Harvests and Business Cycles in Nineteenth-Century America

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Abstract: Most major American industrial business cycles in the era from the late 1870s to the First World War were caused by fluctuations in the size of the cotton harvest due to economically exogenous factors such as weather. The wheat and corn harvests did not affect industrial production; nor did the cotton harvest before the late 1870s. The unique effect of the cotton harvest on nonagricultural activity in this period can be explained by a standard open-economy Keynesian model of the U.S. economy under the gold standard.

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Economists have long been intrigued by the notion that business cycles are caused by a few types of identifiable, exogenous shocks. For the postwar U.S. economy, one possibility is oil prices, following Hamilton's (1983) observation that (with one exception) the "tendency...for oil price increases to be followed by recessions has in fact characterized every recession in the United States since World War II" (p. 229). The apparent relation between oil supply shocks and economic activity has been explained as an outcome of oil prices' real effects on capital productivity and expenditure patterns (Hamilton, 2000, p. 35), or alternatively as the result of interactions between oil prices and monetary policy (Bernanke, Gertler, and Watson, 1997).

Up to the mid-twentieth century, the prime suspect was crop harvest fluctuations caused by weather and other natural events. William Stanley Jevons (1884) speculated that sunspots affected British industrial activity through crop yields in tropical countries. Many economists asserted that an effect of harvests on industry was evident in the United States (Moore, 1914; Robertson, 1915; Pigou, 1927; H. Stanley Jevons, 1933). At the turn of the twentieth century, A. Piatt Andrew claimed that "one cannot review the past forty years without observing that the beginnings of every movement toward business prosperity and the turning-points toward every business decline… were closely connected with the out-turn of crops" (1906, p. 351).

The pioneering business-cycle research of NBER scholars did not confirm such claims. Wesley Mitchell (1951, p. 58), Arthur Burns (1951, pp. 7-8), and Robert A. Gordon (1952, p. 386) all concluded that farm-sector output appeared uniquely *un*related to business cycles. Gordon speculated that "Agriculture may have played a more important role… during the nineteenth century, particularly, when farm products bulked much larger in American exports than they do now and when agriculture accounted for a much larger share of total economic activity" (p. 386). But Edwin Frickey (1942) found no relation between movements in his annual index of industrial production for 1865-1914 and indices of farm-sector production: "The causal relationships between the agricultural and non-agricultural groups certainly did not express themselves in the form of any simple correlation" (p. 229)." In their narrative *Monetary History of the United States,* Friedman and Schwartz (1963) argued that wheat harvests, specifically, did play a limited role in some pre-1914 cycles, when bumper wheat crops boosted export revenues and hence the U.S. money supply under the gold standard (1963, pp. 97-98, 107, 140-141).

Pre-1914 business cycles remain a topic of current research, which has generally found them to resemble postwar business cycles in the behavior of real variables such as consumption, investment and employment (Backus and Kehoe, 1992; Romer, 1994; Calomiris and Hanes, 1995; Basu and Taylor, 1999). But there has been little recent inquiry into the possible causal role of shocks to agricultural production. Solomou and Wu (1999) argue that weather-related harvest fluctuations affected real GDP in Europe over the late nineteenth century, but only because of their direct effects on the agricultural portion of domestic product. Odell and Weidenmier (2004) argue that the American depression of 1907-08 was the result of another type of real shock, the San Francisco earthquake, through the response of central banks to international gold flows associated with insurance payments. For the interwar (1920s-1930s) period, an extensive modern literature has thoroughly explored possible interactions between the farm sector and industrial business cycles in the U.S. and other countries (e.g. Temin, 1976; Martin, 1998; Madsen, 2001).

In this paper, we re-examine the relation between American business cycles and harvests of the country's staple crops – cotton, wheat, and corn – from the early nineteenth century to the First World War. We focus specifically on the relation between harvests and fluctuations in *nonagricultural* output indicated by industrial production indexes. Our results should alter views of historical business cycles and attract the attention of macroeconomic theorists.

From the end of the 1870s to 1914, year-to-year fluctuations in the American cotton harvest caused business-cycle variations in American industrial production. Indeed, the cotton harvest accounts for *most* major American business cycles of this era, including the depressions of 1884, 1893 and 1895 (and the aborted upturn of 1894), and 1910. The relation between cotton harvests and business cycles was clearly one of cause and effect: it holds for fluctuations due to weather in southern cotton-growing regions – a factor exogenous to economic activity, and unlikely to affect industrial production through other channels. The harvest's effect on the nonagricultural economy was unique to the cotton crop and to the post-1870s era. Industrial production was *not* affected by harvests of wheat or corn, or by cotton harvests in the antebellum period.

After demonstrating these patterns, we propose an essentially monetary explanation. The unique effect of the cotton crop in the post-1870s era is consistent with an open-economy Keynesian model, given the history of U.S. monetary regimes and two more proximate effects of crops' harvests: on export revenues, and on high-powered money demand. We spell out implications of our explanation for available data on monetary quantities, price indexes, exchange rates, and interest rates. In the last section of the paper, we show that these implications are consistent with the data.

Whether or not we are correct about the channel from the cotton harvest and industrial production, our results leave little doubt that cotton harvest fluctuations were the ultimate, exogenous cause of many pre-World War I business cycles.

I. Pre-1914 data on production in agriculture and industry

For nineteenth-century America, indices of industrial production (IP) are the only reliable cyclical-frequency indicators of real activity outside agriculture. For most of the nineteenth century the shortest available frequency is annual.[1] The most comprehensive nineteenth-century IP series, and the only one that covers years preceding the War Between the States, was constructed by Joseph Davis (2004) to indicate production over calendar years from 1790 through 1915. Our samples begin with 1828 because many important components of the Davis index enter during 1827. We present results from samples that end with 1913 to avoid possible effects of special factors associated with the outbreak of the First World War (Friedman and Schwartz, 1963, p. 196), but results were substantially the same from samples extended through 1914.

Two components of the Davis index are directly related to farm output in a way that is undesirable for our purposes: U.S. consumption of raw cotton, and shipments of milled wheat flour. As a robustness check, we also present results from a specially-

[1] Estimates of national unemployment and national income and product accounts can be calculated for census years, based on information from the Federal Census. Annual-frequency estimates of employment and NIPA variables for pre-1914 eras, such as the real GNP series of Robert Gallman or Thomas Berry, are interpolations between these census-year estimates based on IP series or nominal variables such as price indexes (Rhode, 2002; Berry, 1988). The monthly IP index constructed by Miron and Romer (1990) begins with January 1884.

constructed Davis index excluding these two components. For postbellum years, we use the Frickey (1947) annual index of manufacturing production as another check.

In American agriculture, the most important products were animals for slaughter and three "staple" crops: cotton, wheat, and corn (maize). There are no reliable annual data for wheat or corn production over antebellum years, or for livestock over any pre-1914 period.[2] But beginning in 1866, the U.S. Department of Agriculture (USDA) estimated annual production of all three staple crops, based on surveys of thousands of local crop reporters. For the antebellum period, USDA statisticians published annual estimates of cotton production based on different but apparently reliable sources. Year-to-year movements in both the antebellum and postbellum series match narrative accounts of good and bad crops such as Thorp (1926). Thus, we are able to examine harvest fluctuations of cotton, wheat and corn in the postbellum era, and of cotton alone in the antebellum era. Arguably, cotton production was subject to a variety of special factors in the immediate postbellum years, so to avoid their effects our postbellum samples begin with 1869, but our results were substantially the same for samples beginning with 1866.

We define business-cycle industrial fluctuations as deviations from estimated trends in the log of IP series, with trends estimated separately over 1828-1860 and 1869-1913. We refer to these deviations as the “IP gap.” To span most definitions of cyclical fluctuations *versus* trends, we estimate trends two ways: quadratic in time; and using the Hodrick-Prescott (HP) filter with the smoothing parameter set to the conventional value for annual data. As is well known, the HP filter incorporates some relatively high-frequency movements into the trend.

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[2] Strauss and Bean's (1940) annual livestock production figures are dubious interpolations.

Figure 1 shows the standard Davis series IP gap from quadratic trends. Shading represents peak-trough dates of NBER reference cycles. The NBER chronology for pre-1914 cycles has been contested by Romer (1994), Watson (1994), and Davis (2006), who all argue that several pre-1914 peaks and troughs would not be classed as such if NBER researchers had applied standards consistent with those used to identify business cycles in later periods. That said, all NBER peak-trough dates appear as fluctuations in the Davis series. There is no disagreement about the existence - and historical importance - of the major depressions and booms apparent in the figure, including the downturns following 1873, 1883, 1892 and 1895 with the brief upturn in between, 1903, 1907 and 1910.

Parallel to our definition of IP gaps, we define crop harvest fluctuations as deviations of log output from quadratic-time or Hodrick-Prescott trends. Figure 2 shows log output and estimated quadratic time trends for each crop. Table 1 presents statistics on IP gaps (standard Davis index) and harvest fluctiations in the antebellum and postbellum eras. In panel A, IP gaps show slightly greater volatility in the postbellum era and strong serial correlation in both eras. Cotton harvest fluctuations show similar volatility across the antebellum and postbellum eras and no serial correlation. Wheat and corn harvest fluctuations are similar to cotton's in volatility and the absence of serial correlation. Panel B shows contemporaneous correlations across the output series' deviations from quadratic trends. (Deviations from HP trends gave similar results.) None of the cross-correlations is strong.

II. Staple crops in the American economy

Table 2 presents summary statistics on American production and use of the three staple crops over the nineteenth century. The cotton crop was never more than five percent of U.S. GDP, but raw cotton was about half of U.S. visible exports in the antebellum era, about a quarter in the postbellum era. Nearly the entire crop was used as an input to factory textile production. Most raw cotton was exported, primarily to Britain, which had the world's largest cotton textile industry through the early twentieth century. Raw cotton was always a more important input to the British economy than to the American economy, in the sense that the value of cotton consumed and U.S. cotton imports were larger shares of British national product. The U.S. crop's share of the world cotton market (indicated by the industrial world's cotton consumption) fell somewhat from the antebellum to the postbellum era.

Wheat was milled into flour for human consumption. Most of the crop was consumed within the U.S., but wheat and wheat flour still made up about fifteen percent of U.S. visible exports over the postbellum period.

Corn, unlike cotton and wheat, was mainly an input to American agricultural production, fed to draft and meat animals. Thus, valued at market prices the corn crop was a larger share of U.S. income than were wheat or cotton, but the value of corn sold off the farm was smaller, and corn was a much smaller share of visible exports.

Three more aspects of crop production are important here. One is its fundamental seasonality and time lag between planting and harvest. All three crops were harvested within a fall season spanning the months from July through November, and planted in the previous spring or earlier.[3] Another is geographic location. Cotton was planted almost

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[3] Cotton was planted from March through May; the harvest began in August (Covert, 1912, p. 93). In the 1900s, more than sixty percent of the cotton harvest was completed by the end of October (U.S. Bureau of the Census, *Cotton Production in the United States* , Washington, DC : GPO, 1905-1913). Corn was planted in the spring and harvested from early September through November (Covert, 1912, p. 17). Wheat was planted in two distinct seasons: "winter wheat" was planted from September through October; "spring

exclusively in the southern "cotton belt" stretching from North Carolina west to Texas. The bulk of industrial production took place elsewhere, in the Northeast and Midwest. Wheat was grown in the Midwest and West, closer to industrial centers but far from the cotton belt. Corn was concentrated in the Midwest, overlapping wheat areas.[4]

Finally, we note the apparent relations between harvest fluctuations, as we have defined them, and U.S. export revenues. In the postbellum era, export revenues were positively related to both cotton and wheat harvest fluctuations, but they were not strongly related to corn harvests. In the antebellum era, there was no relation between cotton harvests and export revenues.

These patterns are apparent in data on U.S. exports by commodity, which are available on an annual basis starting in the early nineteenth century, and fortunately cover twelve-month spans that correspond closely to one harvest season's exports (see Appendix B). We regressed the log of revenue from all crop-related exports - the sum of revenue from raw cotton, wheat and wheat flour, corn and corn flour - on the preceding season's harvest fluctuations, quadratic time trend terms and the log of the WPI over the twelve months preceding the harvest season (ending June) to control for the general price level. Table 3, columns (1) – (3) show results. For the antebellum era, the coefficient on the cotton harvest fluctuations is not significantly different from zero (and close to zero in point estimate). For the postbellum era, the cotton harvest coefficient is positive and

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wheat" was planted from March through May. But both wheat plantings were harvested in late summer, mostly in July and August (Covert, 1912, pp. 30, 41; *Monthly Crop Reporter* Sept.1920, p. 100).

[4] In the postbellum period, about 70 percent of the U.S. wheat crop came from Ohio, Michigan, Indiana, Illinois, Wisconsin, Minnesota, Indiana, Missouri, the Dakotas, Kansas and Nebraska (U.S. Department of Agriculture, 1955). Over 1910-1914, about sixty percent of the corn crop came from Iowa, Illinois, Missouri, Indiana, Nebraska, Ohio and Kansas (U.S. Department of Agriculture, 1954). In the late nineteenth century the cotton belt states developed a large cotton textile industry, but as late as 1895 northern mills consumed two-thirds of the cotton used within the U.S. (Hammond, p. 343).

significant at the one percent level. When wheat and corn fluctuations are added to the right-hand side (column 3), the wheat coefficient is positive, significant at the one percent level, and of similar magnitude to the cotton coefficient. The corn coefficient is smaller in magnitude and significant only at the eight percent level.

The change from the antebellum to the postbellum era in the relation between cotton harvests and export revenues appears to reflect the behavior of cotton prices, rather than export quantities. In the antebellum era, cotton harvest fluctuations were positively related to export quantities but *negatively* related to cotton prices. In the postbellum era, cotton exports were still positively related to harvest fluctuations, but the negative relation between harvests and cotton prices was weaker, leaving a positive relation between harvests and export revenue.

These patterns are indicated by the remaining columns of Table 3. Columns (4) and (5) show results of regressing log cotton export quantity (in pounds) on harvest fluctuations: coefficients are positive for both eras. For (6) – (9), left-hand side variables were crops' spot prices in American markets (New York for cotton, Chicago for wheat and corn) averaged over the twelve months beginning with the fall harvest season (July through the following June).[5] The antebellum cotton harvest coefficient indicates an elasticity close to one. (The p-value testing a hypothesis that the coefficient is equal to negative one is 0.67.) The postbellum cotton harvest coefficient indicates a smaller

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[5] For sources see Appendix B. Of course, these prices are at best rough indicators of prices received by exporters. In the antebellum period, cotton was sold in many port cities, and there appears to have been substantial short-run variation in cotton prices across ports (Hammond, 1897, pp. 278-291; Woodman, 1968, pp. 19-42). Unfortunately, there is no way to identify the fraction of total exports sold at a given local price (cotton shipped from a given port was not necessarily sold by the exporter at that port's price) and price records are unavailable from many markets. In the postbellum period, there was tighter correlation of prices across local markets, but there were active futures markets in both cotton and wheat (Stevens, 1887), so spot prices are not necessarily equal to export prices.

elasticity. (At the one percent level, one rejects the hypothesis that the coefficient equals negative one.) An explanation of this change in the relation between U.S. cotton harvests and prices is beyond the scope of this paper, but it is consistent with the decrease after the antebellum era in the U.S. crop's share of the world market (Table 2). Perhaps more importantly, cotton futures markets came into existence over the 1860s, which may have tended to reduce the sensitivity of prices to short-run supply shocks.[6]

Column (8) shows that U.S. harvests had little relation to wheat prices, consistent with the relatively small share of U.S. wheat in the world market. This explains why wheat and cotton harvests appear to affect U.S. export revenues with similar magnitudes in column (3), even though wheat and wheat flour were a smaller share of U.S. export revenue. Corn prices, in column (8), had a strong negative relation to corn harvests.

IV. Causes of harvest fluctuations

What caused harvest fluctuations? Were they a response to nonagricultural business cycles (through demand for crops, for example)? Do they reflect some third factor or factors that affected output in both agriculture and industry? We can begin to answer these questions by regressing fall harvest fluctuations on the IP gap in the same calendar year and the previous year. Given the fundamental lag between planting and harvest, there is no reason to believe that a common third factor could affect crop output *before* it affected IP. Thus, effects on harvest fluctuations of nonagricultural business cycles *or* common third factors should be revealed by positive coefficients on current

[6] The introduction of futures markets may have allowed textile manufacturers and middlemen to hold larger stocks of cotton, which could reduce the effect of supply fluctuations on spot market prices. Textile manufacturers and middlemen used futures to hedge the risk of a decrease in the value of their stocks of cotton, which allowed them to hold larger stocks with smaller risk (Hammond, 1897, pp. 300-314; Woodman, 289-294). According to Hammond (1897, p. 311), "not the least of the services which the

and/or lagged IP gaps. Performing this exercise, we find no evidence that cotton or corn harvest fluctuations were caused by industrial business cycles or common third factors. For the wheat crop only, there is some evidence of a relation between the harvest and IP in the same year.

Table 4 shows results. The next-to-last row of the table shows the *p*-value on a test of the hypothesis that all of the regression coefficients are equal to zero. The last row shows the p-value for a test that the IP gap coefficients are both zero. For cotton and corn, one cannot reject the hypothesis that coefficients on all of the right-hand side variables are equal to zero. For the wheat crop only, using HP trends, the coefficient on the current-year IP gap is positive and significant at the three percent level.

The apparently weak relations between crop output and IP in the same year are consistent with observations of early NBER researchers, who found no conformity between business cycles and measures of crop outputs or farm employment (Burns, 1951, pp. 7-8; Gordon, 1952, p. 385-387; Kuznets, 1951, p. 159). Mitchell (1951) concluded that "the basic industry of growing crops does not expand and contract in unison with mining, manufacturing, trading, transportations and finance," and argued this was because: "farmers cannot control the short-term fluctuations in their output. To a limited extent they can shift their acreage from one crop to another, and alter the intensity of cultivation. But the factor that dominates year-to-year changes in the harvests is that intricate complex called weather. Plant diseases and insect pests also exert an appreciable influence." (pp. 56, 57).

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system of future delivery contracts has rendered to the cotton trade, is the greater steadiness in prices which it has introduced."

Weather, plant diseases and pests are indeed plausible causes of harvest fluctuations, as we have defined them. Contemporary observers often attributed drastic changes in crop output to these factors, and many of the fluctuations apparent in figures 2-4 are associated with well-known events of this type.[7] Their effects are also consistent with the absence of serial correlation in harvest fluctuations. Long-run effects of most newly-introduced crop diseases and pests were mitigated by innovative responses in agricultural technique (Olmstead and Rhode, 2002). Year-to-year effects depended on interactions with weather. The boll weevil, for example, which entered the U.S. and affected cotton production beginning in 1892, caused most damage in years of especially wet, warm weather (Henry, 1925, p. 523; Kincer, 1928). As we will detail below, a number of studies have found systematic, and technologically sensible, relations between time-series weather data and annual variations in harvests of all three crops.

V. Effects of harvests on industrial production

To observe the effects of harvest fluctuations on nonagricultural business cycles, we begin by running OLS regressions of IP gaps on the previous fall's harvest fluctuations and lagged IP gaps. Results indicate a positive relation of very high statistical significance between a year's IP gap and the previous fall's cotton harvest, within the postbellum era only. There is no such relation for the postbellum wheat or corn harvests, or for the cotton harvest in the antebellum era.

Next, we ask whether cotton harvests were related to IP throughout the postbellum era, or only within a portion of the era. Given the small number of observations in question, we cannot claim definitive evidence on this point. However, in

[7] For cotton, infestations of cotton worms in 1846, 1866, 1868 and the early 1870s, of the boll worm in

a variety of specifications, the relation between cotton harvests and IP does *not* appear within the 1870s, though it holds in every other decade from the 1880s through 1913. Thus, we conclude that the cotton harvests' effect on IP was most likely confined to the period after the 1870s.

Finally, to establish the direction of causality between cotton harvests and IP, we observe the relation between the IP gap and cotton harvest fluctuations specifically due to weather, using time-series weather data in two-stage least squares. Recall we have found no reason to believe *any* cotton harvest fluctuations reflect reverse causation from IP or common effects of third factors. But the natural experiments created by weather events reveal causality in an unusually definitive way. In the nineteenth and early twentieth centuries, if not the twenty-first, weather was unaffected by industrial activity. There is no reason to believe that the weather relevant for cotton could affect industrial production through channels other than the cotton harvest. Industrial production might be affected by northern weather – for example, an especially cold winter could hinder shipping by freezing waterways. But cotton-growing was affected by southern weather. Our IV results confirm that the post-1870s relation between the fall cotton harvest and the following year's IP was indeed one of cause and effect. They are also consistent with the absence of similar effects from wheat and corn.

OLS regressions

Table 5, panel A shows results of regressing IP gaps on the previous two years' IP gaps and the previous two years' harvest fluctuations, for various IP series and trend definitions. The first four columns show results for the standard Davis index and the

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1881, and of the boll weevil in 1909 and 1915; the Mississippi River flood in 1892 (Thorp, 1926).

Davis index excluding textiles and food, using quadratic trends. The next four columns show results for two sector-specific component indices of the Davis series which are particularly far removed from crop inputs: metals (mainly iron and steel production), and machinery. Results from HP trends and the Frickey index are in (9) – (11). All variants give similar results. For the postbellum era, the coefficient on the previous years' cotton harvest fluctuation is positive and significantly different from zero at the one percent level; coefficients on the wheat and corn harvests are not significantly different from zero and are sometimes negative in sign. For the antebellum era, the coefficient on the prevous year's cotton harvest is not significantly from zero (and is negative in sign). Coefficients on the second lags of crop harvests and IP gaps are not significantly different from zero in any samples, individually or jointly (p-values in the last row of the table), except for the machinery index in the antebellum sample. Panel B shows results when the second lags of the IP gap and harvest fluctuations are excluded from the right-hand side. This has little effect on the estimated coefficients on the previous year's harvests.

Simple scatterplots of the first-difference of (log) IP gap against the previous fall's harvest fluctuation should give good representations of the patterns indicated by Table 5, because estimated coefficients on the previous year's IP gap are close to one, and correlations across different crops' harvest fluctuations are low. Figure 3 a) is a scatterplot for the cotton harvest (standard Davis series, quadratic time trends) in the postbellum period. For comparison, figures 3) b), c) and d) shows the corresponding scatterplots for the antebellum cotton harvest and the wheat and corn harvests. The unique postbellum relation between cotton harvests and IP is clearly apparent in the scatterplots. The obvious outlier is the observation for 1908 (cotton harvest of fall 1907).

The 1870s versus *the rest of the postbellum era*

To observe whether cotton harvests affected IP throughout *all* of the postbellum era, we examine the year-by-year correspondence between the IP gap forecast by cotton harvests and the actual IP gap (standard Davis index, quadratic time trend). Figure 4 plots forecasts from two different regressions. For one, the IP gap was regressed on the previous two years' cotton harvest fluctuations. For the other, the IP gap was regressed on the previous year's IP gap and cotton harvest. To produce the forecast from the second regression, values for lagged IP gaps were lagged forecast values (starting from the true IP gap values for 1869 and 1870), so that forecast IP gaps are determined by cotton harvests *alone*.

In the figure, there is no obvious relation between the forecast and actual IP gaps within the 1870s. After the 1870s, there is an obvious correspondence: all of the big swings in IP forecast by the cotton harvest appear in the actual IP gap, with one exception. The exception is around 1899, when the harvest forecasts a large downturn while actual IP grows to a peak at 1902. With respect to major depressions, the harvest accounts for those following 1883, 1892, 1895, and 1910. It does not account for the downturn following 1907.

Table 6 shows results of a specification to test a hypothesis that the cotton-harvest coefficient was different in the 1870s from the rest of the sample. Here the right-hand side includes the previous year's IP gap, the previous year's cotton harvest, a dummy variable for observations 1870-1879 and an interaction between the dummy and the previous year's cotton harvest. If there was no relation between IP gaps and the cotton harvest within the 1870s, three patterns should appear: the cotton harvest coefficient should be larger than that from the corresponding specification in Table 5; the interaction-term coefficient should be negative; and the sum of the interaction coefficient and the cotton harvest coefficient should be close to zero, implying that the cotton harvest coefficient is zero within 1870-1879. These patterns hold for all variants.

To see whether the 1870s years were *unique* in the apparent absence of a cotton harvest effect on IP, we ran 35 separate OLS regressions, defining a dummy and interaction term for each successive ten-year span: one regression with terms defined for 1871-1880; another with terms defined for 1872-1881; and so on. The resulting coefficients on the cotton harvest, and the sum of the cotton harvest coefficient and the interaction term, are plotted in Figure 5, with the last year of each ten-year span on the horizontal axis. Thus, at 1880, the figure plots the coefficients from column (1) of Table 6. The 1870s indeed appear to be unique: no ten-year span *outside* the 1870s gives a shift coefficient that is negative and close in magnitude to the cotton-harvest coefficient; and defining the shift terms for the 1870s span gives the largest magnitude for the cotton-harvest coefficient.

IV results

The U.S. Weather Bureau began operations in summer 1891, taking over and eventually expanding data-gathering operations that had been handled earlier by a variety of Federal agencies. In the early 1890s the Weather Bureau began to publish time series on monthly average temperature and precipitation, by state. In a pioneering statistical work, Moore (1917) showed that a substantial portion of the annual variation in a number of southern states' cotton harvests over 1894-1914 could be forecast from just three of these Weather Bureau series (May rainfall, July temperature, August temperature), expressed as deviations from the preceding three years' average value (p. 119).

Published Weather Bureau series do not extend back before the late 1880s. However, for the postbellum era we were able to construct measures of the same variables for the cotton belt states as a whole, from databases of observations by thousands of individual weather stations. Unfortunately, the same weather variables are not available for a meaningful portion of the antebellum era (see Appendix A).

We ran two-stage least squares regressions of IP gaps on the previous year's cotton harvest fluctuations 1880-1913. Following Moore as closely as possible, the variables to predict cotton harvests 1879-1912 in the first stage were the three cotton belt weather variables, expressed as deviations from the preceding three years' average value. To allow for possible changes in weather effects associated with the arrival of the boll weevil, and for differences in the nature of the weather data associated with the establishment of the civilian Weather Bureau, we allow the first-stage weather coefficients (and the constant) to differ before 1892.

For comparison, we performed similar exercises for the postbellum wheat and corn harvests, guided by early twentieth-century studies of relations between those crops and Weather Bureau data (Bean, 1942; Moore, 1920; Hanney, 1931; Henry et. al., 1925; Smith, 1914; Wallace, 1920; Kincer and Mattice, 1928; Mattice, 1931). Based on those studies we chose four weather variables to predict wheat harvest fluctuations (January temperature, May temperature, June precipitation, and precipitation in October of the year preceding the harvest - recall some fall-harvest wheat was "winter" wheat, planted in the previous fall) and four variables for corn (July and August precipitation, April and

July temperature). We constructed postbellum time series of those variables from observations of individual weather stations located in grain belt states. Otherwise our first-stage specifications for wheat and corn were exactly the same as for cotton.

Generally, each crop's set of weather variables give a strong instrument for its own harvest fluctuations, but are not strongly related to other crops' harvests. This is shown by panel A of Table 7, which shows R2's and p-values from regressions of harvests on the different sets of weather variables.

Panel B shows results of the 2SLS regressions for 1880-1913; results of matching OLS regressions are in panel C. The first three columns of 7B show results of specifications following Table 5B, with IP gaps (standard Davis series, quadratic trends) regressed on the previous year's IP gap and harvest fluctuation. The last three columns show results of regressing the first difference of log IP on the previous year's harvest fluctuation alone. In all specifications, coefficients on cotton harvests are positive and significantly different from zero at the one percent level. Coefficients on the wheat and corn harvests are not significantly different from zero, and are close to zero in magnitude. Other trends and IP series gave similar results.

V. Explanation

Why did the cotton harvest affect U.S. IP after the 1870s but not in the antebellum era, when raw cotton was a larger share of U.S. output and income? Why was IP affected by the cotton harvest alone after the 1870s, even though wheat and corn were similar shares of national income and wheat harvest fluctuations had similar effects on export revenues? In this section of the paper, we briefly consider and reject a real explanation suggested by the literature on oil-price shocks. At greater length, we propose a monetary explanation in the context of a simple open-economy Keynesian model.

Real explanation: cotton harvests as shocks to raw material supply

The modern real business cycle literature has not dealt with harvest shocks as such.[8] The persistent productivity shocks common in RBC models are essentially different from harvest fluctuations as we have defined them. Crop output variations caused by weather, for example, affect the outcome of factor inputs applied in the past, not the expected productivity of current or future inputs. A single good harvest will not attract labor or capital into farming, except to the degree that they are needed to bring in a larger crop. Nor is there any sense in which a positive harvest fluctuation could release labor to nonagricultural sectors.

However, models of oil shocks as disruptions to the supply of a sector-specific raw material input (e.g. Hamilton, 1988; Aguiar-Conraria and Wen, 2007) could perhaps be applied to the supply of cotton as an input to the cotton textile industry. An obvious test of this approach is to observe the relation between U.S. cotton harvests and British IP. As noted above, American cotton was always a more important input to the British industrial economy than to America's. The drastic reduction of cotton supply during the War Between the States had clear effects on the British economy (Henderson, 1934) which were not apparent in the northern U.S. (Hammond, 1897, p. 265). If the cotton harvest affected U.S. IP through cotton's role as a raw material input, one would expect

[8] Da-Rocha and Restuccia (2006) present a model to show that the existence of a large farm sector within an economy can amplify the effects of productivity shocks *outside* agriculture, by increasing the elasticity of labor supply to non-agricultural sectors.

to observe stronger effects on British IP. British IP gaps can be defined in the same way we define U.S. IP gaps using Hoffman's (1955) index of British IP.

Table 8 shows results of regressing each country's IP gap on the other country's IP gap, its own lagged IP gap, and the lagged U.S. cotton harvest fluctuation. With the U.S. IP gap on the left-hand side, results are as before with respect to the cotton harvest coefficient: it is positive and significant at the one percent level in the postbellum era, whether the postbellum sample begins with 1870 or 1880. With the British IP gap on the left-hand side, in the antebellum era the cotton coefficient is positive and significantly different from zero at the seven percent level. But in either postbellum era, the cotton coefficient is very small in magnitude and not significantly different from zero at conventional levels. Thus, it does not appear that the cotton harvest had an effect on British IP similar to its effect on U.S. IP in the postbellum era.

Monetary explanation

The various effects of harvests on industrial business cycles in the U.S. and Britain are consistent with a simple open-economy Keynesian model along the lines of many that have been used to analyze monetary policy in open economies (e.g. Svensson, 1997; Ball, 1999), with the monetary side of the model tailored to the regime prevailing in the postbellum U.S. Such a model also has testable implications for monetary quantities, price indexes, exchange rates, and interest rates. To see this, it is necessary to go into some detail about the history of American monetary regimes and available data.

In the antebellum era the American dollar was officially on a bimetallic standard. U.S. trading partners were on gold, silver, or bimetallic standards. Up to 1834, the U.S. mint's prices left gold undervalued relative to the prices paid by the largest bimetallic country, France, so that the dollar was effectively silver; in 1834 a revision of the U.S. mint's prices left silver undervalued, so the dollar became tied to gold instead (Friedman, 1990). In 1862 redemption of the dollar in gold was suspended: dollars began to trade at a floating rate against gold. Over the 1870s, most U.S. trading partners adopted gold convertibility, constituting a monetary regime known as the international gold standard (Meissner, 2005). Meanwhile, U.S. policymakers took steps to deflate the price level and bring the dollar price of gold back to the pre-1862 parity. In January 1879, the Treasury again began to redeem dollars in gold. Up until the presidential election of 1896, financial-market participants appear to have perceived a risk that the dollar would again be floated or devalued (Calomiris, 1993). At the outbreak of the First World War in 1914, belligerents took steps to control gold payments, eventually suspended currency redemption in gold.

Thus, the period marked by a clear cotton-harvest effect on U.S. IP, from the end of the 1870s through 1913, coincides with U.S. membership in the international gold standard. Under this regime, the excess (deficit) of a country's trade balance over its international capital outflow was balanced by an inflow (outflow) of specie, while currency exchange rates were tied to the "parity" value defined by relative specie content: the exchange rate between two financial centers could not remain outside the bounds that just covered the costs of transporting specie between them. Throughout the period, London financial markets played a special role. Most international payments between any two countries were negotiated through claims to London sterling funds. Arbitrage tied short-term interest rates in continental financial centers tightly to London's; rates were less tightly linked across continental financial centers (Bordo and MacDonald, 2005).

The United States, unlike most European countries, had no central bank in this period. The high-powered money supply held by banks and the nonbank public consisted of gold and various forms of nongold money backed by a promise of redemption in gold by the U.S. Treasury. International payments were negotiated through claims to London sterling purchased from, or sold to, financial institutions in New York City (Myers, 1931, p. 338-350). The effective exchange rate was the dollar price in New York of claims to London funds. International gold shipments occurred when this exchange rate approached (or perhaps exceeded) the "gold points" determined by the costs of shipping gold between New York and London. These costs were low enough to hold the rate within a range that was too small to make a difference for the relative price of foreign goods: for purposes of international trade, the exchange rate was practically fixed.[9]

Given the fixed exchange rate, it is likely that dollar prices of internationally-traded commodities such as cotton and wheat were directly determined on international markets. But it appears that most U.S. prices were not constrained by purchasing-power-parity except in the very long run (Lipsey, 1984; Diebold, Husted and Rush, 1991; Lothian and Taylor, 1996). Studies of the U.S. Phillips curve in pre-1914 periods generally find a strong positive relation between real activity and inflation, rather than the change in inflation (Gordon, 1990; Backus and Kehoe, 1992). This is consistent with an expectations-augmented aggregate supply function assuming U.S. prices were expected to return to a PPP level eventually, but could deviate at business-cycle frequencies (Alogoskoufis and Smith, 1991).

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[9] According to Officer (1996), the New York-London gold points were within two-thirds of a percent above or below parity from the 1880s through the 1900s (1996, Table 9.20). According to Canjels, Prakash-Canjels and Taylor (2004), the largest deviation from parity in the New York-London rate on any *day* from 1879 through 1913 was 1.06 percent (p. 870).

Along with arbitrage between exchange rates and gold prices, financial institutions in New York and London engaged in many types of arbitrage between the two cities' asset markets, responding to differences in interest rates and expected future exchange-rate movements within the gold points (Goodhart, 1969). Thus, capital flows to the postbellum U.S. were clearly sensitive to expected rate-of-return differentials between New York and London. However, the weight of empirical evidence suggests that uncovered interest-rate parity did not hold between New York and London: there was imperfect rather than perfect international capital mobility to the U.S.[10]

Commercial paper was the most liquid short-term asset, available throughout the country, with an observable interest rate: it was actively traded at market-determined prices in New York. Banks all over the country, including rural banks, bought commercial paper, in the New York market through the agency of a correspondent bank or locally from an agent of a national commercial-paper dealer (James, 1978, pp. 102, 174-198).[11] Returns on these assets constituted the opportunity cost of funds for banks' loans to local borrowers (Sylla, 1969). The supply of loans through the bank credit channel – that is, the rates banks charged and the degree of credit rationing – may have

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[10] At times, the New York-London interest rate spread obviously exceeded the range of possible future exchange-rate variation *assuming* the dollar remained tied to gold (Morgenstern, 1959, 166-68; Giovannini, 1993, pp. 133-136). But financial market participants may have factored in a risk that the dollar would be devalued or floated, at least before 1896. Foster (1994) finds clearer evidence against uncovered interest-rate parity in seasonal patterns: month to month, New York interest rates were relatively low just when financial market participants should have been expecting a regular seasonal depreciation of the dollar. Studies of the covered differential - the spread between London interest rates and New York investments that were not subject to the risk of a dollar devaluation - generally indicate that covered interest-rate parity failed to hold at seasonal or business-cycle frequencies (Calomiris and Hubbard, 1996; Obstfeld and Taylor, 1998, pp. 361-363; Juhl, Miles and Weidenmier, 2005). Calomiris and Hubbard (1996) conclude that "Clearly, interest rate parity did not hold perfectly across the Atlantic" (p. 195).

[11] Another money-center asset held by banks all over the country was correspondent bank accounts in New York (James, p. 109-111), but these accounts did not pay an observable market rate: the return an out-of-town bank received on its New York account consisted of payment and other services provided by the correspondent bank *plus* explicit interest at an effectively fixed rate (James, p. 103, 109-111).

been more important to the industrial economy in the nineteenth century than in later eras (Miron, Romer and Weil, 1994). Certainly, the pre-1914 American economy was subject to financial panics which affected both the demand for high-powered money and the supply of loans corresponding to any given interest rates on liquid bonds and bills.

The following model is meant to describe potential effects of crop harvests in this economy, focusing on variables that have a relatively straightforward correspondence to available data. Data sources and details are in appendix B.

Model

Variables correspond to average values or changes over a twelve-month span starting with one harvest season, ending just before the next harvest season. Variables subscripted (-1) are values for the preceding twelve-month span. All variables other than interest rates and inflation rates are expressed in logs or deviations of logs from long-run trend values. All coefficients' signs are positive, except where noted.

The model has a conventional IS curve:

$$(1) \qquad y = -\gamma_r (i - E\pi) + \gamma_{lag}\, y_{-1} + \varepsilon_y$$

where y is nonagricultural output over the months of the post-harvest period, i is the short-term interest rate averaged over the months of the post-harvest period, $E\pi$ is the average expected rate of price inflation over corresponding maturities, and γ_y reflects all other factors affecting nonagricultural output. In terms of available data, we take y to be positively correlated with deviations from trend in an IP index, and i to be the New York commercial paper rate for which there are monthly data beginning in the late 1850s. Missing from expression (1) is any depiction of the bank credit channel. Unfortunately, no data indicate cyclical-frequency movements in required returns to bank lending, or the degree of bank credit rationing, in a straightforward way.[12] To the degree that shocks to the bank credit channel and more general "credit crunches" are triggered by high interest rates (a possibility discussed by Romer and Romer, 1990, p. 187), they amplify the interest-rate coefficient in (1).

Realized inflation over the post-harvest period follows a pre-1914 Phillips curve:

$$(2) \qquad \Delta p = \alpha y + \varepsilon_p$$

where Δp is the change in the (log) price level across the harvest and post-harvest months. ε_p reflects "cost-push" shocks. For the price level, the best available cyclical-frequency series are indices of wholesale prices.[13] The standard monthly wholesale price index for pre-1914 eras (Warren and Pearson [1932] linked to the BLS index) puts heavy weight on prices of raw cotton, wheat and corn, so we also make use of a WPI constructed from the standard series' components *excluding* raw farm products and foods.

High-powered money demand (following standard empirical specifications [Goldfeld and Sichel, 1990]) is:

$$(3) \qquad m - p = \mu_y y - \mu_i i + \mu_{lag} (m_{-1} - p_{-1}) + \varepsilon_{md} \quad \text{where } 0 \le \mu_{lag} \le 1$$

where m is the quantity of money and p is the log price level at the end of the post-harvest period. The change in the high-powered money supply across the period is:

$$(4) \qquad \Delta m = g + \varepsilon_{ms}$$

where g is the international gold inflow over the period (as a fraction of the pre-harvest money supply) and ε_{ms} reflects changes in the supply of nongold high-powered money.

[12] From pre-1914 bank call reports, one can calculate the ratio of reported earnings from loans to outstanding loan balances. A number of studies (e.g. Bodenhorn, 1995) have used this figure to indicate long-term trends in required returns to bank lending. Its relation to cyclical-frequency movements is not obvious.

Monthly data on gold flows and high-powered money supply components are available beginning in the late 1870s.

The gold inflow is equal to the balance of international payments from capital flows and net exports. Assuming exchange-rate fluctuations are too small to affect the relative price of foreign goods, a log approximation is:

$$(5) \qquad g = \theta_{CF} (i - i^{*} - E\dot{e}) - \theta_y y - \theta_p p + \varepsilon_{bop}$$

The first term on the right-hand side of (5) describes capital flow, determined by the spread between the domestic interest rate and the expected return to foreign short-term assets. i^* denotes the foreign interest rate, corresponding to the London open-market bill rate (available from the early nineteenth century on). $E\dot{e}$ is the expected change in the log exchange rate over corresponding maturities. The next two terms account for possible effects on net exports of nonagricultural output (through domestic demand for imports) and the price level (a higher domestic price level reduces the relative price of foreign goods). Factors affecting net exports at given values of domestic income and the price level are reflected in the disturbance term γ_{bop} .

Gold flow is also related to the post-harvest period's average exchange rate, on the assumption that a larger gold flow over the period causes the rate to be driven to the gold point for a larger fraction of the period's days.[14] Thus:

$$(6) \qquad e = - \eta g + \varepsilon_e$$

[13] There are no true GDP (or GNP) deflators or CPIs for most pre-1914 years (Hanes, 1999).

[14] Alternatively, one could assume that the marginal costs of shipping gold at a particular point in time increased with the amount of gold shipped, as argued by Canjels, Prakash-Canjels and Taylor (2004). In that case, the exchange rate on a particular day could range further from parity when the balance-of-payments gap was bigger.

where e is the average dollar price of London sight exchange in New York, available from January 1879.

Finally, expected inflation in (1) can be related to experienced inflation:

$$(7) \qquad E\pi = - \varphi_\pi \Delta p + \varepsilon_{E\pi}$$

and expected exchange-rate change in (6) can be related to the post-harvest period's average exchange rate:

$$(8) \qquad E\dot{e} = - \varphi_e \, e + \varepsilon_{Ee}$$

We need not specify the signs of φ_π and φ_e, which depend on the nature of expectations (rational or otherwise) among other things. If a relatively low exchange rate is usually accompanied by expectations of a future rise, consistent with the long-run stability enforced by the gold standard, then $\varphi_e > 0$. If the price level is believed to be mean-reverting or a random walk, then $\varphi_\pi \geq 0$. We do have to make two assumptions about parameters' relative values. Making some substitutions gives:

$$(9) \qquad y = [\, - \gamma_r \, i + \gamma_{lag} \, y_{-1} + \varepsilon_y - \gamma_r \, (\, \varphi_\pi \, \varepsilon_p + \varepsilon_{E\pi} \,) \,] \, / \, \beta_1$$

$$\text{where } \beta_1 = (\, 1 + \alpha \, \varphi_\pi \, \gamma_r \,).$$

$$(10) \qquad g = [\, - \theta_y - \theta_p \, p + \theta_{CF} (\, i - i^* \,) + \varepsilon_{bop} + \theta_{CF} (\, \varphi_e \, \varepsilon_e - \varepsilon_{Ee} \,) \,] \, / \, \beta_2$$

$$\text{where } \beta_2 = (1 + \theta_{CF} \, \varphi_e \eta).$$

We must assume that $\beta_1 > 0$ and $\beta_2 > 0$, which means an exogenous increase in the domestic interest rate would tend to reduce output (expression 9) and draw in gold (10).

Harvest fluctuations enter the model through the disturbance terms. "Real" effects on production costs or spending would correspond to relations between harvest fluctuations and γ_y in (1) and/or ε_p in (2). We focus instead on possible effects of harvest fluctuations through the monetary side, which affect nonagricultural output and inflation only through the interest rate *i*.

Harvest effects on export revenues and potential high-powered money supply

We have shown that both cotton and wheat harvest fluctuations were positively related to crop export revenue in the postbellum era. Denoting a harvest fluctuation by *h,* that means $\partial\gamma_{bop} / \partial h > 0$. By itself, this effect would tend to create a positive relation between harvests and nonagricultural output. Consider the effect of a bumper harvest. From (5), the positive balance-of-payments disturbance must be accompanied by some combination of a decrease in the international interest-rate spread and a larger gold inflow. From (4), a larger gold inflow means faster growth in the money supply. From (3) and (1), faster money-supply growth must be accompanied by a decrease in U.S. interest rates (consistent with the decrease in the international interest-rate spread) and an increase in nonagricultural output.

Fels (1959, pp. 60, 87, 181, 220) and Friedman and Schwartz (1963, pp. 97-99, 107, 140-141) argue that wheat harvests affected U.S. real activity in this way in the postbellum gold-standard period. Oddly, neither study mentions cotton harvests in the same context. But many pre-World War I contemporaries argued that both the cotton and wheat harvests affected money-market conditions, associating big crops with gold inflows and lower short-term interest rates (e.g. Monetary Convention 1898, p. 220; Sprague, 1903, p. 50; 1915, p. 499; Andrew, 1906, p. 326).

This explanation of the cotton harvest effect is consistent with the absence of an effect on British IP, or on U.S. IP before the end of the 1870s. Before the restoration of dollar-gold convertibility in January 1879, the mechanism need not operate.[15] Under the antebellum specie standard, export-revenue shocks might have affected the U.S. economy through monetary channels.[16] But in the antebellum era, cotton harvest fluctuations were not related to export revenue

Of course, the positive relation between export revenues and the wheat crop suggests that the latter should also have had a positive effect on IP. Thus, the puzzle is the *absence* of a wheat harvest effect on IP.

In principle, the potential effect of wheat export-revenue fluctuations on the U.S. money supply could have been blocked by the actions of monetary authorities. For whatever reason, Treasury actions could have created a negative relation between wheat harvests and the nongold money supply so that $\partial\gamma_{ms} / \partial h < 0$: gold inflows would merely replace nongold high-powered money with no effect on the total money supply.[17]

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[15] We do not mean to argue that the 1870s monetary regime was equivalent to a simple fiat-money floating exchange-rate regime. Some contracts (such as federal government bonds) were paid in gold dollars at the antebellum rate. Banks offered gold-dollar accounts and held gold reserves, and gold dollars remained the medium of exchange in the far West (Friedman and Schwartz, 1960, pp. 26-29, 58, 83). Calomiris (1988) argues that in the later 1870s the dollar-gold rate was pinned down by a firm expectation of resumption in 1879, and the money supply was endogenously determined by international flows given the Treasury's efforts to amass a gold reserve. On this argument, one might expect the harvest-export revenue-interest rate mechanism to operate in the late 1870s, before resumption.

[16] Friedman (1990) and Flandreau (1996) argue that the silver, gold and bimetallic standards prevailing through the 1850s constituted a single specie standard essentially similar to the international gold standard, because the gold-silver price ratio was fixed by the policy of bimetallic France.

[17] The nongold high-powered money supply consisted of greenbacks, silver notes and national banknotes, and silver coins. The Treasury also held money of all types in its vaults, in a stock which varied over time as a result of imbalances between Federal payments and revenues and as the Treasury transferred funds between its vaults and commercial bank accounts. Thus, the supply of nongold high-powered money to banks and the public was proximately determined by the change in the total stock of nongold high-powered money and the fraction of the country's total high-powered money stock held as Treasury vault cash (Friedman and Schwartz, 1963, 124-134). By all accounts, the total stock of nongold money in the U.S. was unresponsive to international gold flows or economic conditions at the frequency of business cycles: the quantity of greenbacks was simply fixed; the rate at which the Treasury created new silver notes was governed by longstanding political factors (Myers, 1931, pp. 396-398; 402); and the rate at which banks created national bank notes was remarkably insensitive to variations in interest rates and business activity (Meyers, 1931, p. 403; Cagan, 1965, p. 91). But on occasion Treasury officials deliberately managed the

Alternatively, foreign central banks could have taken actions to raise the foreign interest rate in response to large U.S. wheat harvests, so that $\partial i^* / \partial h > 0$: increased crop export revenues could be counteracted by decreased capital inflow, leaving gold flows and the U.S. money supply unaffected.[18]

To check these possibilities, we regressed changes from pre- to post-harvest periods in the nongold money supply, and London interest rates, on harvest fluctuations. Generally, we found no significant negative coefficients on wheat harvest fluctuations. Table 9 shows some typical results. Thus, the potential money-supply effect of wheat harvests does not appear to have been countered by actions of monetary authorities.

Harvest effects on high-powered money demand

Wheat harvest fluctuations could have affected gold flows and the money supply but *not* IP if wheat harvests were also associated with relatively strong, positive shocks to high-powered money demand. Such harvest effects on money demand are plausible given other, well-known features of the pre-1914 American economy.

A feature which has attracted the attention of modern economists is that autumn months were marked by a regular seasonal increase in high-powered money demand (Miron, 1986; Clark, 1986; Barsky, Mankiw, Miron and Weil, 1988). The autumn

quantity of Treasury vault cash to affect money-market conditions (Myers, 1931, pp. 370-386; Timberlake, 1978).

[18] Foreign short-term rates were proximately determined by the policy decisions of European central banks, which sometimes took actions (including but not limited to hikes in central-bank discount rates) to raise local money-market rates in response to large, persistent outflows of gold (Sayers, 1976). They might have done so in response to gold flows caused by wheat harvest fluctuations, if those flows were large enough relative to world monetary gold stocks. Friedman and Schwartz (1965, p. 89 footnote) guessed that the U.S. held less than twenty percent of the world monetary gold stock over the late nineteenth century. Any attempt to quantify the possible effect of U.S. money-demand variations on the gold-standard world's interest rates would be dubious.

money-demand surge was so strong that U.S. short-term interest rates and the New York-London interest-rate spread tended to increase from the summer to the fall, even though U.S. net export revenues were highest in the autumn (Goodhart, 1968, pp. 51-52; Kemmerer, 1910, pp. 136-140).

An obvious source of the autumn surge in high-powered money demand was rural households' and businesses' demand for cash. Compared with later eras, before the First World War fewer households held bank deposits; cash outside banks was larger relative to standard monetary aggregates or to total high-powered money (Cagan, 1965, 119-123). In rural areas households were especially unlikely to hold bank accounts and an especially large portion of payments were in cash (Fisher, 1913, p. 51; James, 1978, p. 32-33). To meet the rural public's autumn demand for cash, rural banks drew down their correspondent balances held in money-center banks and sold commercial paper (James, 1978, pp. 125-127; Kemmerer, 1910, p. 52) resulting in massive cash shipments from the urban northeast to the south, midwest and west from August through early December. The cash returned over the following year, with large return shipments in the early summer through July (Kemmerer, 1910, pp. 128-129).

Contemporaries observed that rural households received most of their years' income in the fall, as payments for crop sales and wages for harvest labor, and held cash hoards to cover expenses over the following months (e.g. Wright, 1922, p. 71; Young, 1925, p. 21). Farmowners with mortgages held cash hoards to make debt payments. Unlike today, mortgage payments were due only once a year, usually around May (Wright, 1922, p. 92; Kemmerer, p. 99). Also unlike today, mortgages were for terms of five years or less, paid off when a farmer's income was high; renewed or falling into arrears when income was low (Murray, 1933, p. 381; Hinman and Rankin, 1933, pp. 30-35; Bogue, 1955, pp. 53, 66, 72). A factor that tended to reduce cash demand was the use of "book credit" extended by retail merchants, as households could buy “on account” and pay off the debt when they received their incomes (Fisher, 1913, p. 81). The 1898 Report of the Indianapolis Monetary Commission described all of these phenomena:

The farmer on selling his crops may indeed receive a check in payment; but as he and a large part of the community with which he deals do not find the check and deposit system convenient, he is not satisfied with that sort of payment. He cashes the check at the bank, or through some merchant, and thus secures the form of currency which he requires. If he cashes it with a merchant, a portion may be merely offset against his account at the “store” where he deals, and to that extent the demand may be satisfied without resort to note-currency. But not so with the balance: for that he must have coin or notes. Some of this currency is used at once in settling outstanding accounts, and thus gets back to the bank almost immediately through the deposits of the tradesmen. To this extent the demand is of short duration. The rest of the currency is paid out from time to time during the fall and winter for “help,” and in the purchase of the winter’s supplies, or is held in cash to meet spring payments on a mortgage (p. 313).

These observations suggest that harvest fluctuations could affect high-powered money demand over the months following the harvest, for at least two reasons. To the degree that harvest fluctuations were positively related to crop sale revenue, they should be positively related to the cash demand of farm operators – for example, as farmowners made bigger mortgage payments in a year of high income. Apart from crop sale revenue, a larger harvest could require more wage labor to handle the crop, with larger incomes to rural laborers. Either way, it is plausible that $\partial\gamma_{\text{md}} / \partial h > 0$.

It is also plausible that the effect of a harvest on cash demand could be stronger for wheat than for cotton. Contemporaries noted several differences between southern and northern rural institutions that reduced southern rural cash demand. A typical northern farmer employed "hired hands" and casual labor who received specified money wages; he sold his crop to grain dealers or grain-elevator operators (U.S. Industrial Commission, 1901, p. 50). Many southern cotton producers sold their crop to the same enterprise that furnished them supplies on credit throughout the year – a planter sold to a factor, a small farmer to a local merchant, a tenant farmer to a local merchant or the landlord - in a transaction that merely extinguished the debt or created a credit on the books of that enterprise: little (if any) cash changed hands (Brooks, 1898, p. 242; Brown, 1927, pp. 374-375; Hammond, 1896, p. 382; Woodman, 1968, pp. 288, 302, 308). "Crop lien" laws, unique to the southern states, allowed a tenant with little property to buy more on credit, as they gave his creditors a senior claim on the tenant's crop proceeds at harvest. A landowner's wageworkers were often paid not in cash but in "scrip" redeemable at a local store (Woodman. 1968 p. 302). One contemporary claimed that in the rural south "Merchants are frequently found who are unable to give the difference between their cash and credit prices, because none of their customers ever buys for cash" (Hammond, 1897, p.155). Cotton farmers also had less need to hold cash for mortgage payments: a much smaller fraction of Southern farms (by number or land area) were mortgaged (U.S. Bureau of the Census, 1914, pp. 159, 162-63).

Allowing for both the money-demand and export-revenue effects of a harvest fluctuation, the model implies:

(11) $\partial\Delta y / \partial h = (1/\beta_3)\,[\,(1/\beta_2)\,\partial\gamma_{BOP}/\partial h \;-\; \partial\gamma_{md}/\partial h\,]$ *where*

$$\beta_3 = \alpha + \mu_y + \beta_1 (\mu_i / \gamma_r) + (1/\beta_2)\,(\theta_y + \alpha\,\theta_p + \beta_1 (\theta_{CF} / \gamma_r) > 0$$

(12) $\partial g / \partial h = \partial\Delta m / \partial h = \partial\gamma_{md}/\partial h + (\alpha + \mu_y + \beta_1 (\mu_i / \gamma_r))\;\partial\Delta y/\partial h$

(13) $\partial e/\partial h = -\,\eta\,(\partial g / \partial h)$

(14) $\partial(i - i^*)/\partial h = \partial \Delta i/\partial h = -(\beta_1/\gamma_r)\ \partial \Delta y/\partial h$

(15) $\partial \Delta p/\partial h = \alpha\ \partial \Delta y/\partial h$

Expression (11) shows that the effect of a crop's harvest on nonagricultural output depends on the strength of its money-demand effect relative to its export-revenue effect. If a crop's money-demand effect is strong enough, its harvest fluctuation can have *no* effect on nonagricultural output, even if its harvest fluctuations are associated with a positive shock to export revenue. This can explain why the wheat harvest failed to affect IP in the postbellum period.

The remaining expressions have two sets of implications for the behavior of observable variables other than IP.

Cotton-caused business cycles versus *other business cycles*

If cotton harvest fluctuations affected IP because of the monetary mechanism illustrated by the model, then variations in IP growth caused by cotton harvests should be positively associated with gold inflow and money-supply growth (expression 12); negatively associated with the exchange rate (expression 13), the international interest-rate spread and the change in the short-term interest rate (14). Cotton-caused IP variations should be positively related to price inflation (15), reflecting the interaction between the cotton-caused aggregate-demand shock and the Phillips curve.

The same relations need not hold for IP fluctuations in general. For example, changes in nonagricultural output caused by ε_y ("IS shocks") would be positively correlated with changes in the domestic interest rate *i* and the international interest-rate spread $(i - i^*)$; variations in ε_{md} (disturbances to money demand) generate negative correlations between output growth and the same variables; exogenous variations in the foreign interest rate i^* generate negative correlations between output growth and changes in the domestic interest rate, but positive correlations between output and the international interest-rate spread; and so on.

Effects of cotton versus *wheat harvests*

If wheat harvest fluctuations failed to affect IP because wheat harvests were associated with relatively large money-demand shocks, then wheat harvests should be positively related to gold inflow g and growth in the high-powered money supply Δm (expression 12) and negatively related to the exchange rate e (expression 13). Wheat harvests should *not* be negatively related to the international interest-rate spread $(i - i^*)$, the change in the domestic interest rate Δi (14), or related to inflation Δp (15).

VI. Tests: monetary quantities, interest and exchange rates and inflation

To test these implications, we run two sets of regressions on samples 1880-1913, that is beginning with the first harvest season of the gold standard period (fall 1879). In both sets of regressions, left-hand side variables include: net gold imports over the months from July of the harvest season through the June following the harvest season, as a fraction of the initial month's high-powered money supply; the July-to-July change in the log high-powered money supply; the average exchange rate across months from July through the following June; the average July-through-June spread between the New York commercial paper rate and the London bill rate; the change in the average commercial paper rate from the July-to-June period preceding the harvest to the following July-to-June period; the change in the log of the standard WPI, July to July across the harvest season; and the change in the log of the constructed WPI excluding farm and food products over the same span. For the international interest-rate spread, we added to the right-hand side a dummy variable for years after 1896, to allow for a change in the spread associated with the decreased probability of dollar devaluation.

Cotton-caused IP fluctuations versus *other IP fluctuations*

The first set of regressions, with results shown in Table 10, compares relations between the variables and IP fluctuations in general *versus* IP fluctuations specifically due to the cotton harvest. To observe relations between the variables and IP fluctuations in general, we ran OLS regressions with the change in log IP on the right-hand side (row a). To observe relations between these variables and IP fluctuations due to cotton harvests, we ran two-stage least squares regressions with the change in log IP instrumented by cotton harvest fluctuations in the first stage (row b). Finally (row c) we ran OLS regressions where the right-hand side variable was the residual of the first-stage regressions for (b). These results show relations between the variables and IP fluctuations due to causes *other* than the cotton harvest.

Results are as predicted. With respect to monetary quantities and interest rates, cotton-caused IP changes are clearly different from other IP changes. Cotton-caused IP changes are positively related to gold inflow and money-supply growth; negatively related to the exchange rate, the international interest-rate spread and the domestic interest-rate change. Those patterns hold less strongly for IP fluctuations in general and not at all for IP fluctuations due to other causes. Only with respect to inflation do all types of IP changes appear similar (which suggests that the pre-1914 Phillips curve was rarely, if ever, disturbed by cost-push shocks correlated with IP movements).

Cotton harvest fluctuations versus *other harvest fluctuations*

To test implications for cotton harvest fluctuations *versus* other crops', we ran OLS regressions with the three crops' harvest fluctuations on the right-hand side. We also ran three sets of 2SLS regressions, one set for each crop, using the weather instruments for Table 7. Left-hand side variables included those for Table 9 and two more: crop export revenue in the year following the harvest, as a fraction of the preceding July's high-powered money supply; and a rough estimate of the change in (log) cash outside national banks, from the early-summer months preceding the harvest to the early-summer months of the following year. The last variable is the closest one can get to cash held by the nonbank public, though it includes cash held by state banks and trust companies. Unfortunately, no cyclical-frequency data allow a true estimate of cash held by the nonbank public, let alone cash held by rural households see appendix B).

Results are again consistent with the model's implications. Coefficients from OLS regressions are shown in Table 11, panel A. For export revenues, growth in cash outside national banks, gold inflow and the change in high-powered money supply, both the cotton and wheat harvest coefficients are positive and significantly different from zero at the five percent level or better. For the exchange rate, both the cotton and wheat coefficients are negative and significant at the two percent level or better. But for the international interest-rate spread and the interest-rate change, only the cotton coefficient is negative and significantly different from zero. Corn harvest coefficients for these variables are generally of small magnitude and are not significantly different from zero at conventional levels. For inflation, results depend somewhat on the price index. For the standard WPI, which includes farm products and foods, the corn coefficient is negative and significant at the ten percent level. For the WPI excluding farm and food prices, the corn coefficient is much smaller in magnitude and not significantly different from zero. The last result suggests that the corn harvest's apparent negative effect on the standard WPI merely reflects its direct effect on corn prices. For either WPI, the cotton harvest coefficient is positive and significant at the five percent level.

In 2SLS results, panel B, cotton coefficients and wheat coefficients for export revenues, monetary quantities and exchange rates are similar in magnitude to their OLS counterparts. They generally have larger standard errors, so some are not significant at conventional levels.

VII: Conclusion

Between the late 1870s and the First World War, year-to-year fluctuations in the U.S. cotton harvest caused by weather, crop diseases and other factors specific to cotton-growing had a significant effect on U.S. industrial production. In terms of an R-squared, the cotton harvest caused about 40 percent of the variation in annual IP growth over the period. In terms of generally-recognized business cycles, the cotton harvest was responsible for the depressions of 1883, 1893, 1896, and 1910. Wheat and corn harvests did not affect IP. Cotton harvests did not affect IP in other historical periods.

We have argued that the cotton harvest's unique effect on nonagricultural production after the 1870s was the outcome of interactions between crop harvests, export revenues, high-powered money demand and America's gold-standard monetary regime of 1879-1914. Under this regime, a positive shock to U.S. export revenue allowed for faster growth in the high-powered money supply through gold inflows, lower U.S. interest rates relative to foreign interest rates, and higher nonagricultural output. A positive shock to U.S. money demand tended to boost high-powered money supply through gold inflows, but increase U.S. interest rates and depress nonagricultural output. Cotton harvest fluctuations affected IP because they had strong effects on export revenues and relatively weak effects on money demand. Wheat harvests failed to affect IP because they had strong effects on money demand as well as on export revenues.

Our explanation's implications for the behavior of interest rates, exchange rates and monetary quantities are clearly consistent with data from the period. Large cotton harvests tended to increase gold inflows, money-supply growth and the foreign exchange value of the dollar, while they decreased American short-term interest rates relative to London rates, and to American interest rates prevailing before the harvest. Wheat harvests affected gold flows, the money supply and the exchange rate but not American interest rates. Of course, there are many interesting aspects of this mechanism that we have left unexplored in this paper, including interactions between cotton harvest fluctuations and the pre-1914 U.S. banking system's propensity to panics; the month-to-month timing of the economy's response to harvest shocks; and the effect of shocks to crop harvests in foreign countries.[19]

We have not attempted to rule out alternative explanations based on real channels, but we suspect that such explanations may prove difficult to reconcile with some of the empirical facts, especially the lack of an IP effect from the wheat or corn harvests; the lack of a cotton effect on British IP; and the positive effect of a large cotton harvest on price inflation, which is consistent with interactions between a Phillips curve and aggregate demand shocks, rather than a supply shock.

[19] The latter question is unfortunately complicated by the absence of harvest statistics for many important foreign producers of wheat, notably Russia.

Appendix A Weather variables

Individual weather station data are available from the United States Historical Climatology Network (USHCN, www.ncdc.noaa.gov/oa/climate/research/ushcn/ushcn.html) and the National Oceanic and Atmospheric Administration, Nineteenth Century U.S. Climate Data Set Project (website lwf.ncdc.noaa.gov/oa/climate/onlinedata/forts/forts.html). Temperature data are available beginning with 1822, but precipitation data are unavailable before 1837.

From these we created monthly temperature and precipitation indices for the cotton belt (North Carolina, South Carolina, Georgia, Florida, Tennessee, Alabama, Mississippi, Louisiana, Arkansas, and Texas) and for the corn and wheat belt (Ohio, Indiana, Michigan, Illinois, Wisconsin, Minnesota, Iowa, Missouri, North Dakota, South Dakota, Nebraska, and Kansas). To obtain a weather variable, for example January mean temperature or July precipitation, we ran a fixed-effect regression with dummies for each year and each individual weather station, using the combined data sets. We took coefficients for a given year to represent "average" weather conditions in the region.

Appendix B: Data sources and construction

Sources for Table 2

Crop values relative to GNP: Ratios for 1840-1860 show single-year cotton's value added from Gallman (1960, pp. 46-47) over national income from Gallman (1966, p. 26). Ratios for 1870-1910 are calendar-year crop values from Strauss and Bean (1937, pp. 36, 39-40, 64-65) relative to nominal income from Balke and Gordon (1989, pp. 84-85).

Crop as a share of merchandise exports: Historical Statistics of the United States, Millennial Edition (2006): Series Ee366, Ee571, Ee576. Corn export values is the quantity of corn exported valued at Chicago prices as reported in *Agricultural Statistics, 1936*, pp. 32-33.

Share of crop exported: 1840-1860 from USDA, Bureau of Statistics, *Cotton Crop of the United States, 1790-1911*, Circular No. 32, (1912); 1870-1910 from USDA, *Agricultural Statistics, 1940*, pp. 9-10, 45-46, 108-109.

Cotton consumption as share of national income: U.S. GNP/GDP from *Historical Statistics of the United States, Millennial Edition* (2006) series Ca10. Share of U.S. GNP outside agriculture from Gallman (2000, p. 50). U.S. cotton consumption from U.S. Bureau of the Census (1911, p. 21). U.S. cotton price (to value consumption) from *Historical Statistics of the United States, Millenial Edition* (2006), series Cc222, Cc223. British GNP, nonagricultural GNP, cotton consumption quantities, cotton import quantities, and cotton prices (to value quantities) from Mitchell (1988, pp. 332, 760, 822).

Cotton output as a share of European and America consumption: T. Ellison's estimates as reported in US Treasury Department, Bureau of Statistics, *Finance, Commerce, and Immigration of the United States*, August 1895 SS3450, p. 304.

Time-series data

Crop prices: Cotton prices on the New York cotton exchange, through 1861 from Cole (1938); beginning September 1870 from NBER (series 04006a); for years ending June 1870 and June 1871 calculated from quarterly data in Mitchell (1908, Appendix Table II.). Wheat and corn prices in Chicago from NBER (m04001, m04005).

WPI: Warren and Pearson (1932) wholesale price index before 1890 linked to the BLS wholesale price index thereafter (NBER series m04048). Index excluding farm products and foods is calculated from the other component indexes using Warren and Pearson's 1889 weights (p. 184).

High-powered money supply, nongold money supply: Monthly data on the various components of the high-powered money stock in and outside the Treasury's vaults begin with June 1878 (Friedman and Schwartz, 1970, pp. 205-211). We took values from the NBER macro history database (14135, 14080, 14124, 14076).

Cash outside national banks: Cash held by the nonbank public must be estimated as high-powered money outside the Treasury *minus* "vault cash" held by financial institutions. There are only spotty records of cash held by state banks and trust companies (Friedman and Schwartz, 1970, p. 208-211). For national banks, Annual Reports of the Comptroller of the Currency give figures on vault cash (the sum of a bank's holdings of specie, fractional currency, Treasury-issued notes and national bank notes issued by other banks) at Call Report dates, available as NBER series 14177. Call Reports took place at irregular points in the year. To estimate cash outside national banks in spring and early summer, we took call reports occuring in the months of May, June or July. We subtracted this vault cash figure from the average value of high-powered money outside the Treasury across May, June, and July.

Export values: Export values starting in 1851 are from U.S. Department of Agriculture, Bureau of Statistics (1910) supplemented by U.S. Department of Agriculture (1913, 1916). The value of cotton exports for earlier years are from U.S. Department of Agriculture, Bureau of Statistics (1912). Wheat (and flour) and corn (and meal) exports for the earlier years are from the U.S. Department of Treasury (1848, 1849, 1850, 1851). All of these figures were based on U.S. customs officials' estimates of outward shipment values, which were supposed to reflect the actual current selling price of the commodity shipped (Irwin, 2006). Annual figures for years before 1843 are for twelve-month spans ending September 30th. After 1843, firgures are for spans ending June 30th. Figures for 1843 cover the nine months from October 1842 through June 1843. We exclude that year's figure from our samples.

New York – London exchange rate: Neal and Weidenmier (2003) collected New York bid and ask prices for London exchange from the New York *Commercial and Financial Chronicle,* at a weekly frequency. Weidenmier kindly provided us with these data (at the time of this writing, available on his website ebutts05.tripod.com/nealweidenmiergsd). We calculate monthly averages of the bid-ask mean, for sight exchange. For most weeks, the *Commercial and Financial Chronicle* gave exchange rates as dollar prices per pound sterling. For some weeks in January 1881, exchange rates were given as percent of par value, during a short-lived effort by foreign-exchange dealers to shift the market to quotations on that basis (Meyers, 1931, p. 347). For these weeks, we assumed a par value of $4.8665. We corrected the *Commercial and Financial Chronicle* quote for January 8, 1881, faithfully reproduced in the Neal-Weidenmier database. This was the first week that exchange dealers gave quotes as percent of par, and the *Chronicle* wrongly recorded the percent figures as dollar figures. (Converted to dollars, the values for this week are bid 4.8242, ask 4.83.) For months prior to January 1880, we took sight exchange rates from Schneider, Schwarzer and Zellfelder (1991, p. 330).

Interest rates: New York commercial paper rate from MacAulay (1938, Table 10; NBER series 13002). London open-market bill rate is NBER series 13016, computed from weekly figures in the *Economist*.

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Figure 1

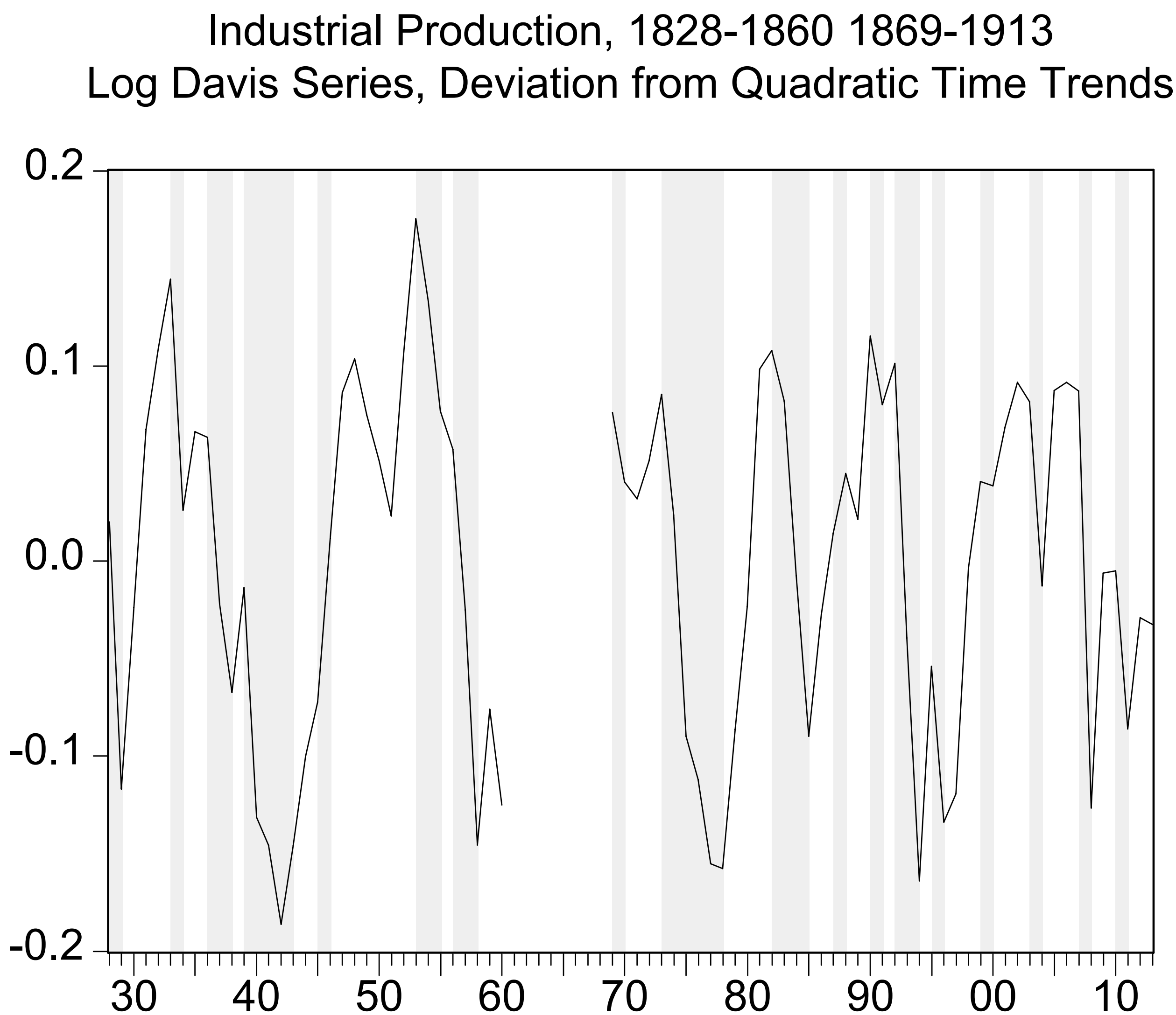

Industrial Production, 1828-1860 1869-1913
Log Davis Series, Deviation from Quadratic Time Trends
0.2
0.1
0.0
-0.1
-0.2
30
40
50
60
70
80
90
00
10

Figure 2 Crop production and trends

a)

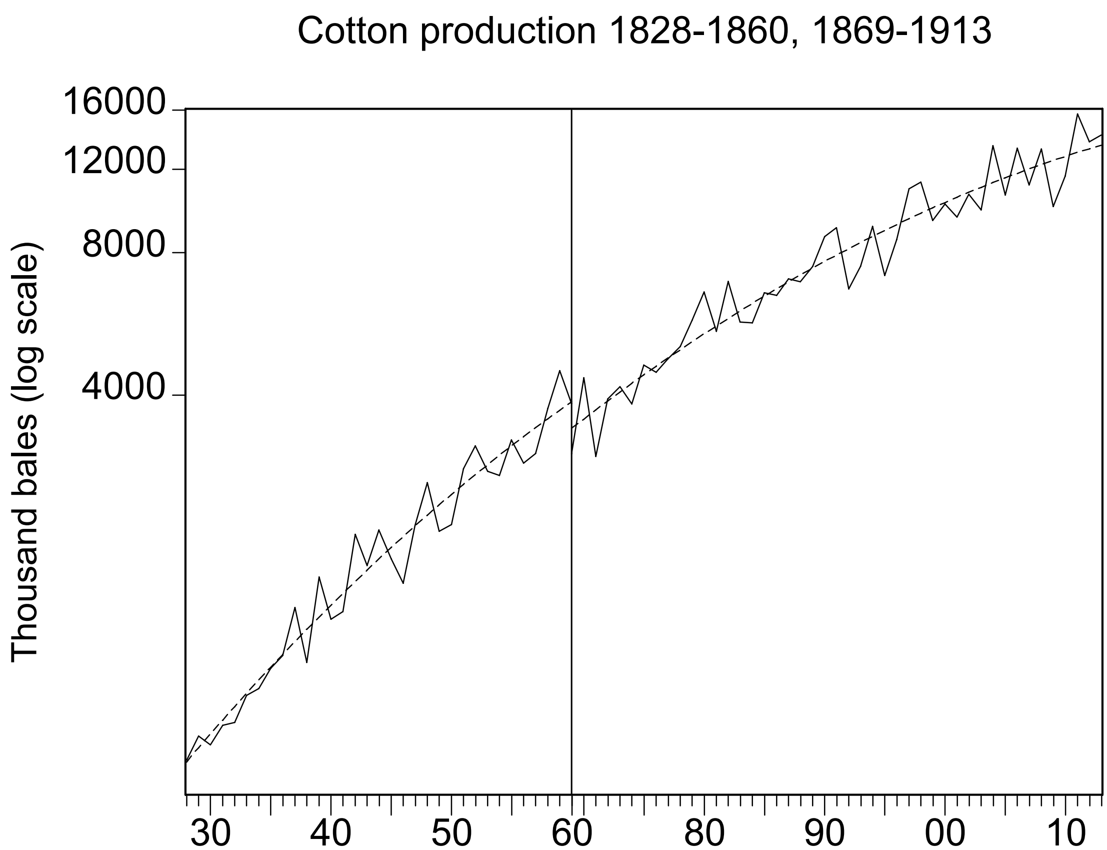
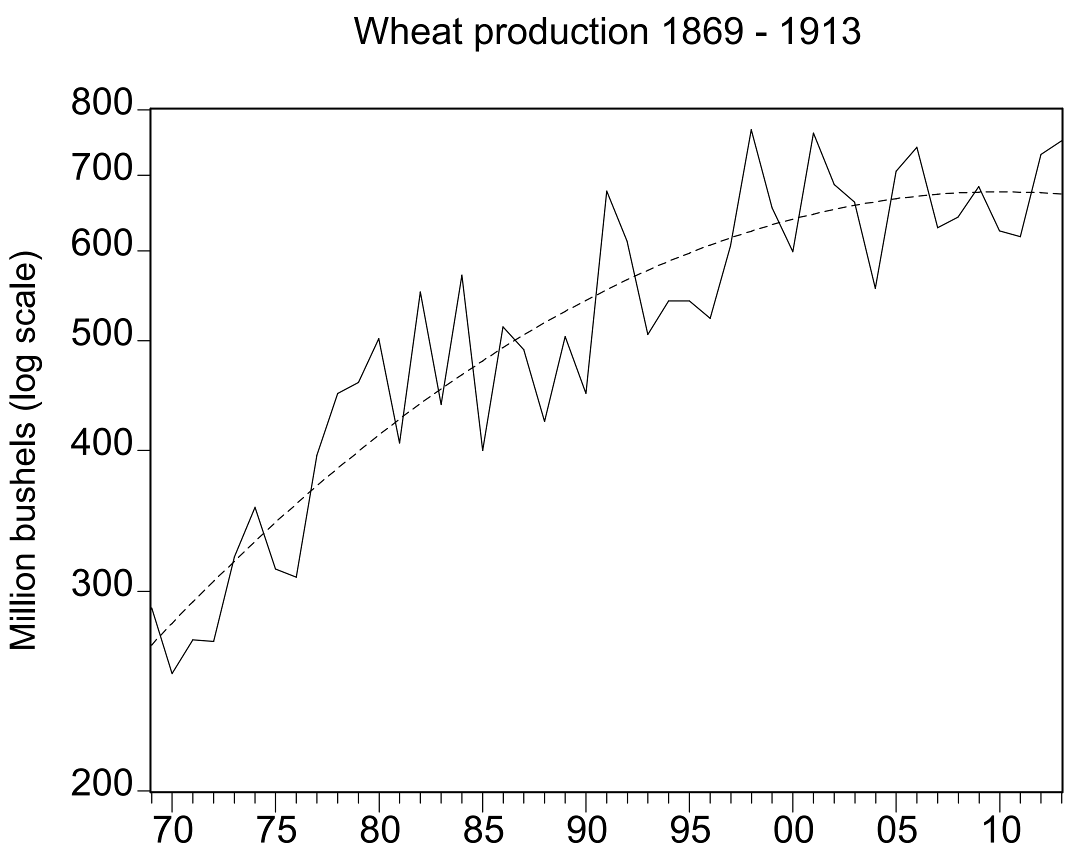


Figure 2

b)



Wheat production 1869 - 1913
Million bushels (log scale)
800
700
600
500
400
300
200
70
75
80
85
90
95
00
05
10

Figure 2

c)

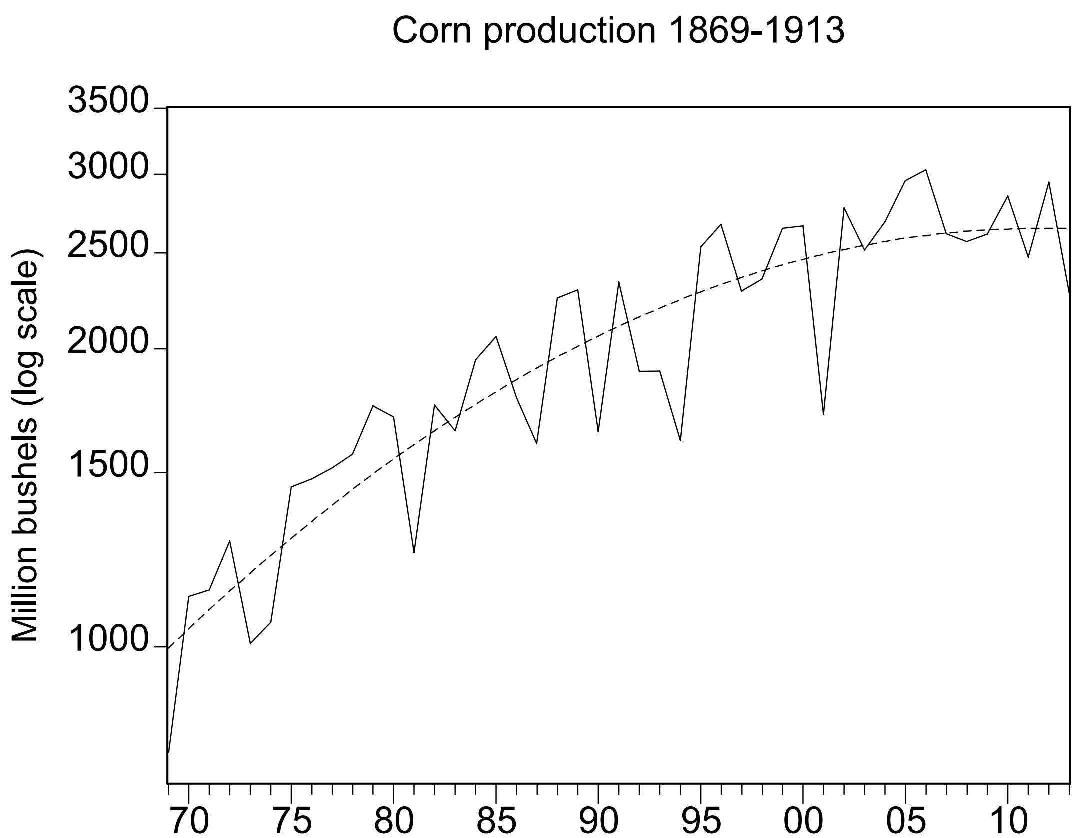
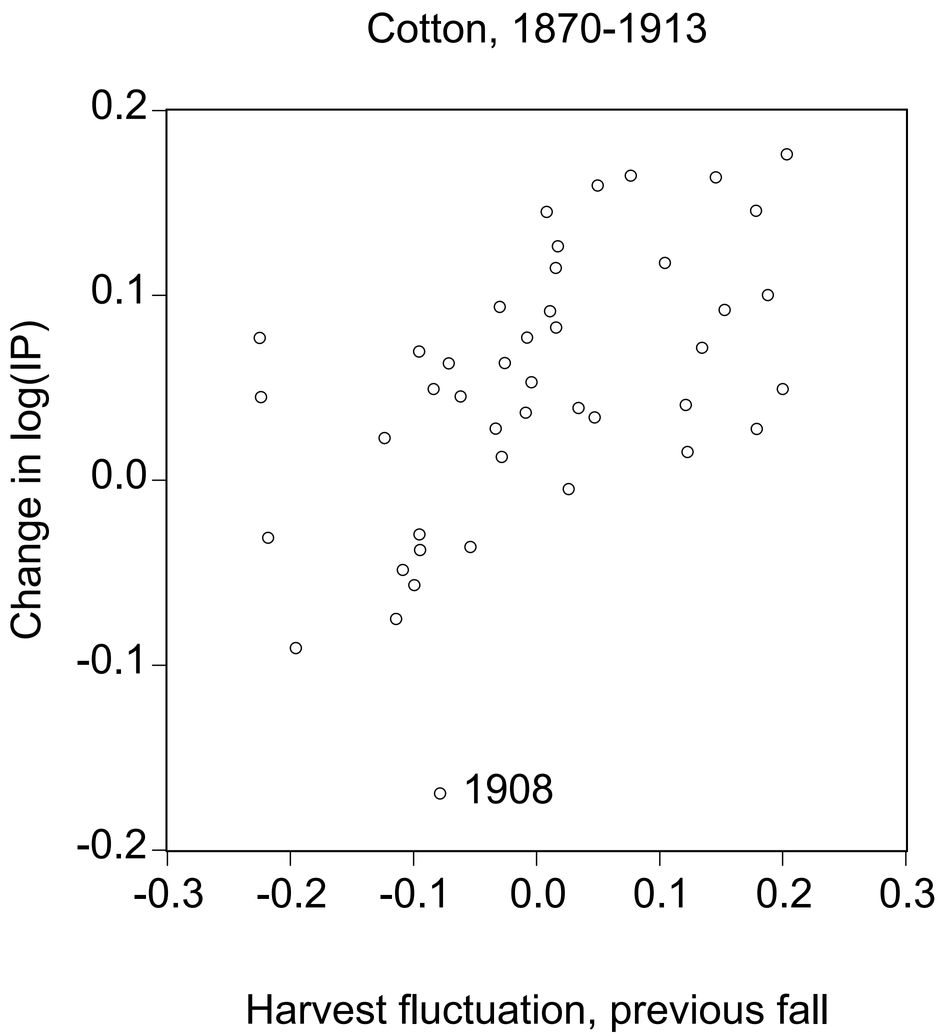
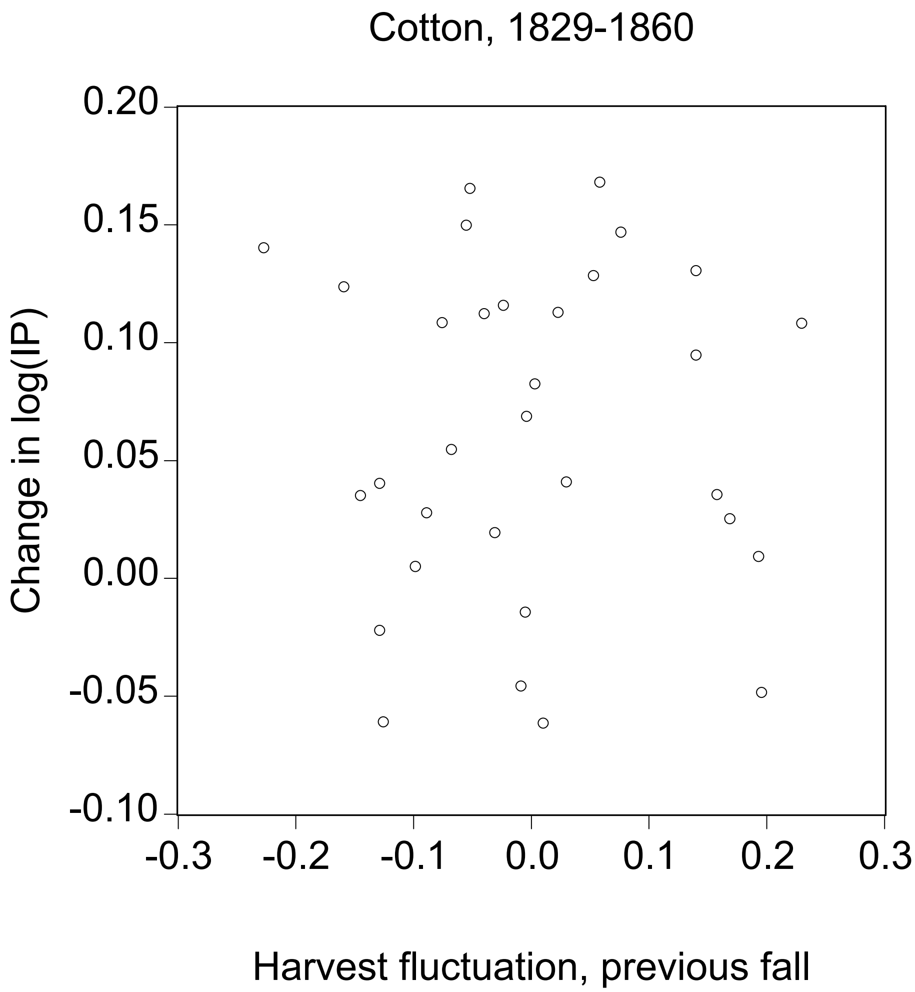

Corn production 1869-1913
Million bushels (log scale)
3500
3000
2500
2000
1500
1000
70
75
80
85
90
95
00
05
10

Figure 3 ΔLn(IP) and harvest fluctuations

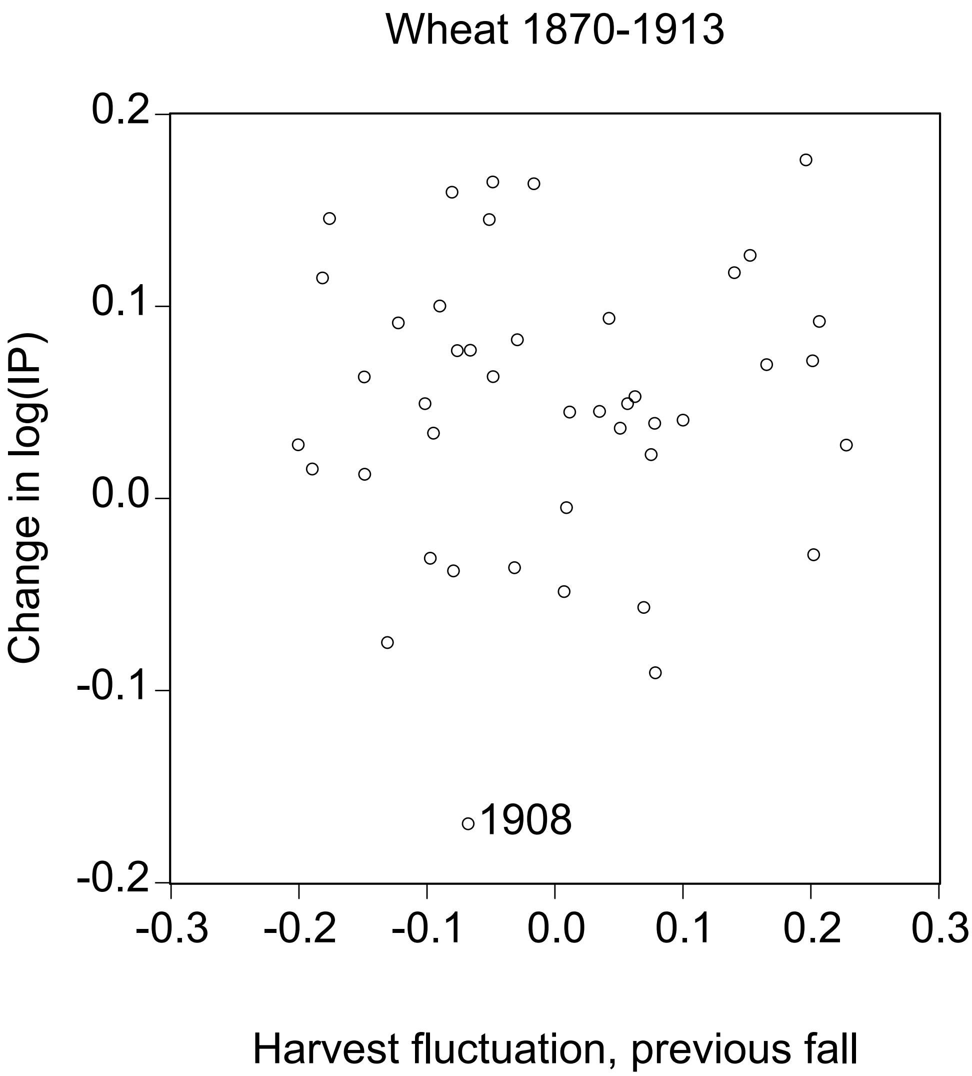
a)



b)


Cotton, 1829-1860
0.20
0.15
0.10
0.05
0.00
-0.05
-0.10
Change in log(IP)
-0.3
-0.2
-0.1
0.0
0.1
0.2
0.3
Harvest fluctuation, previous fall

c)



Wheat 1870-1913
0.2
0.1
0.0
-0.1
-0.2
Change in log(IP)
1908
-0.3
-0.2
-0.1
0.0
0.1
0.2
0.3
Harvest fluctuation, previous fall

d)

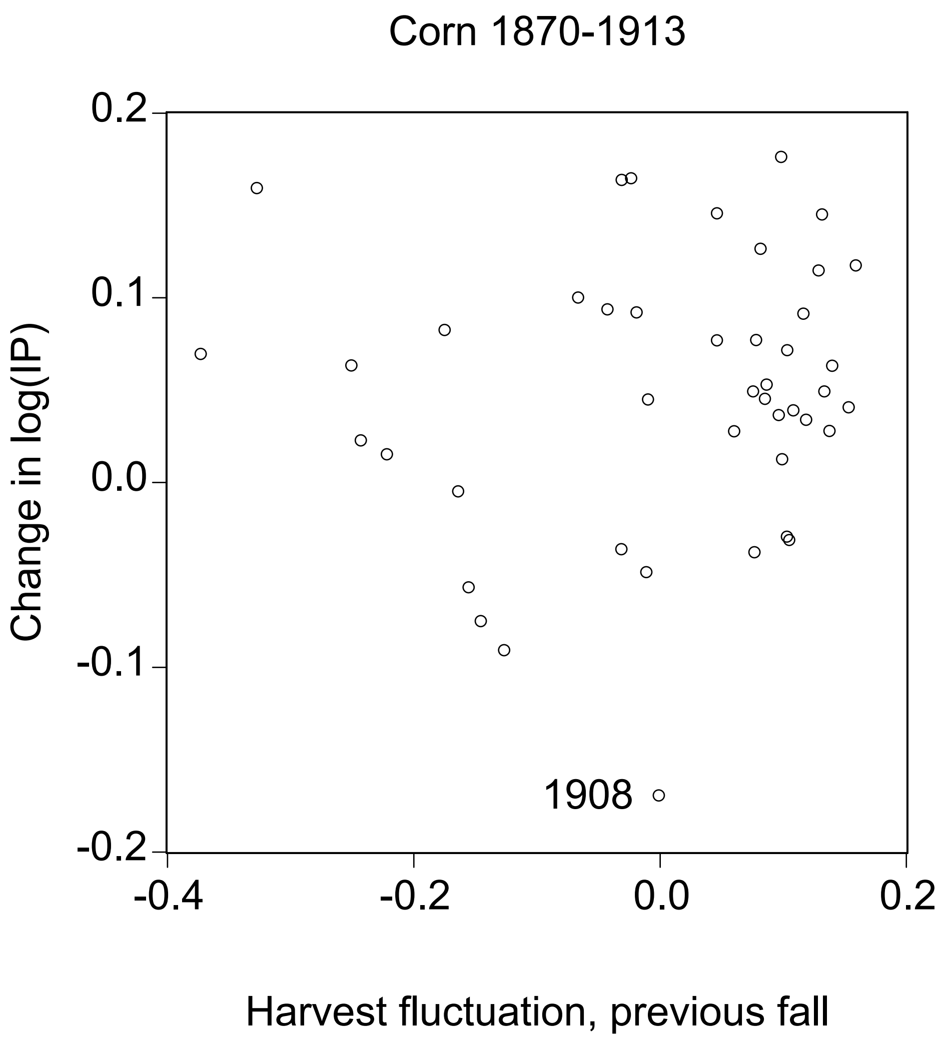
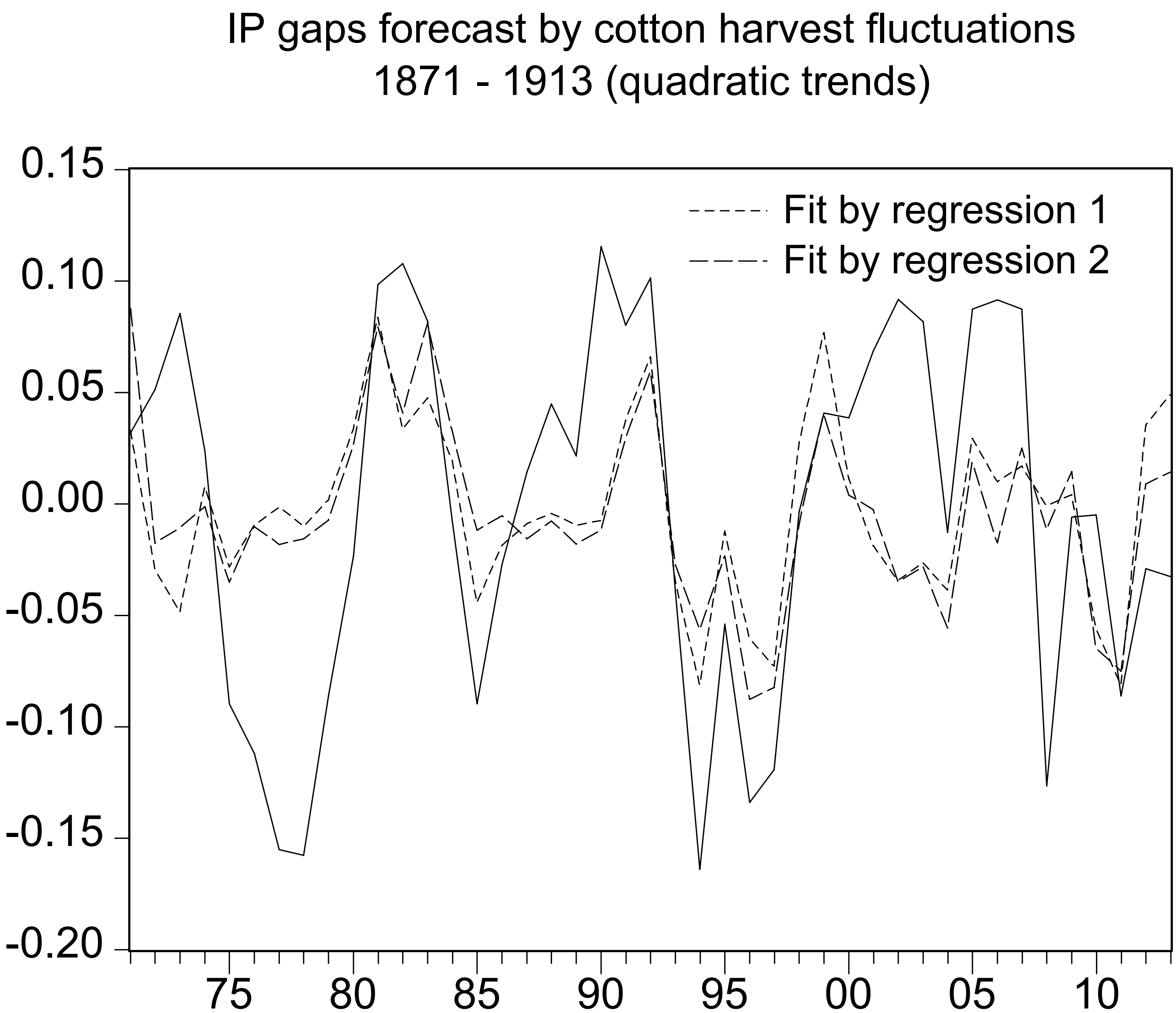

Corn 1870-1913
0.2
0.1
0.0
-0.1
-0.2
Change in log(IP)
1908
-0.4
-0.2
0.0
0.2
Harvest fluctuation, previous fall

Figure 4:



Regression 1 RHS: two lags cotton
Regression 2 RHS: one lag cotton, one lag IP gap

Figure 5

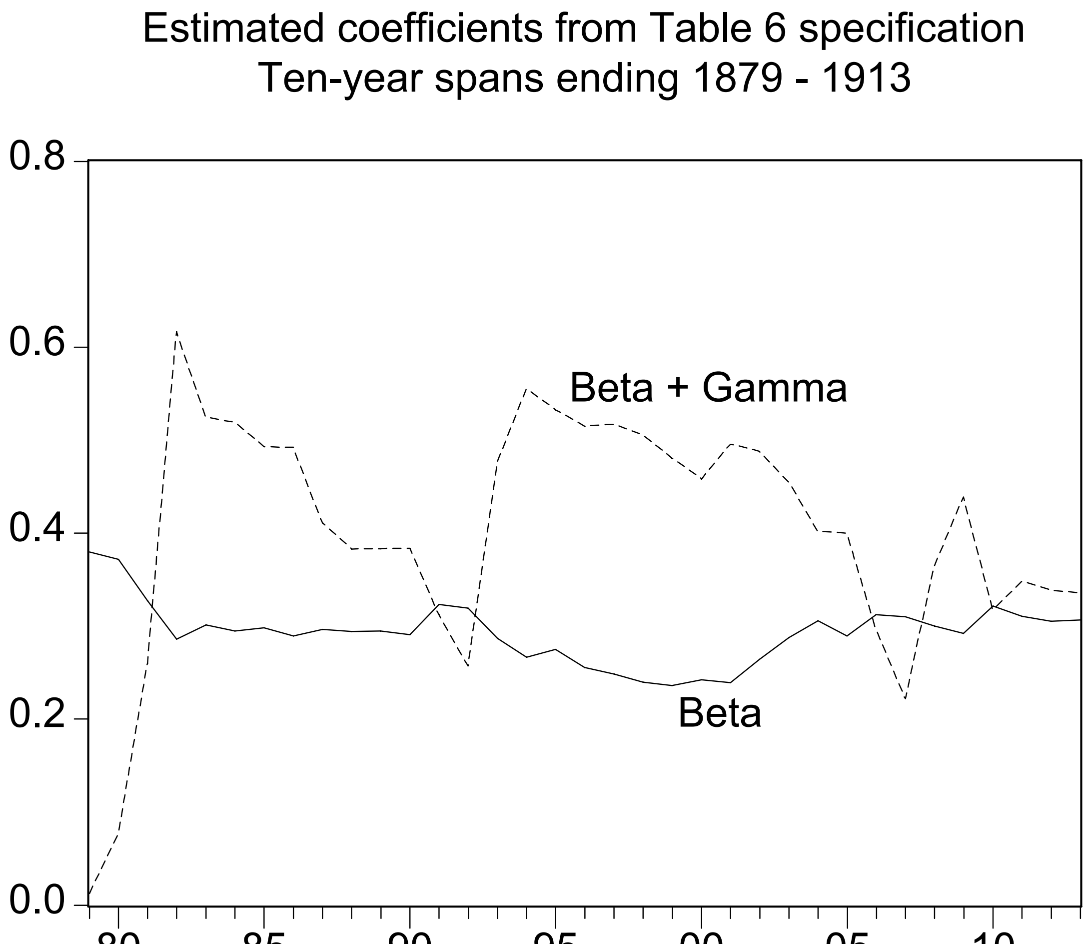

Estimated coefficients from Table 6 specification
Ten-year spans ending 1879 - 1913
0.8
0.6
0.4
0.2
0.0
80
85
90
95
00
05
10
Beta + Gamma
Beta

Table 1: Descriptive Statistics: IP and Harvest Deviations from Trend

A)

Trend:	Quadratic						Hodrick-Prescott					
Series:	IP		Cotton		Wheat	Corn	IP		Cotton		Wheat	Corn
Period	1828-1860	1869-1913	1828-1860	1869-1913	1869-1913	1869-1913	1828-1860	1869-1913	1828-1860	1869-1913	1869-1913	1869-1913
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Max.	0.175	0.115	0.229	0.203	0.228	0.159	0.117	0.115	0.209	0.234	0.239	0.170
Min.	-0.186	-0.164	-0.227	-0.224	-0.201	-0.373	-0.136	-0.147	-0.223	-0.223	-0.192	-0.374
Std. Dev.	0.101	0.082	0.116	0.116	0.120	0.139	0.066	0.069	0.111	0.112	0.110	0.133
Serial Corr. Coeff.	0.76	0.60	-0.152	-0.21	0.02	-0.11	0.54	0.47	-0.22	-0.28	-0.15	-0.18

B) Contemporaneous Correlations

	1828-1860	1869-1913		
	IP	IP	Cotton	Wheat
Cotton	-0.210	-0.14		
Wheat		0.16	0.13	
Corn		-0.16	0.12	-0.02

Table 2 Statistics on staple crops 1840-1910

Per cent

	1840	1850	1860	1870	1880	1890	1900	1910
Crop value/GNP*								
Cotton	3.9	3.7	4.8	3.5	2.8	2.6	1.9	2.3
Wheat				3.0	3.9	2.5	2.2	1.7
Corn				7.4	7.9	6.8	4.5	5.5
Corn (sold off the farm)				1.4	1.8	1.4	1.1	1.1
Exports/U.S. merchandise exports*								
Cotton	60.1	49.7	47.0	46.0	26.0	31.4	19.8	26.2
Wheat and wheat flour				11.8	20.6	14.5	13.1	6.4
Corn				2.3	4.9	3.4	4.9	1.6
Exports/Total crop*								
Cotton	78.7	86.8	82.0	67.0	66.4	66.3	69.2	67.9
Wheat				17.1	34.1	26.7	36.2	15.9
Corn				1.4	5.2	2.9	6.7	1.8
Cotton consumed (value)/GNP								
U.S.	0.01	0.01	0.01	0.02	0.01	0.01	0.01	NA
Britain**	1.26	1.44	2.69	2.35	1.83	1.26	0.94	1.36
Cotton consumed (value)/Nonagricultural GNP								
U.S.	0.01	0.02	0.02	0.02	0.01	0.01	0.01	NA
Britain**	1.62	1.81	3.27	2.74	2.04	1.38	1.01	1.44
Imports of U.S. cotton by Britain (value)								
/GNP	1.03	1.31	2.19	2.02	1.55	1.23	0.89	1.20
/Nonagricultural GNP	1.32	1.64	2.66	2.36	1.72	1.34	0.95	1.28
Cotton output /(European +American cotton consumption)								
U.S.***	82.4	86.8	84.4	55.2	75.2	76.9	NA	NA

*Values for centered five-year moving averages except cotton values for 1840 (1839), 1850 (1849) and 1860 (1859).

**Values are for 1841, 1851, 1861, 1871, 1881, 1891, 1901, 1907.

*** Average of previous five years, 1840 is 1836-40.

Sources: see data appendix

Table 3: Crop export revenue, cotton exports and crop prices, 1829-60 and 1870-1913

Coefficient
[Standard error]
p-value

LHS variable:	Total crop export revenue			Cotton export quantity		Crop price, year following harvest			
						Cotton		Wheat	Corn
Period:	1829-1860*	1870-1913	1870-1913	1829-1860*	1870-1913	1829-1860*	1870-1913	1870-1913	1870-1913
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Cotton(-1)	0.019	0.640	0.534	1.333	1.062	-0.868	-0.500		
	[0.295]	[0.168]	[0.137]	[0.133]	[0.050]	[0.303]	[0.148]		
	0.95	*0.00*	*0.00*	*0.00*	*0.00*	*0.01*	*0.00*		
Wheat(-1)			0.589					-0.151	
			[0.132]					[0.193]	
			0.00					*0.44*	
Corn(-1)			0.210						-0.815
			[0.115]						[0.151]
			0.08						*0.00*
Pre-harvest WPI	0.862	0.325	0.312			0.703	1.053	0.581	2.003
	[0.292]	[0.300]	[0.243]			[0.323]	[0.265]	[0.355]	[0.320]
	0.01	0.29	0.20			0.04	*0.00*	*0.11*	*0.00*
Time	0.034	0.021	0.020	0.106	0.051	-0.094	-0.025	-0.010	0.067
	[0.058]	[0.018]	[0.015]	[0.025]	[0.002]	[0.063]	[0.016]	[0.022]	[0.020]
	0.56	*0.26*	*0.19*	*0.00*	*0.00*	*0.15*	*0.14*	*0.64*	*0.00*
Time Sqr / 1000	0.135	-0.045	0.014	-0.418	-0.373	0.728	0.508	0.196	-0.979
	[0.451]	[-0.333]	[0.269]	[0.190]	[0.040]	[0.489]	[0.294]	[0.394]	[0.356]
	0.77	*0.99*	*0.96*	*0.04*	*0.00*	*0.15*	*0.09*	*0.62*	*0.01*
R-sqr	0.90	0.79	0.87	0.98	0.99	0.41	0.88	0.52	0.76

Table 4: Harvest Fluctuations Regressed on Current and Lagged IP Gaps

Coefficient
[standard error]
p-value

Trend:	Quadratic				Hodrick-Prescott			
Period:	1829-1860	1870-1913			1829-1860	1870-1913		
LHS variable:	Cotton (1)	Cotton (2)	Wheat (3)	Corn (4)	Cotton (5)	Cotton (6)	Wheat (7)	Corn (8)
IP	-0.060	-0.084	0.471	-0.141	0.018	-0.045	0.581	-0.222
	[0.317]	[0.322]	[0.279]	[0.318]	[0.361]	[0.334]	[0.266]	[0.323]
	0.85	*0.80*	*0.10*	*0.66*	*0.96*	*0.89*	*0.03*	*0.50*
IP(-1)	-0.321	0.011	-0.412	-0.153	-0.383	0.069	-0.132	-0.228
	[0.325]	[0.302]	[0.275]	[0.319]	[0.363]	[0.303]	[0.267]	[0.327]
	0.33	*0.97*	*0.14*	*0.63*	*0.30*	*0.82*	*0.62*	*0.49*
Crop(-1)	-0.223	-0.186	-0.002	-0.130	-0.241	-0.259	-0.218	-0.208
	[0.183]	[0.184]	[0.157]	[0.154]	[0.181]	[0.184]	[0.154]	[0.152]
	0.23	*0.32*	*0.99*	*0.40*	*0.19*	*0.17*	*0.17*	*0.18*
p-value								
test 1	*0.32*	*0.58*	*0.37*	*0.67*	*0.41*	*0.35*	*0.13*	*0.37*
test 2	*0.25*	*0.95*	*0.21*	*0.59*	*0.48*	*0.97*	*0.09*	*0.42*

Test 1: coefficients on all RHS variables equal to zero
Test 2: coefficients on IP and IP(-1) equal to zero

Table 5: IP Gaps Regressed on Lagged Harvest Fluctuations

Coefficient
[standard error]
A) *p-value*

Trend	Quadratic							
IP series	Davis		Davis exc. textiles, food		Davis metals		Davis machinery	
Period	1830-1860	1871-1913	1830-1860	1871-1913	1830-1860	1871-1913	1830-1860	1871-1913
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Cotton(-1)	-0.045	0.331	-0.169	0.315	-0.127	0.360	0.055	0.481
	[0.106]	[0.081]	[0.110]	[0.093]	[0.274]	[0.152]	[0.241]	[0.193]
	0.68	*0.00*	*0.14*	*0.00*	*0.65*	*0.02*	*0.82*	*0.02*
Wheat(-1)		0.003		0.012		-0.051		0.091
		[0.083]		[0.096]		[0.157]		[0.196]
		0.96		*0.90*		*0.75*		*0.64*
Corn(-1)		-0.007		-0.009		0.030		-0.004
		[0.068]		[0.078]		[0.127]		[0.161]
		0.92		*0.91*		*0.81*		*0.98*
IP(-1)	0.917	0.790	1.037	0.795	0.374	0.484	1.150	1.022
	[0.181]	[0.162]	[0.172]	[0.163]	[0.187]	[0.164]	[0.174]	[0.158]
	0.00	*0.00*	*0.00*	*0.00*	*0.06*	*0.01*	*0.00*	*0.00*
Cotton(-2)	0.068	0.007	0.167	0.013	0.313	0.116	0.280	-0.044
	[0.109]	[0.099]	[0.116]	[0.110]	[0.269]	[0.167]	[0.249]	[0.221]
	0.54	*0.95*	*0.16*	*0.91*	*0.25*	*0.49*	*0.27*	*0.84*
Wheat(-2)		-0.095		-0.087		-0.211		-0.142
		[0.077]		[0.088]		[0.142]		[0.180]
		0.22		*0.33*		*0.15*		*0.44*
Corn(-2)		0.051		0.059		0.082		0.137
		[0.067]		[0.076]		[0.122]		[0.157]
		0.45		*0.45*		*0.51*		*0.39*
IP(-2)	-0.172	-0.180	-0.277	-0.193	-0.105	-0.081	-0.432	-0.346
	[0.186]	[0.152]	[0.174]	[0.155]	[0.198]	[0.161]	[0.181]	[0.154]
	0.36	*0.25*	*0.12*	*0.22*	*0.60*	*0.62*	*0.02*	*0.03*
p-value[1]	*0.50*	*0.36*	*0.14*	*0.43*	*0.40*	*0.42*	*0.04*	*0.15*

[1] p-value for test of hypothesis that all coefficients on second lags equal to zero

A) (cont)

Trend	HP		Quadratic
IP series	Davis		Frickey
Period	1830-1860	1871-1913	1871-1913
	(9)	(10)	(11)
Cotton(-1)	-0.017	0.334	0.323
	[0.089]	[0.075	[0.103]
	0.85	*0.00*	*0.00*
Wheat(-1)		0.017	-0.030
		[0.082]	[0.107]
		0.84	*0.78*
Corn(-1)		-0.013	-0.047
		[0.064]	[0.087]
		0.84	*0.60*
IP(-1)	0.634	0.625	0.534
	[0.171]	[0.159]	[0.165]
	0.00	*0.00*	*0.00*
Cotton(-2)	0.074	0.047	0.102
	[0.091]	[0.091]	[0.112]
	0.42	*0.61*	*0.39*
Wheat(-2)		-0.091	-0.128
		[0.078]	[0.097]
		0.25	*0.196*
Corn(-2)		0.048	0.058
		[0.064]	[0.083]
		0.46	*0.49*
IP(-2)	-0.158	-0.197	-0.102
	[0.174]	[0.145]	[0.162]
	0.37	*0.18*	*0.54*
p-value	*0.45*	*0.19*	*0.39*

B)

Trend	Quadratic							
IP series	Davis		Davis exc. textiles, food		Davis metals		Davis machinery	
Period	1829-1860	1870-1913	1829-1860	1870-1913	1829-1860	1870-1913	1829-1860	1870-1913
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Cotton(-1)	-0.047	0.312	-0.172	0.293	-0.125	0.315	-0.009	0.494
	[0.107]	[0.078]	[0.115]	[0.088]	[0.248]	[0.142]	[0.258]	[0.188]
	0.67	*0.00*	*0.14*	*0.00*	*0.62*	*0.03*	*0.97*	*0.01*
Wheat(-1)		0.036		0.051		0.015		0.148
		[0.076]		[0.086]		[0.140]		[0.182]
		0.64		*0.56*		*0.91*		*0.42*
Corn(-1)		-0.018		-0.023		0.007		-0.035
		[0.065]		[0.074]		[0.119]		[0.160]
		0.79		*0.75*		*0.95*		*0.83*
IP(-1)	0.769	0.640	0.792	0.644	0.345	0.449	0.787	0.742
	[0.126]	[0.110]	[0.114]	[0.111]	[0.170]	[0.136]	[0.120]	[0.104]
	0.00	*0.00*	*0.00*	*0.00*	*0.05*	*0.00*	*0.00*	*0.00*

Trend	HP		Quadratic
IP series	Davis		Frickey
Period	1829-1860	1870-1913	1870-1913
	(9)	(10)	(11)
Cotton(-1)	-0.022	0.307	0.290
	[0.093]	[0.073]	[0.097]
	0.81	*0.00*	*0.00*
Wheat(-1)		0.061	0.027
		[0.076]	[0.095]
		0.43	*0.78*
Corn(-1)		-0.015	-0.048
		[0.062]	[0.081]
		0.81	*0.56*
IP(-1)	0.537	0.498	0.477
	[0.158]	[0.123]	[0.132]
	0.00	*0.00*	*0.00*

Table 6 Allowing for shift in cotton harvest effect 1870-1879

Specification:

$$IP = Const. + Dummy_{1870\text{-}1879} + \beta Cotton(-1) + \gamma\,(Dummy_{1870\text{-}1879} * Cotton(-1)) + \eta\, IP(-1)$$

IP Series	Davis		Davis exc. text. & food	
Trend	Quadratic	HP	Quadratic	HP
	(1)	(2)	(3)	(4)
β Cotton(-1)	0.380 [0.080] 0.00	0.377 [0.078] 0.00	0.374 [0.092] 0.00	0.370 [0.089] 0.00
γ Cotton(-1) coefficient shift	-0.367 [0.179] 0.05	-0.327 [0.169] 0.06	-0.430 [0.204] 0.04	-0.375 [0.194] 0.06
η IP(-1)	0.636 [0.102] 0.00	0.533 [0.113] 0.00	0.643 [0.104] 0.00	0.542 [0.116] 0.00
$\beta + \gamma$	0.012	0.050	-0.055	-0.006

Table 7: IV estimates, Harvest effects on IP

A) Regressions of harvest fluctuations on weather variables, 1879-1912

	R2	Rbar2	p-value, all coefficients zero
Cotton harvest on			
cotton weather	0.62	0.49	0.00
wheat weather	0.26	-0.02	0.51
corn weather	0.28	0.02	0.42
Wheat harvest on			
cotton weather	0.26	0.03	0.38
wheat weather	0.60	0.45	0.00
corn weather	0.33	0.08	0.27
Corn harvest on			
cotton weather	0.22	-0.03	0.54
wheat weather	0.19	-0.11	0.76
corn weather	0.65	0.52	0.00

B) 2SLS regressions, IP gap on harvest fluctuations and lagged IP gap, 1880-1913

LHS variarible	IP gap (quadratic trend)			ΔLn(IP)		
	(1)	(2)	(3)	(4)	(5)	(6)
Cotton(-1)	0.467			0.517		
	[0.108]			[0.124]		
	0.00			0.00		
Wheat(-1)		0.088			0.038	
		[0.127]			[0.146]	
		0.49			0.79	
Corn(-1)			-0.011			-0.019
			[0.108]			[0.125]
			0.92			0.88
IP(-1)	0.585	0.442	0.478			
	[0.123]	[0.159]	[0.154]			
	0.00	0.01	0.00			
R2	0.53	0.27	0.24	0.37	0.00	0.00

C) Corresponding OLS estimates

LHS variarible	IP gap (quadratic trend)			ΔLn(IP)		
	(1)	(2)	(3)	(4)	(5)	(6)
Cotton(-1)	0.372			0.421		
	[0.080]			[0.093]		
	0.00			0.00		
Wheat(-1)		0.125			0.032	
		[0.099]			[0.113]	
		0.22			0.78	
Corn(-1)			-0.001			0.009
			[0.087]			[0.101]
			0.99			0.93
IP(-1)	0.564	0.427	0.479			
	[0.120]	[0.156]	[0.154]			
	0.00	0.01	0.00			
R2	0.55	0.27	0.24	0.39	0.00	0.00

Table 8: Cotton harvests and British *versus* American IP, 1880-1913

Coefficient
[Standard error]
p-value

	1829-1860		1870-1913		1880-1913	
LHS variable	IP US	IP UK	IP US	IP UK	IP US	IP UK
	(1)	(2)	(3)	(4)	(5)	(6)
Cotton(-1)	-0.083	0.115	0.292	0.036	0.340	0.067
	[0.110]	[0.060]	[0.079]	[0.049]	[0.087]	[0.057]
	0.46	*0.07*	*0.00*	*0.46*	*0.00*	*0.25*
IP (-1)	0.754	0.214	0.616	0.390	0.534	0.295
	[0.126]	[0.179]	[0.113]	[0.133]	[0.124]	[0.057]
	0.00	*0.24*	*0.00*	*0.01*	*0.00*	*0.25*
Other country IP	0.406	0.096	0.217	0.140	0.266	0.089
	[0.328]	[0.068]	[0.235]	[0.071]	[0.270]	[0.092]
	0.23	*0.17*	*0.36*	*0.05*	*0.33*	*0.34*
R sqr	0.60	0.15	0.56	0.33	0.56	0.28

Table 9: Harvests, nongold money supply, London interest rates, 1880-1913

LHS variables:
(1) Change in log (nongold money outside the Treasury, average of months from July to June)
(2) Change in London bill rate (average of months from July to June)

Coefficient
[Standard error]
p-value

	(1)	(2)
Cotton(-1)	0.032	-1.321
	[0.039]	[1.225]
	0.42	*0.30*
Wheat(-1)	0.046	-0.312
	[0.037]	[1.166]
	0.22	0.79
Corn(-1)	0.015	1.277
	[0.032]	[1.200]
	0.64	*0.22*
R sqr	0.10	0.08
p-value[1]	0.38	0.45

[1]Test that all harvest coefficients equal zero

Table 10: Cotton-caused IP fluctuations *versus* other IP fluctuations

Left-hand side variables:

Δg Net gold imports/ money supply (previous July)
Δm Exchange rate, annual average ending June
e Change in log monetary gold stock, July to July
(i – i)* New York – London interest rate spread, annual average ending June
Δi Change in New York interest rate (annual average ending June)
Δp WPI Change in log WPI, July to July
Δp WPI exc. Change in log WPI excluding farm products and food, July to July

Specifications:

(a) OLS with Δy as RHS variable
(b) Two-stage least squares with cotton harvest deviation as instrument for Δy
(c) OLS with residual variation in Δy as RHS variable

Coefficient
[Standard error]
p-value

	Δg	*Δm*	*e*	*(i – i*)*	*Δi*	*Δp* *WPI*	*Δp* *WPI exc.*
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
(a)	0.144	0.086	-0.021	-2.289	-3.604	0.480	0.527
	[0.073]	[0.098]	[0.021]	[1.137]	[1.961]	[0.120]	[0.120]
	0.06	*0.39*	*0.34*	*0.05*	*0.08*	*0.00*	*0.00*
(b)	0.284	0.350	-0.083	-4.155	-7.262	0.459	0.542
	[0.124]	[0.174]	[0.038]	[1.902]	[3.314]	[0.192]	[0.193]
	0.03	*0.05*	*0.04*	*0.04*	*0.04*	*0.02*	*0.01*
(c)	0.055	-0.082	0.019	-1.105	-1.284	0.493	0.518
	[0.098]	[0.126]	[0.027]	[1.533]	[2.626]	[0.166]	[0.171]
	0.58	*0.52*	*0.48*	*0.48*	*0.63*	*0.01*	*0.00*

Table 11: Macroeconomic variables and crop fluctuations, 1880-1913

Left-hand side variables:
Exp. rev. Crop export revenue/money supply (previous July)
Δ*Cash* Change in log cash outside national banks, spring to spring
and as for Table 10

Coefficient
[Standard error]
p-value

A) OLS results

	Exp. rev. (1)	Δ*Cash* (2)	*Δg* (3)	*Δm* (4)	*e* (5)	*(i – i*)* (6)	*Δi* (7)	*Δp* *WPI* (8)	*WPI exc.* (9)
Cotton(-1)	0.266	0.148	0.095	0.120	-0.027	-1.883	-3.592	0.192	0.205
	[0.114]	[0.063]	[0.044]	[0.058]	[0.011]	[0.779]	[1.247]	[0.093]	[0.096]
	0.03	*0.03*	*0.04*	*0.05*	*0.02*	*0.02*	*0.01*	*0.05*	*0.04*
Wheat(-1)	0.258	0.132	0.103	0.124	-0.036	0.781	2.182	0.071	0.122
	[0.109]	[0.060]	[0.042]	[0.056]	[0.011]	[0.742]	[1.187]	[0.088]	[0.092]
	0.02	*0.04*	*0.02*	*0.03*	*0.00*	*0.30*	*0.08*	*0.43*	*0.20*
Corn(-1)	0.102	0.049	0.048	0.058	-0.009	-0.186	1.220	-0.135	-0.002
	[0.095]	[0.052]	[0.037]	[0.049]	[0.009]	[0.650]	[1.038]	[0.077]	[0.080]
	0.29	*0.36*	*0.20*	*0.24*	*0.35*	*0.78*	*0.25*	*0.09*	*0.98*
Post-1896 dummy						-1.252			
						[0.181]			
						0.00			
R sqr	0.34	0.32	0.35	0.31	0.44	0.66	0.28	0.21	0.20

Source: see data appendix

B) 2SLS results

	Exp. rev. (1)	ΔCash (2)	Δg (3)	Δm (4)	e (5)	(i – i*) (6)	Δp/Δi (7)	WPI (8)	WPI exc. (9)
Cotton(-1)	0.368	0.179	0.064	0.085	-0.023	-1.683	-2.654	0.232	0.338
	[0.155]	[0.084]	[0.062]	[0.080]	[0.017]	[0.942]	[1.646]	[0.119]	[0.123]
	0.02	*0.04*	*0.31*	*0.30*	*0.18*	*0.08*	*0.12*	*0.06*	*0.01*
Post-1896 dummy						-1.245			
						[0.178]			
						0.00			

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Wheat(-1)	0.349	0.153	0.122	0.145	-0.041	0.264	1.604	0.003	0.039
	[0.148]	[0.081]	[0.057]	[0.074]	[0.015]	[0.972]	[1.663]	[0.121]	[0.124]
	0.02	*0.07*	*0.04*	*0.06*	*0.01*	*0.79*	*0.34*	*0.98*	*0.76*
Post-1896 dummy						-1.264			
						[0.192]			
						0.00			

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Corn(-1)	0.028	-0.027	0.032	-0.027	0.007	-0.961	0.423	-0.247	-0.116
	[0.139]	[0.078]	[0.057]	[0.072]	[0.015]	[0.829]	[1.442]	[0.105]	[0.111]
	0.84	*0.73*	*0.58*	*0.71*	*0.66*	*0.26*	*0.77*	*0.02*	*0.31*
Post-1896 dummy						-1.237			
						[0.196]			
						0.00			