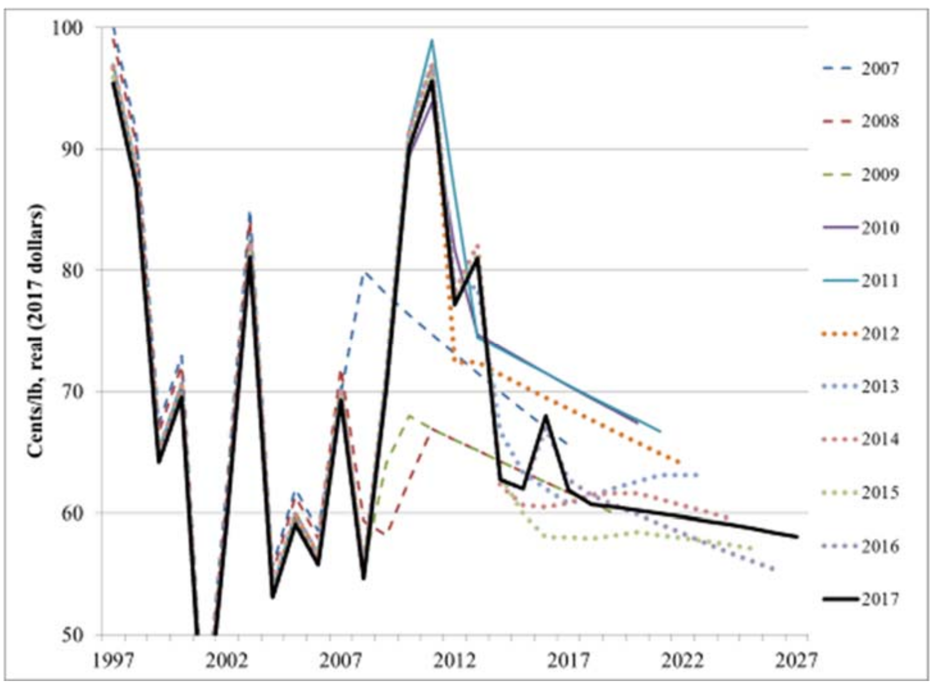

Figure 8. Real (2017 dollars) U.S. upland farm price, USDA baseline forecasts: 2007-2017.

Table 1. Cycles of extreme cotton price changes, 1792-2017.

	Cycle's largest absolute change†		
Duration	Negative		Positive
1808-19	-78		100
1824-26*	-103		57
1833*		48	
1837-40	-61		50
1845		-55	
1848-52	-57		60
1861-72*	-133		115
1900*		49	
1904-05*	-70		47
1909-11*	-48		48
1914-23	-122		75
1926-27	-52		51
1930-34	-54		51
1937		-46	
1941-42*		53	
1973-77*	-88		100
1981		-54	
1986-87	-79		71
1992		-45	
2001-03	-78		49
2003-05*	-51		54
2009-12	-88		94

†a subset of milder, shorter cycles include extremes in only one direction
*positive shock preceded negative

Table 2. Recent studies of long run cotton price trends: summary of results

		Price Series Characteristics Found			
Authors	Sample	Break dates & type	Deterministic trend	Random drift	Other
Leon and Soto (1997)	1900-1997	1967, trend 1985, intercept	Negative	Mixed	Unit root with intercept shift
Kim, et al (2003)	1900-1998	n/a	None	Yes	--
Ocampo and Parra (2010)	1900-2000	None	None	Yes	--
Kellard and Wohar (2006)	1900-1998	1929. both 1949, both	None	Yes	Negative trends common for ag
Balagatas and Holt (2009)	1900-1998	~1957-67 ~1980-85 (intercept)	None	No	Corn, rice, and wheat have negative trends
Enders and Holt (2012)	1960-2010 (monthly)	9 mean shifts (3 since 1985)	Long run not discussed	Mixed	--
Azerzki, et al. (2014)	1872-2005	1945, both	Negative	No	--
Azerzki, et al. (2014)	1900-2005	1930, both 1946, both	Negative, since 1946	No	--

Table 3. Major events and periods affecting U.S. cotton and commodity price volatility

Disruptive		Stabilizing	
1803-15	Napoleonic Wars		
1818-21	Return to metallic currency standards in U.S. and Britain	1815-1913	"Pax Britannica"; U.K.-centric global economic integration
1861-65	U.S. Civil War		
1866-73	Return to de facto U.S. gold standard		
		1870-1913	Global gold standard
1914-18	First World War		
1920-25	Return to gold standard		
1930-40	Great Depression		
1939-45	Second World War		
		1941-66	U.S. farm price support policy; strategic commodity stockpiling; petroleum price management
		1947-71	Bretton Woods System; fixed exchange rates; U.S.-centric global financial system
1971-75	U.S. exchange rate unfixed		
2008-10	Global Financial Crisis shock and rebound		