Long Run Trends and Fluctuations In Cotton Prices

MacDonald, Stephen and Meyer, Leslie

World Agricultural Outlook Board, USDA, Economic Research Service, USDA

22 January 2018

LONG RUN TRENDS AND FLUCTUATIONS IN COTTON PRICES

Stephen MacDonald
WAOB/USDA
Washington, DC
Leslie Meyer
ERS/USDA
Washington, DC

Abstract

One revelation from the 2008 Global Financial Crisis was the fragility of models and assumptions based on samples too short to include periods of high volatility, and this study attempts to remedy that short-coming for USDA's development of long run cotton price projections. 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, largely correlated with macroeconomic instability. Cotton's period of greatest instability—during the U.S. Civil War—was primarily driven by cotton-specific trade and production disruptions, but since the Civil War, cotton volatility has largely coincided with broader commodity price volatility. One of cotton's most volatility\e episodes since 18th century 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. Looking ahead, cotton price volatility over 2018-27 is likely to be greater than the volatility experienced during 2016-17, when volatility was unusually low, likely reduced by China's large sales from its National Reserve.

(The opinions and conclusions expressed herein are solely those of the authors and should not be construed to represent the opinions or policy of the U.S. Department of Agriculture.)

Introduction

In this paper, issues concerning forecasting the long run direction of cotton prices is largely addressed through literature review. The statistical problems involved in the analysis are complex enough that our individual findings can be regarded as tentative. Trends evident each year in USDA's published long run real cotton price forecasts are clearly downward trending, but the shifts from one publication year to the next in the 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 U.S. commodity prices over time is measured as early as the 1790s, and periods of general price volatility are identified through cross-sectional aggregation of volatility measures across sets of commodity prices. Cotton price volatility over 1960-2017 is estimated with a GARCH model, and other measures. 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 2010-11 cotton 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 individual volatility measures 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, centered sub-samples of the log first-differences of the price, and 3) the magnitude of the year-to-year logged-price change if that change is in the 90th percentile of the sample's absolute year-to-year changes ($\lambda_{n\,t}$). General commodity volatility is measured as 1) the median at each time (Ψ_{1t}) of a database's N price series' sub-sample standard deviations ($\hat{\delta}_{n\,t}$), and 2) the proportion at each time (Ψ_{2t}) of the N individual commodity prices in a database that have absolute year-to-year changes in the 90th percentile (i.e., when $\lambda_{n\,t} \neq 0$).

All three individual volatility measures are related to the theoretical properties of a 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 from the beginning, focusing only on the extreme values of these differences in set of T dates (changes whose absolute value is in the 90th percentile of the sample). In our monthly U.S. cotton price data the threshold for the 90th percentile was 45.3 percent. 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 absolute 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 in which 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 the USDA/AMS 7-market U.S. average spot quotations for base quality (color 41, leaf 4, staple 34). Consistent with changing commercial practice and market standards prevailing in different time periods, the grade of quoted prices and the transaction location of the quotes varies in the earlier years of the dataset. Grading standards, driven by the average characteristics of the fiber produced in the United States and demanded by textile mills around the world, have 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 and 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 role of U.S. commodity production and consumption has declined, market activity has sometimes 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 1) the median (Ψ_{1t}) at each time t of the dataset's N standard deviations ($\sigma_{n,t}$) of the dataset's prices' logged annual price changes over rolling, centered, 5-year intervals, and 2) the proportion of prices with 90th percentile changes each year (Ψ_{2t}).

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 monthly absolute logged-price changes (λ_t) used to calculate Ψ_{2t} were 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.

All prices were adjusted for inflation with the U.S. CPI (BLS, 2017), which the Bureau of Labor Statistics publishes back to January 1913. Annual data back for 1912-1791 are from a data set compiled by Reinhart and Rogoff (2010), raised to a monthly frequency using EViews quadratic-match-average option for the 226-year, monthly cotton price series.

Results

Results of λ_t Calculation

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

In the monthly cotton price data, 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 has extreme changes in a given direction that is sometimes followed within about 12 months by another episode with changes in the same direction, but more frequently by an episode with opposite-signed changes. We group these sets of adjacent episodes together and term the group a cycle (Table 1). Thus, one type of episode is at the start of a cycle, which occurs after a relatively long period following the end of the last preceding cycle, the median gap being 44 months over the 226-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 often 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 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, the longest such episode in our sample. Prices during this episode were as much as λ_t = 115 percent higher than 12 months earlier in real terms, the largest positive difference observed. Conversely, 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 macroeconomy. While 19th century business cycles were 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. Additionally, Jacks et al. (2011) GARCH modeling of monthly Philadelphia commodity prices over 1784-1896 results in h_t estimates with similarly-sized peaks in most of the same years as our Ψ_{1t} and Ψ_{2t} estimates.

Note that the Panic of 1819 in part reflected the prolonged impact of the 1815 eruption of Mount Tambora (Wood, 2014), and also the 1818 payment on the debt incurred before the War of 1812 for the Louisiana Purchase (Rothbard, 1962). But the 1819 event is best understood as part of the transition between war-time and peace-time government finance in the United States, Britain, and elsewhere. The other years (1826, 1837, and 1848) are peace-time economic downturns coinciding with downward cotton price extremes. Both the conflict-related and peace-time episodes are 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 decline 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 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, and/or borrowed extensively, to later drive domestic prices back down to pre-War levels.

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 most similar to 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 monthly values for the general volatility measure Ψ_{2t} for 1961-2017. Trends in the monthly Ψ_{2t}—and differentiating between the negative and positive components of the calculated share—illustrates the association of extreme cotton price changes with macroeconomic disruption. Figure 3 shows the full 1961-2017 series of monthly cotton price changes from 12 months earlier, and the monthly level of Ψ_{2t}—the share of the database realizing extreme changes—broken out into positive and negative extreme changes. As in Figure 2, the pre-1971 lack of price volatility is apparent Figure 3's general volatility measure (Ψ_{2t}) data, although the cotton price data in Figure 3 clearly shows an impact from the 1966 U.S. farm legislation's cuts in price support. The effect of the 1985 U.S. farm legislation shows up as a pair of brief price changes in 1986 and 1987.

The pair of maximum values for the cotton price changes and Ψ_{2t} 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 (e.g. Financial Times, 2010).

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

Annually-based Ψ_{2t} calculations (Figure 4), show the same 1960-2017 patterns in general commodity price volatility as the monthly data. Additionally, the annual data extend 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, so slightly different conclusions can be drawn depending on which data are examined.

One example is that with the annually-based data the 2011 value of Ψ_{2t} becomes among the highest of the 226-year sample, while in the monthly data 2011 is far less remarkable: another is that the 2009 peak apparent in the monthly calculations is less remarkable in the annual data. The relative positions of the upward and downward values for λ_t also differ with the choice of annual or monthly data: the absolute value of the 2012 decline exceeds the absolute value of either of the preceding years of positive values. Although different in certain respects, the results of both annual and monthly data analysis both support the conclusion that 2009-11 was a period both general commodity price and cotton price volatility. For example, the 2011 cotton price increase coincides with $\Psi_{2t} = 55$ percent, only the fourth time we observe $\Psi_{2t} > 50$ percent in the post-1900 annually-based data. The annually-measured 2011 price increases reflect low prices in 2010, which in turn were a consequence of the declines that were realized during the months of 2009.

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. The annual Ψ_{2t} data also highlight the 1930s as a period of general price volatility comparable to the 1930s. The onset of the Great Depression on the subsequent global exchange rate devaluations and collapse of the gold standard was a period of significant macroeconomic uncertainty and volatility.

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. The global monetary systems prevailing in each of these two periods revolved around a major large economy, with fixed exchange rates. Note that the 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 until the first World War. The annually-based λ_t cotton calculations show one gold standard period extreme value—in 1900—and the monthly-based λ_t calculations show several, minor extreme cotton price changes during 1900-11. This volatility 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). This later period also included some historically notorious efforts to manipulate U.S. cotton futures prices (Baker and Hahn, 2016), but the history of 19th century U.S. commodity markets is rife with episodes of real or purported manipulation, and the important question is why cotton prices avoided extreme changes early in the gold standard era, but not later.

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

Since λ_t and Ψ_{2t} are unconventional volatility measures, we also calculate standard deviations of log-difference real annual prices ($\hat{\delta}_{nt}$) over 1792-2016, using 5-year-centered rolling samples, and then calculate the median of the N $\hat{\delta}_{nt}$ 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 224-year sample, and starting in 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.

A smaller outlier over 2001-05 can be observed representing a cycle of cotton price volatility driven by a mix of macroeconomic and cotton-specific events. The events during the cycle show similarities to those during 2009-12, so a brief discussion here of 2001-05 will help illuminate the later analysis of the 2009-12 cycle. In 2001, cotton production rose sharply around the world and China raised expectations of large sales from its reserves just as a global economic slowdown curtailed consumption growth, leading to a sharp decline in price. In 2003, the impact of rebounding prices due to tight supplies (a consequence of the negative production responses to the 2001 price decline) was compounded by severe late-season weather damage to China's 2003/04 production, resulting in unprecedented U.S. export sales to China, and a second, temporary, surge in cotton prices.

Returning briefly to the big picture, with Ψ_{1t}—as with Ψ_{2t}—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.

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. This could be a function of the greater role international trade played in determining U.S. cotton prices compared with other commodity prices.

Results of GARCH Model

The GARCH modelling effort focused only on cotton prices, and 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 proceeded 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 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 of the error process, based on conventional information criteria.

The estimated conditional variances (h_t) (Figure 7) show remarkably low volatility was realized during 2016-17. Median volatility was 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 again 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 cotton price volatility than was the case in the 1970s.

The absence of a common, relatively extraordinary shock across commodities (Ψ_{1t} and Ψ_{2t}) at that time completely comparable to cotton's volatility as measured first by $\hat{\delta}_{cotton,t}$ and λ_t—and now more formally by h_t—suggests an important role for cotton-market-specific events during the upward portion of the 2009-12 cycle.

Discussion

The 2009-12 cotton price cycle was driven by general economic factors and cotton-specific factors. Most analysis of the period of peak cotton price levels in 2010-11 focus on a sub-set of the cotton-specific factors. Often overlooked in these accounts is the role of macroeconomic events in the cycle's initiation.

One aspect of cotton's unusual response to the Global Financial Crisis is the greater responsiveness of cotton consumption to income—particularly downward shocks—than the consumption of other agricultural commodities (MacDonald and Vollrath, 2005). 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 1831-2019. 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 help trigger the later establishment of the U.S. Federal Reserve System.

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 (August-July) world consumption forecast was raised 4 million bales between January and December 2010. Since spring 2009 plantings were depressed, 2009/10 production was 5 million bales lower than the year before and 17 million bales lower than two years earlier. With prices rising in the spring of 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.

Two developments specific to cotton during the period when cotton prices began to approach nominal levels last seen during the U.S. Civil War included the tightening of export controls by India and the apparent depletion of saleable cotton from China's National Reserve. In April 2010, India (the world's second largest exporter after the United States) first announced export restraints on cotton, and early in October 2010 India introduced licensing requirements that would have prohibited shipment of many of their export sales. China had been using purchases and sales by its National Reserve to limit price volatility from the start of the Global Financial Crisis. World cotton price declines in 2008/09 were arguably limited through the Reserves purchases of 13 million bales, and then starting in May 2009 the reserve sold 16.6 million bales (equivalent to 14 percent of world consumption) to smooth rebounding prices. But the reserve halted sales in November 2010, a tangible signal that the Reserve's undisclosed level has reached a low threshold, and cutting off an important source of cotton for China's textile industry.

Under these unusual circumstances, cotton markets behaved in an unusual manner. U.S. cotton futures in November 2010 experienced one of the 4 most outstanding periods of explosive bi-directional price changes realized in any futures market for commodities over 1970-2013 (Etienne, et al. 2014). USDA's U.S. Export Sales reporting system also showed remarkably high early season sales during that time, consistent with precautionary buying in excess of ordinary seasonal demands. These two developments indicate a possible role for herding behavior and feedback trading by market participants at some points during the price spike.

Mass media accounts of the price spike often cited production shortfalls in their analysis, but our analysis indicates that assuming a large negative weather shock was the source of the price shock would be inappropriate. The global supply impact of shocks to cotton production was mixed in 2010/11, with unusually and unexpectedly good weather in the United States (third largest global 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. But these corrections primarily reflected unexpected declines in area rather than yield.

The unexpected nature of the decline in area may have reflected a shock to the information flows coming out of China in 2010. China's government severed international telephone and all internet access to Xinjiang for nearly a year (in the case of internet) starting in July 2009, and imposed other security responses that continued afterwards, due to a significant outbreak of ethnic violence there (Hogg, 2010). Given that Xinjiang's contact with the outside world was hindered through its planting season, the traditional channels for conveying planted-area information from this strategic region might not have been capable of ex post discovery of planted area for many months.

Regardless of the source of the unusual forecast error, the remarkably high upward errors in virtually all forecasts of China's production until October 2010, was a contributing factor to the sharp rises in cotton prices observed in October and November 2010.

Making the leap from simply noting the association between various events and the price spike to the next stage of 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 a secondary set of events. For example, 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 the response to higher grain prices in the years before 2009 (Gouel, 2013). Thus, for cotton in 2010, these could be regarded as typical endogenous 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). The similarities between China's role in the smaller 2001-03 cycle and the 2009-12 cycle suggest a dynamic in China's market that made cotton prices more vulnerable to the after-effects of earlier macroeconomic shocks. Ultimately, in both cases, only the macro shock seems to warrant a completely independent important causal role. The degree of inevitability or independence of causality for subsequent events associated with the price's continued drive to nominal levels unseen since the U.S. Civil War is debatable, and awaits future research.

Forecasting Long Run Price Trends

The impact of the 2010-11 price shock continued through 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 each of the 11 sets of USDA 10-year projections includes periods of declining real prices, the mean of these projections varies substantially, and is highly correlated (75 percent) with the price expected in the year the forecast was created.

Both of these characteristics of long-run price projections (downward trends vulnerability to shocks) are analogous to aspects of the findings typical 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 price volatility in the evolution of commodity prices. That ephemeral shocks are difficult to distinguish from shifts in the mean is one such characteristic. 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.

Casual examination of Figure 2 of real U.S. cotton prices over 1900-2017 suggests 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). Baffes and Etienne (2015) provide a concise recent summary of studies testing the PSH, and Table 3 summarizes the most recent studies that included tests 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.

On 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 (e.g. Olmsted and Rhode, 2008 ;Gordon, 2012; O'Donoghue et al., 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 the 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. The importance of correctly measuring inflation is indicated by Svedberg and Tilton (2006) who argue that real copper prices have actually risen in the long run when corrected for inflation-bias, and Wang and Tomek (2007) who highlight that inappropriate transformations of price data utilizing poorly-measured inflation could introduce spurious findings.

Baffes and Etienne (2015) abstract from the need to confirm a specific statistical property of a commodity price series by integrating the often-overlooked causal half of the PSH with the trend question in a model that tests the long run relationship between cotton prices and income. They find a significant negative relationship, and since world income has a positive trend, their finding is consistent with a declining cotton trend. In addition, in their model, the channel through which income growth causes a real decline in commodity prices is by increasing the index of non-commodity prices, again highlighting the central role of inflation measures in the issue of real commodity price trends.

The variety of conclusions in the literature argues for caution in the interpretation of any study of long-run price levels. But the consistency over long periods between inflation 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 during 2016-17 is probably not a good basis for expectations of volatility over 2018-27.

On one level, the assertion that commodity price stability is contingent of macroeconomic stability is too obvious to be useful. Few would be surprised that a large negative shock to global income had serious implications for price stability. But the kind of macroeconomic stability that has in the past resulted in commodity price stability is of a higher order than annual GDP stability. Figure 6 with 1831-2019 world GDP growth 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 governance channels).

Regarding the prospects for a differential between 2016-17 and 2018-27 volatility: China made large amounts of cotton available from its National Reserve over 2016-17 in a consistent, flexible, and relatively transparent manner. A subsequent decline in the Reserve to its desired long-run level would mean the sales would stop, conceivably in an unexpected manner due to uncertainty about the size of the Reserve. After net sales stop, global cotton markets will have to contend with both the loss of a stable source of cotton, and the likely return of large and varying import demand from China.

Thinking more generally about the long-run outlook, recall that 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.

References

Arezki, R., Hadri K., Loungani, P., and Yao Rao. 2014. Testing the Prebisch–Singer hypothesis since 1650: Evidence from panel techniques that allow for multiple breaks, Journal of International Money and Finance 42:208–223.

Baffes, J., and X. Etienne. 2015. Analyzing Food Price Trends in the Context of Engel's Law and the Prebisch-Singer Hypothesis, Policy Research Working Paper 7424.

Baker, B., and B. Hahn. 2016. The Cotton Kings: Capitalism and Corruption in Turn-of-the-Century New York and New Orleans. Oxford University Press.

Balagtas, J. V. and M. T. Holt. 2009. The commodity terms of trade, unit roots, and nonlinear alternatives: a smooth transition approach, American Journal of Agricultural Economics, 91, 87–105.

Block, F. 1977. The Origins of International Economic Disorder, University of California Press.

Bollerslev, T., 1986, Generalized autoregressive conditional heteroskedasticity, J. of Econometrics 31, 307-327.

Cafiero, C., Bobenrieth, E., Bobenrieth, J. and B. Wright. 2011. The empirical relevance of the competitive storage model, Journal of Econometrics, 162(1): 44-54.

Chen, S., Jackson, J., Kim, H., and P. Resiandini. 2014. What Drives Commodity Prices?, American Journal of Agricultural Economics, 96(5):1455–1468.

Cole, A. 1938. Wholesale Prices in the United States, 1700-1861, Statistical Supplement, Actual Wholesale Prices of Various Commodities. Harvard University Press, Cambridge, MA.

Eichengreen, B. 2008. Globalizing Capital: A History of the International Monetary System, Princeton University Press.

Enders, W. 2010. Applied Econometric Time Series. John Wiley & Sons. Hoboken, NJ.

Enders, W., and M. Holt. 2012. Sharp Breaks or Smooth Shifts? An Investigation of the Evolution of Primary Commodity Prices, American Journal of Agricultural Economics 94 (3): 659–73.

Engle, R., 1982, Autoregressive conditional heteroscedasticity with estimates of the variance of United Kingdom inflation, Econometrica, 50, 987-1007.

Etienne, X., Irwin, S., and P. Garcia. 2014. Bubbles in food commodity markets: Four decades of evidence, Journal of International Money and Finance, 42:129-155

Financial Times. 2010. "Cotton Prices Surge to 15-year Peak," September 2.

Friedman, M., and A. Schwartz, 1965. A Monetary History of the United States, 1865-1960. Princeton University Press.

Fuglie, K. 2012. "Productivity growth and technology capital in the global agricultural economy," in Productivity Growth in Agriculture: an International Perspective, (ed.) Fuglie, Keith, Wang, Sun Ling, and Eldon Ball. Centre for Agribusiness and Biosciences International.

Gordon, R. 2012. Is U.S. Economic Growth Over? Faltering Innovation Confronts the Six Headwinds. Working Paper No. 18315. National Bureau of Economic Research.

Grilli, E. and M. C. Yang. 1988. Primary commodity prices, manufactured goods prices, and the terms of trade of developing countries: What the long run shows, The World Bank Economic Review, 2, 1–47

Gouel, C. 2013. Food Price Volatility and Domestic Stabilization Policies in Developing Countries, World Bank, Policy Research Working Paper 6393.

Gustafson, R. 1958. Carryover Levels for Grains: A Method for Determining Amounts That Are Optimal Under Specified Conditions. Technical Bulletin No. 1178. U.S. Department of Agriculture.

Hogg, Chris. 2010. "China Restores Xinjiang Internet," BBC News, May 14, 2010.

Huffman, W. and J. Lothian. 1984. "The Gold Standard and the Transmission of Business Cycles, 1833-1932," in Bordo, M., and A. Schwartz (ed.), A Retrospective on the Classical Gold Standard, 1821-1931, University of Chicago Press.

International Monetary Fund. 2016. International Financial Statistics.

Jacks, D., O'Rourke, K., and J. Williamson. 2011. Commodity price volatility and world market integration since 1700. The Review of Economics and Statistics, 93: 800–813.

Kellard, N. and M. Wohar. 2006. On the prevalence of trends in primary commodity prices, Journal of Development Economics, 79: 146–167.

Kim, T., Pfaffenzeller, S., Rayner, T., and P. Newbold. 2003. Testing for linear trend with applications to relative primary commodity prices, Journal of Time Series Analysis, 24: 539–551

Leon, J. and R. Soto. 1997. Structural breaks and long–run trends in commodity prices, Journal of International Development, 9: 347–366.

MacDonald, S., Gale, F., and J. Hansen. 2015. Cotton Policy In China, USDA/ERS, CWS-15C-01.

MacDonald, S., and T. Vollrath. 2005. The Forces Shaping World Cotton Consumption After the Multifiber Arrangement, USDA/ERS, CWS-05c-01.

Maddison, A. 2010. Historical Statistics of the World Economy: 1-2008 AD.

Nordhaus, W. 1998. Quality Change in Price Indexes. Journal of Economic Perspectives, 12(1): 59–68.

O'Donoghue, E., Hoppe, R., Banker, D., Ebel, R., Fuglie, K., Korb, P., Livingston, M., Nickerson, C., and C. Sandretto. 2011. The Changing Organization of U.S. Farming, Economic Information Bull., EIB-88. U.S. Department of Agriculture, Economic Research Service.

Ocampo, J. and M. Parra-Lancourt. 2010. The terms of trade for commodities since the mid–19th century, Journal of Iberian and Latin American Economic History, 28:11–43

Prebisch, R. 1950. The Economic Development of Latin America and Its Principal Problems. Lake Success NY: UN Dept. of Economic Affairs.

Olmstead, A., and P. Rhode. 2008. Creating Abundance: Biological Innovation and American Agricultural Development. Cambridge University Press.

Quark, A. 2013. Global Rivalries: Standards Wars and the Transnational Cotton Trade. University of Chicago Press.

Reinhart, Carmen, and Kenneth Rogoff. 2010. This Time is Different: Eight Centuries of Financial Folly. Princeton University Press.

Romer, C. 1986. Spurious Volatility in Historical Unemployment Data. Journal of Political Economy, 94: 1-37

Rothbard, M. 1962. The Panic of 1819: Reactions and Policies. Columbia University Press.

Singer, Hans W. 1950. "US Foreign Investment in Underdeveloped Areas: The Distribution of Gains Between Investing and Borrowing Countries." American Economic Review (Papers and Proceedings). 40, pp. 473-85.

Svedberg, P. and J. Tilton. 2006. The Real, Real Price of Nonrenewable Resources: Copper 1870–2000, World Development, 34(3):501-19.

U.S. Department of Agriculture, Agricultural Marketing Service (various issues). Cotton Price Statistics.

U.S. Department of Agriculture, Bureau of Agricultural Economics. 1951. *Statistics on Cotton and Related Data*, Statistical Bulletin No. 99.

U.S. Department of Agriculture, Economic Research Service. 1974. *Statistics on Cotton and Related Data, 1920-73*, Stat. Bulletin No. 535.

U.S. Department of Agriculture, Economic Research Service. 1986. Embargoes, Surplus Disposal, and U.S. Agriculture, AER 564, USDA/ERS.

U.S. Department of Labor, Bureau of Labor Statistics. 2017. Historical Consumer Price Index data.

Wang, D., and W. Tomek. 2007. Commodity Prices and Unit Root Tests, American Journal of Agricultural Economics, 89: 873-889.

Davis, J., and M. Weidenmier. 2016. America's First Great Moderation, Working Paper No 21856, NBER.

Wood, G. 2014. Tambora: The Eruption that Changed the World. Princeton University Press.

World Bank. 2016. World Bank Commodity Price Data.

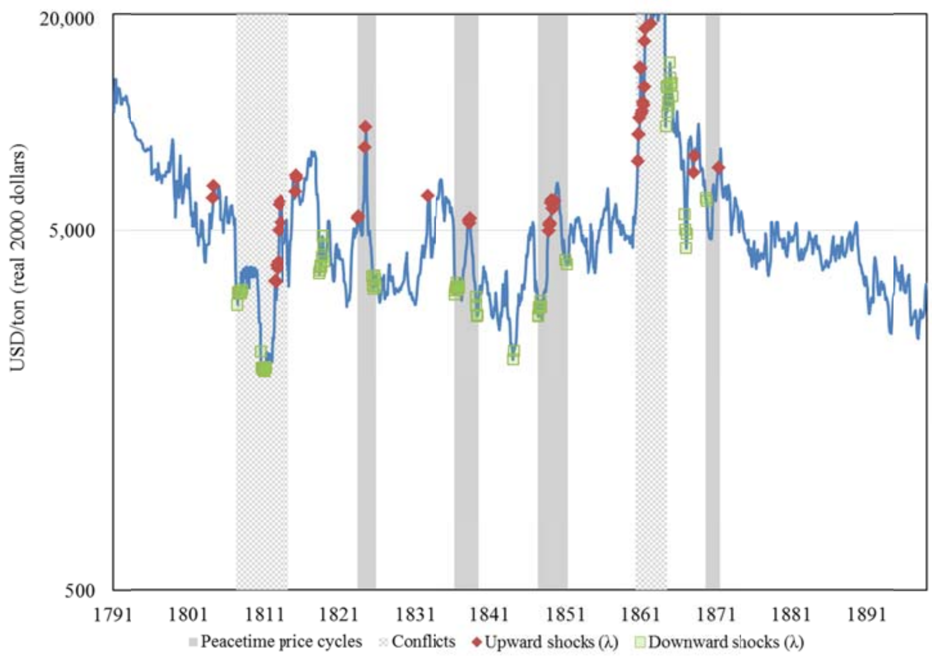

Figure 1. Real U.S. cotton prices and price shocks (λ): 1791-1899.

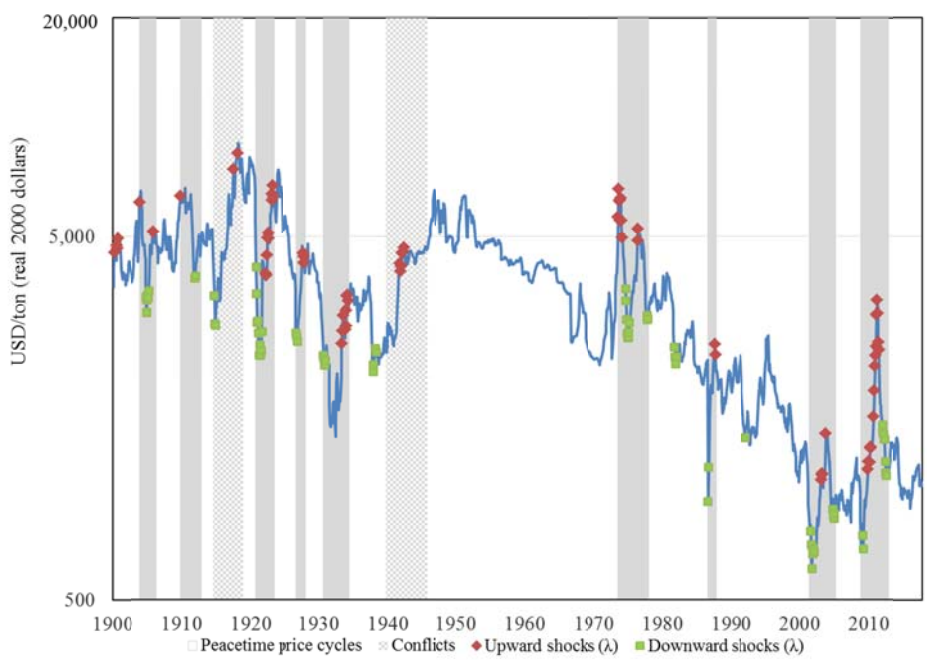

Figure 2. Real U.S. cotton prices and price shocks (λ): 1900-2017.

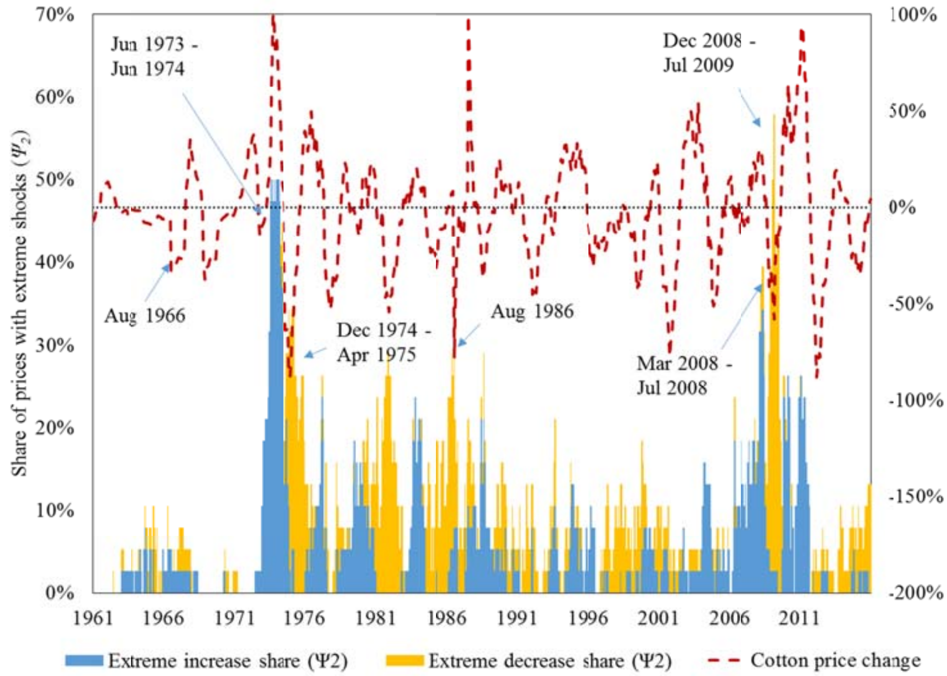

Figure 3. Detecting general commodity price shocks (Ψ_2), 1961-2016,
And level of cotton price changes.

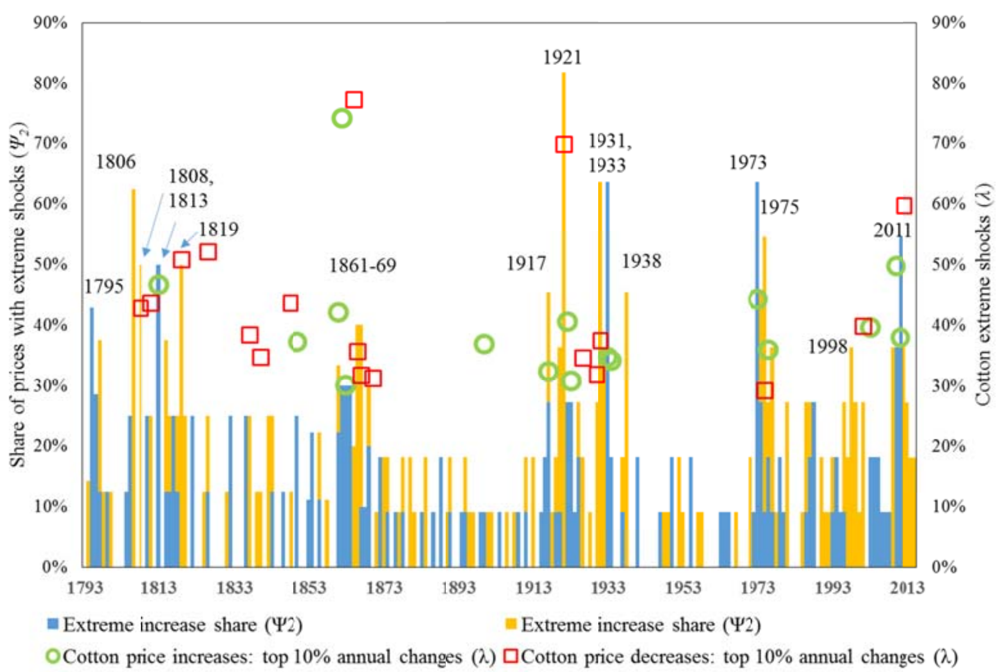

Figure 4. Detecting general commodity price shocks (Ψ_2), 1791-2016,
And level of cotton price shocks (λ).

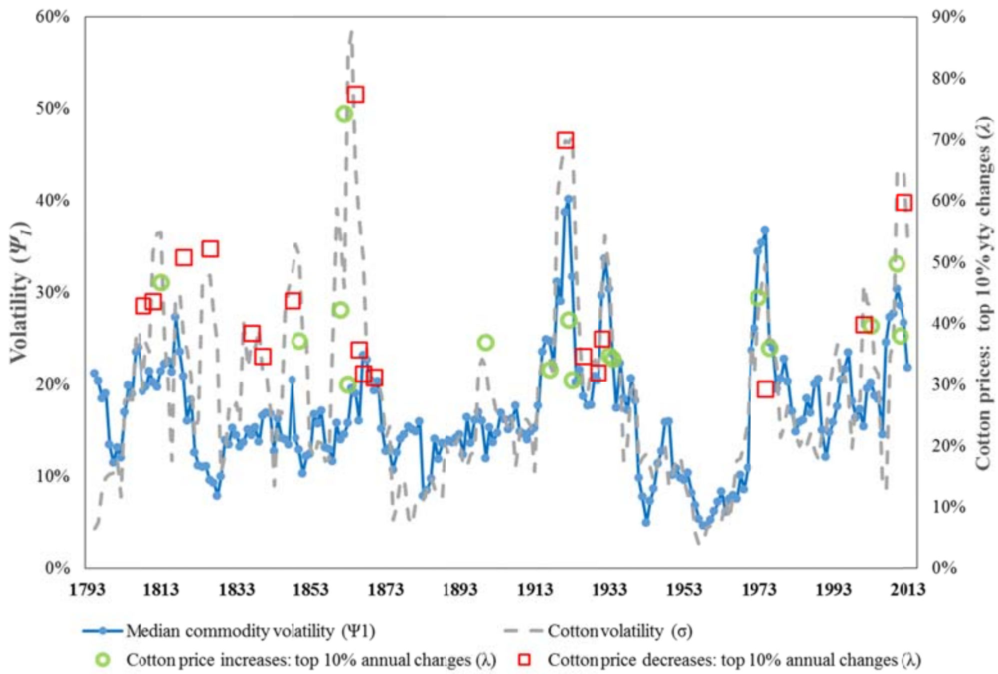

Figure 5. Detecting general commodity price shocks (Ψ_1), 1791-2016, And levels of cotton price shocks (λ).

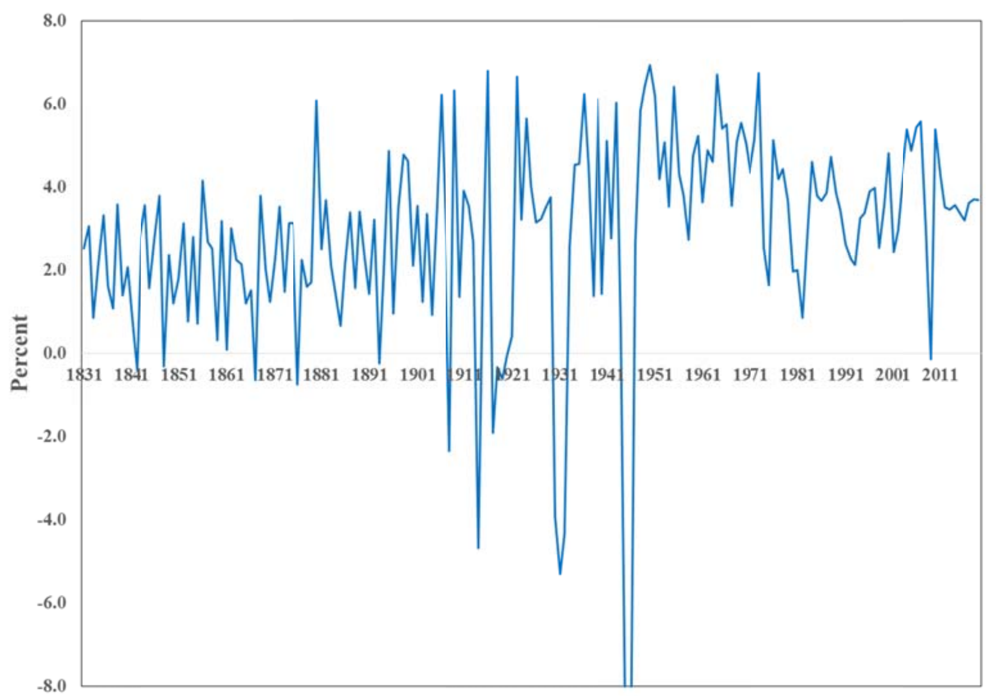

Figure 6. World GDP annual growth, 1831-2019.

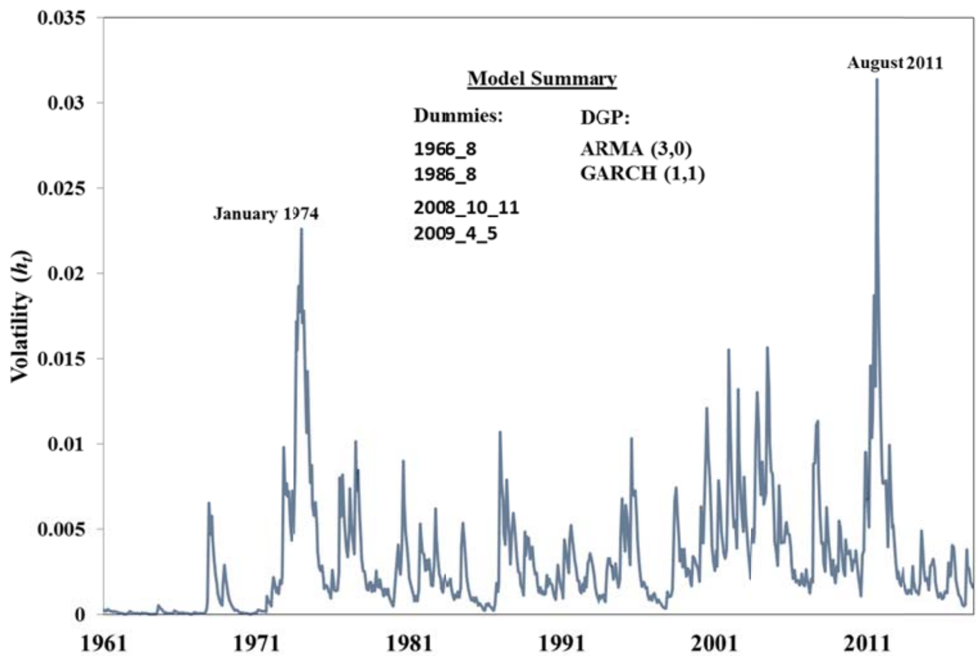

Figure 7. Conditional variance (h_t): U.S. cotton prices monthly, 1961-2017.

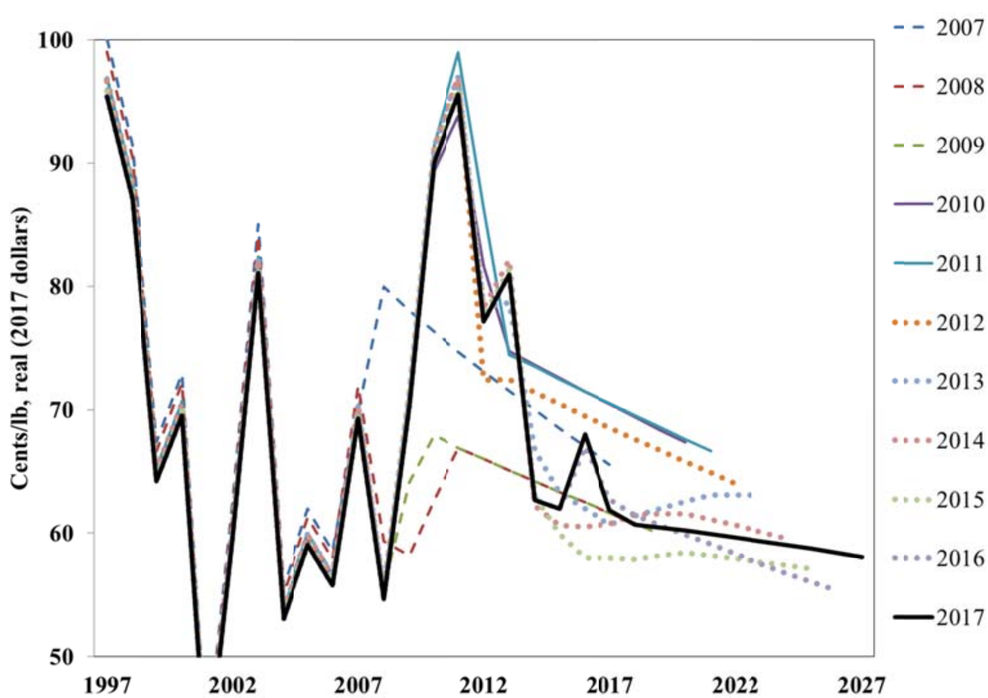

Figure 8. Real (2017 dollars) U.S. upland farm price, USDA baseline forecasts: 2007-2017.

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

	Cycle's largest absolute change (λ_t)		
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		100
1992		-45	
2001-05	-78		54
2009-12	-88		94

†subset of shorter cycles have only one extreme
*positive shock preceded negative shock(s) in cycle

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		