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ABSTRACT

Most major American industrial business cycles from around 1880 to the First World War were caused by fluctuations in the size of the cotton harvest due to economically exogenous factors such as weather. 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 in this period can be explained as an essentially monetary phenomenon, the result of interactions between harvests, international gold flows and high-powered money demand under America's gold-standard regime of 1879-1914.

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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 a result of oil prices' real effects on capital productivity and expenditure patterns (Hamilton 2000, p. 35), or alternatively as the outcome of monetary shocks resulting from policymakers' reactions to oil prices (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).

Subsequent research into business cycles did not support such strong claims. In their *Monetary History of the United States*, Friedman and Schwartz (1963, pp. 97-98, 107, 140-141) argued that the wheat crop, specifically, contributed to a few pre-1914 cycles, through the effects of wheat export revenues on the U.S. money supply under the gold standard. But NBER scholars such as Wesley Mitchell (1951, p. 58), Arthur Burns (1951, pp. 7-8), and Robert A. Gordon (1952, p. 386) concluded that farm-sector output was uniquely *un*related to output in other sectors. Edwin Frickey (1942, p. 229) found no correlations between indices of farm output and his annual index of industrial production for 1865-1914.

Pre-1914 business cycles remain a topic of current research. They are generally found to resemble postwar 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 role of agricultural shocks in pre-1914 business cycles. Solomou and Wu (1999) argue that weather-related harvest fluctuations affected real GDP in Europe in the late nineteenth century, but only because of their direct effects on the agricultural portion of GDP. 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 explored interactions between the farm sector and industrial business cycles in the U.S. and elsewhere (e.g. Temin 1976; 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 indices of industrial production (IP). Our results should alter views of historical business cycles and attract the attention of macroeconomic theorists.

From about 1880 to 1914, year-to-year fluctuations in the American cotton harvest caused business-cycle variations in American IP. Indeed, the cotton harvest accounts for *most* major American business cycles of this era, including the depressions of 1884, 1893, 1895 and 1910. The relation between cotton harvests and business cycles was causal: it holds for harvest fluctuations due to weather in southern cotton-growing regions – a factor exogenous to economic activity and unlikely to affect IP through other channels. It was also unique to the cotton crop and to the postbellum era: IP was *not* affected by wheat or corn harvests, or by cotton in the antebellum era. After demonstrating these patterns we propose an essentially monetary explanation. We argue that the unique IP effect of the cotton harvest in the postbellum era can be accounted for by a standard open-economy sticky-price model, as the outcome of two more proximate effects of harvests: on potential high-powered money supply through export revenues, and on money demand. In the last section of the paper, we test implications of our explanation for monetary quantities, exchange rates, interest rates and inflation.

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

For pre-1914 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 index constructed by Joseph Davis (2004) is the most comprehensive and the only one that covers years preceding the War Between the States. The Davis index indicates production over calendar years from 1790 through 1915. Its year-to-year fluctuations are consistent with other cyclical indicators and with the traditional NBER business cycle chronology (though several NBER downturns appear in the Davis series as growth slowdowns rather than contractions [Davis 2006, pp. 108-109]). Important components enter during 1827, so our samples begin with 1828. To avoid possible effects of the First World War's outbreak (Friedman and Schwartz 1963, p. 196) we present results from samples that end with 1913. Samples ending with 1914 gave very similar results.

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 wheat flour. As a check, we examine a specially-constructed index excluding these two components. For postbellum years, we also use the Frickey (1947) annual index of manufacturing production.

[1] Annual-frequency estimates of aggregate employment and NIPA variables such as GNP are actually interpolations on IP series or on nominal variables such as price indexes, suspended between reliable estimates for census years only (Rhode 2002; Davis 2004). The monthly IP index constructed by Miron and Romer (1990) begins with January 1884.

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 estimates of livestock production before about 1910, or of wheat and corn production in the antebellum era.[2] But beginning with 1866, the U.S. Department of Agriculture (USDA) produced reliable annual estimates of production of all three staple crops, based mainly on information provided by local crop reporters. For cotton alone, the USDA published annual production estimates for antebellum and war years, based on contemporary commercial estimates (Carter et. al. 2006, series Da 696, Da718, Da756). Thus, we can examine harvest fluctuations of cotton, wheat and corn in the postbellum era, and of cotton alone in the antebellum era. In the years just following the War Between the States, cotton production was subject to many special factors (described by Ransom and Sutch 1977) beyond the scope of this paper. Thus, we begin postbellum samples with 1869. Starting samples a few years earlier or later gave similar results.

We measure business-cycle industrial fluctuations as deviation from trend in log IP series - the “IP gap.” 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. 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 at the value (100) used by most other studies of annual historical data (such as Backus and Kehoe 1992). As is well known, the HP filter incorporates some relatively high-frequency movements into the trend; the quadratic does

[2] For years from 1867 on, the USDA assembled annual estimates of the number of head of livestock on farms reproduced in Carter et. al. 2006, series Da968-973), rather than *output* of slaughtered meat. From these USDA "inventory" numbers, Strauss and Bean (1940, pp. 105-123) created estimates of slaughtered meat output by assuming that a fixed fraction of the livestock headcount in each animal category (cattle, hogs, sheep) was slaughtered every year, and applying estimates of livestock weights derived from incomplete records of commercial slaughterhouses. Though they are given on an annual basis, we believe the Strauss and Bean estimates indicate long-term trends in livestock production rather than annual fluctuations, which would be affected by variations in the slaughtered fraction of the headcount, animal mortality from diseases *versus* slaughter, and so on.

not.[3]

We define crop harvest fluctuations parallel to IP gaps, as deviations of log output from the two trends. Figure I plots output of each crop and quadratic trends, which appear to be good descriptions of long-term growth. Table I presents statistics on volatility, persistence and cross-correlations for harvest fluctuations and IP gaps. IP gaps are persistent (high serial correlation) and slightly more volatile in the postbellum era. Harvest fluctuations are not at all persistent; volatility is similar across crops and eras. None of the cross-correlations is strong.

II. Staple crops in the American economy

Crop production was fundamentally seasonal and regional. Cotton, wheat and corn were all harvested within the months from July through November, planted in the previous spring or earlier. Cotton was grown in the southern "cotton belt" from North Carolina to Texas. The bulk of industrial production took place elsewhere, in the Northeast and Midwest. Wheat and corn were concentrated in the "grain belt" of the Midwest and West, closer to industrial centers but far from the cotton belt.[4]

Almost all harvested cotton was sold off the farm for factory textile production. Most was exported, primarily to Britain, which had the world’s largest cotton textile industry. Most harvested wheat was sold off the farm to be milled into flour for human consumption (some was retained for seed and animal feed). Unlike cotton and wheat, most corn was fed to draft and meat animals, often on the same farm where it was grown

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[3] Ravn and Uhlig (2002) show that a smoothing-parameter value of 6.25 for annual-frequency data would be more consistent with the value of 1600 conventionally applied to quarterly- data. Compared with a value of 100, a value of 6.25 would create trends that are even *more* sensitive to short-term fluctuations.

[4] Cotton was planted from March through May, harvested beginning in August (Covert 1912, p. 93). By the end of October over sixty percent of the cotton harvest was completed, at least in the 1900s (U.S. Bureau of the Census 1909, p. 13). Corn was planted in the spring, harvested from early September through November (Covert 1912, p. 17). "Winter wheat" was planted from September through October; "spring wheat" was planted from March through May; *both* wheat plantings were harvested mostly in July and August (Covert 1912, pp. 30, 41; *Monthly Crop Reporter* Sept. 1920, p. 100). In the postbellum era about 70 percent of U.S. wheat 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 corn 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

(USDA 1922, pp. 79, 151-155, 164-165, 199-201, 391-399). The U.S. produced most of the world's marketed cotton, even as late as 1913; the U.S. share of world wheat was much smaller (USDA 1921, pp. 547-548).

Table II indicates crops' roles in U.S. exports and national income. (Underlying figures on crop values and sales incorporate estimates of output retained on the farm [for wheat and corn] and local prices available to farmers [as distinct from central commodity market prices] appear reliable for these long-run averages, though not from year to year.) The value of raw cotton as a share of U.S. export revenue or relative to GNP fell from the antebellum to the postbellum era. In the postbellum era, the cotton and wheat harvests had similar value relative to GNP and generated similar crop sale income to farmers. Cotton was a larger share of export revenue, and had a higher ratio of export revenue to crop sales. Corn had the largest value relative to GNP but generated less sales because most corn was retained on the farm. The lower section of the Table indicates the importance of raw cotton as an input to U.S. and British industry. Raw cotton was always more important to the British economy, in the sense that the value of cotton consumed and U.S. cotton imports were larger relative to British national product.

Relations between harvest fluctuations and U.S. export revenues can be observed in annual data on exports by commodity, available starting in the early nineteenth century for twelve-month spans corresponding to one harvest season's exports. These data show that cotton harvest fluctuations were *not* related to U.S. export revenue in the antebellum era. In the postbellum era, both cotton and wheat harvest fluctuations were positively related to export revenue with similar magnitudes. Corn harvest fluctuations were not strongly related to export revenue. Table III presents results indicating these patterns. We regressed the log of total revenue from crop-related exports - the sum of raw cotton, wheat and wheat flour, corn and corn flour - on the corresponding season's harvest fluctuations (quadratic trends), time trend terms, and the log of the WPI over the twelve

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cotton textile industry, but as late as 1895 northern mills accounted for two-thirds of U.S. raw cotton consumption (Hammond 1897, p. 343).

months preceding the harvest season (ending June) to control for the general price level. The antebellum era's cotton harvest coefficient (column 1) is not significantly different from zero. The postbellum cotton harvest coefficient (column 2) is positive and 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 one percent and of similar magnitude to cotton's; the corn coefficient is smaller and not significantly different from zero at the five percent level.

Remaining columns show that these relations between harvests and export revenues most likely reflect the behavior of export prices, as roughly indicated by observable spot prices in central U.S. commodity markets (New York for cotton, Chicago for wheat and corn).[5] Columns (4) and (5) show results of regressing log cotton export quantity (in pounds) on harvest fluctuations: coefficients are positive for both the antebellum and postbellum eras. For (6) – (9), left-hand side variables were crops' spot prices averaged over the twelve months beginning with the fall harvest season (July through the following June). The antebellum cotton harvest coefficient is close to negative one, not significantly different from negative one at conventional levels (p-value 0.67). The postbellum cotton coefficient is negative but smaller in magnitude; the hypothesis that it is negative one can be rejected at the one percent level. In (8), wheat prices appear largely unrelated to U.S. harvests; in (9) corn prices show a strong negative relation to harvests.

Wright (1974, p. 630) observed the decrease in the relation between cotton harvests and prices from the antebellum to the postbellum period, and argued that it was perhaps a consequence of declining U.S. share in world cotton production. We add that the development of cotton futures markets, which occurred over the 1860s, may have

[5] Actual export prices are unobservable. In the antebellum period, cotton was sold in many port cities and cotton prices varied substantially across ports (Hammond 1897, pp. 278-291; Woodman 1968, pp. 19-42). For many ports prices are unavailable, as is the fraction of 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). In the postbellum period, there was tighter correlation of prices across local markets, but there were active futures markets (Stevens 1887), so spot prices are not necessarily equal to export prices.

dampened the sensitivity of world cotton prices to short-run supply disturbances.[6] The weak relation between wheat prices and U.S. harvests is consistent with the small U.S. share of world wheat supply. Because wheat prices were largely unrelated to U.S. harvests, U.S. wheat harvests' effects on export revenues were similar to cotton's, even though wheat was a smaller share of export revenue on average.

III. Causes of harvest fluctuations

What caused harvest fluctuations? Were they driven by business cycles (through demand for crops, for example), or by some third factor or factors that affected both agriculture and industry? We begin to answer these questions by regressing autumn harvest fluctuations on IP gaps for the same calendar year and the previous year. Given the fundamental lag between planting and harvest, there is no reason to believe a common third factor could affect crop output *before* IP. Thus, effects on harvests of business cycles *or* common third factors should appear as positive coefficients on IP gaps. For cotton and corn, these regressions give no evidence that harvest fluctuations were caused by business cycles or common third factors. For the wheat crop only, there is evidence of a relation between the harvest and IP in the same year.

Table IV shows results**.** The last rows show *p*-values to test hypotheses that coefficients on all right-hand side variables are zero, and that the two IP gap coefficients are zero. For cotton and corn, one cannot reject the hypothesis that all variables' coefficients are zero. For the wheat crop only, the coefficient on the current-year IP gap is positive and significant at conventional levels.

The apparently weak relations between autumn harvests and IP of the same calendar year are consistent with observations of early NBER researchers, who found no conformity between business cycles and indices of crop output or farm employment (Burns 1951, pp. 7-8; Gordon 1952, pp. 385-387; Kuznets 1951, p. 159). Mitchell (1951 pp. 56, 57) concluded that "the basic industry of growing crops does not expand and

[6] 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 (Hammond 1897, pp. 300-314; Woodman 1968,

contract in unison with mining, manufacturing, trading, transportations and finance" because "farmers cannot control the short-term fluctuations in their output...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."

Weather, plant diseases and pests are indeed plausible causes of harvest fluctuations, as we have defined them. Many fluctuations apparent in Figure I are coincident with events of this type noted by contemporary observers (such as, for cotton, cotton worm infestation in 1846 and the early 1870s, boll worms in 1881, the boll weevil in 1909 and 1915; the Mississippi flood in 1892 [Thorp 1926]). 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 innovations in agricultural technique (Olmstead and Rhode 2002). Year-to-year effects depended on interactions with weather. For example, the boll weevil, which began to affect U.S. cotton production in 1892, caused most damage in years of especially wet, warm weather (Henry 1925, p. 523; Kincer 1928).

IV. Effects of harvests on industrial production

To observe the effects of harvest fluctuations on business cycles, we begin by running OLS regressions of IP gaps on lagged IP gaps and the previous fall's harvest fluctuations. 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 a variety of specifications the relation between cotton harvests and IP does *not* appear

289-294); larger stocks could dampen price effects of short-run supply fluctuations.

within the 1870s, though it holds in every other decade from the 1880s through 1913.

Finally, to establish the direction of causality between cotton harvests and IP, we observe the effect of 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 weather relevant for cotton could affect IP 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 cotton harvest and the following year's IP was one of cause and effect. They are also consistent with the absence of effects from wheat and corn.

IV.A) OLS regressions

Table V, panel A shows results of regressing IP gaps on two lags of IP gaps and harvest fluctuations. IP indexes are the standard Davis series, the Davis series excluding cotton textiles and flour, and sector-specific Davis series for two industries particularly far removed from crop inputs: metals (mainly iron and steel), and machinery. The last column shows results from the Frickey index of manufacturing production. In all cases, whether or not the postbellum sample includes the 1870s, the postbellum era's coefficient on the previous year's cotton harvest is positive and significantly different from zero at the two percent level or better; wheat and corn coefficients are not significantly different from zero (and are sometimes negative in sign). The antebellum era's cotton harvest coefficient is not significantly different from zero. In most cases coefficients on the second lags of crop harvests and IP gaps are not significantly different from zero, individually or jointly (p-values in the last row of the Table). Excluding second lags from the right-hand side, in panel B, has little effect on coefficients on the previous fall's harvests.

Scatterplots of the first-difference of (log) IP gap against the previous fall's harvest fluctuations should give good representations of the results in Table V, because estimated coefficients on the previous year's IP gap are close to one, and correlations across different crops' harvest fluctuations are low. Figure II A) is a scatterplot for the cotton harvest (standard Davis series, quadratic time trends) in the postbellum period. For comparison, Figures II) B) C) and D) show scatterplots for the antebellum cotton harvest and the wheat and corn harvests. The unique postbellum relation between cotton harvests and IP is apparent. The outlier is 1908 (harvests of fall 1907).

V. B) The 1870s* versus *the rest of the postbellum era

To observe whether cotton harvests were related to IP *throughout* the postbellum era, we examine the year-by-year correspondence between IP gaps and "forecasts" of IP gaps based cotton harvest fluctuations. We look at forecasts derived from two different regressions: the IP gap regressed on the previous two years' cotton harvest fluctuations; and the IP gap 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 (except for 1869 and 1870), so that both sets of forecast values are determined by cotton harvests *alone*.

Figure III plots actual and forecast IP gaps for quadratic and HP trends (each trend type defines both IP gaps and cotton harvest fluctuations). From the beginning of the 1880s on, most of the big swings in IP forecast by cotton harvests appear in the actual IP gap. Cotton harvests account for the IP peak around 1881 and the downturn to a trough in 1885; the depression of 1893, the brief 1894 upturn and the downturn in 1895; the trough in 1904; and the depression of 1910-1911. Indeed, among the major depressions after 1880, cotton harvests fail to account for only one: 1907-1908. We conclude that cotton harvests were related to nonagricultural business cycles throughout the period from the beginning of the 1880s to the First World War.

Within the 1870s, there is not clear evidence of a relation between cotton harvests and the IP gap. The actual IP gap falls from a peak in 1873 to a trough in 1875 or around 1877 (depending on trend definition), then rises through the end of the decade to the 1881 peak. The IP swings forecast by cotton harvests are clearly different in the early 1870s - a sharp downturn from 1871 and an upturn around 1873 - though they are arguably consistent with the actual IP recovery in the later 1870s.

Given the small number of observations at issue and the difficulties of dating nineteenth-century business cycles, we do not claim to precisely date the inception of the relation between cotton harvests and nonagricultural production, but we cautiously conclude that it did not exist throughout the 1870s: it may have come into force at the end of that decade or within its later years.

Without attempting to distinguish between years within the 1870s, we apply tests to observe whether there is a statistically significant difference between the 1870s as a whole and the rest of the postbellum era in the cotton harvest-IP relation. Table VI shows results of regressing IP gaps on the previous year's IP gap and cotton harvest, a dummy variable for observations 1870-1879, and an interaction between the dummy and the cotton harvest. If IP gaps were unrelated to the cotton harvest within the 1870s, the interaction-term coefficient should be negative and the sum of the interaction coefficient and the cotton harvest coefficient should be close to zero, meaning that the cotton harvest coefficient specific to 1870-1879 is zero. Also, the cotton harvest coefficient should be larger than that from the corresponding specifications in Table V B). These patterns hold for all variants.

To see whether the 1870s years were *unique* in the absence of a cotton harvest effect on IP, for each trend definition we ran 35 separate OLS regressions, defining dummy and interaction terms for each successive ten-year span: one regression with dummy and interaction terms defined for 1871-1880; another with terms defined for

1872-1881; and so on. Figure IV) plots the resulting coefficients on the cotton harvest, and the sums of the cotton harvest coefficient and the interaction term, with the last year of each ten-year span on the horizontal axis. (Thus, coefficients from Table VI are plotted at 1879.) The 1870s are indeed unique: no span *outside* the 1870s gives a shift coefficient that is negative and close in magnitude to the cotton-harvest coefficient; defining the shift terms for the 1870s maximizes the cotton-harvest coefficient.

V. C) IV results

The civilian U.S. Weather Bureau, founded in 1891, took over and expanded data-gathering operations that had been handled earlier by a variety of Federal agencies, and began to publish state-level monthly average temperatures and precipitation. In a pioneering statistical work, Moore (1917) showed that variations in a number of states' cotton harvests over 1894-1914 could be predicted by just three Weather Bureau monthly series (May rainfall, July and August temperatures), expressed as deviations from the average value across the preceding three years (p. 119).

To identify the causal nature of the cotton harvest-IP relation through two-stage least squares, it is desirable to avoid overfitting the first-stage relation between cotton harvests and weather variables. We take our first-stage specification directly from Moore. Published Weather Bureau series do not extend back before the late 1880s. But for all of the postbellum era - unfortunately, not for the antebellum era - we were able to construct measures of these three weather variables for the cotton belt states as a whole, from databases giving observations by thousands of individual weather stations. The data appendix gives details. Following Moore, we converted the series into deviations from the preceding three years' average value. To allow for possible changes in weather effects due to 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 parallel exercises for wheat and corn. Guided by early twentieth-century studies of weather effects on these crops' harvests (Moore 1920; Hanney 1931; Henry et. al. 1925; Kincer and Mattice 1928; and Mattice 1931), we chose four variables to predict wheat (January and May temperatures, June precipitation, and precipitation in the October *preceding* the harvest, as some harvest-season wheat - "winter" wheat – had been planted in the previous fall) and four for corn (July and August precipitation, April and July temperature). We constructed these variables from observations by grain belt states' weather stations (data appendix). Otherwise our first-stage specifications for wheat and corn were the same as for cotton.

Table VII A indicates the quality of these instruments with R2's, and F-statistics with associated p-values, from regressions of harvest fluctuations (quadratic trends) on each crop's set of weather variables. We have fairly strong instruments for all three crops within the 1880-1913 period, though not for wheat over the longer 1870-1913 period.[7] No crop's weather variables are strongly related to harvests of *other* crops.

Table VIII) panel A) shows results of 2SLS regressions for 1870-1913 and 1880-1913; matching OLS regressions are in panel B). For the first three columns, specifications follow Table V, panel B, with IP gaps regressed on the previous year's IP gap and harvest fluctuation (quadratic). For the last three columns, the first difference of log IP was regressed on the previous year's harvest fluctuation alone.

In both specifications, coefficients on cotton harvests are positive and significant at one percent. Coefficients on wheat and corn are not significantly different from zero, and are close to zero in magnitude. Other IP series and HP trends gave similar results.

V. Explaining harvests' effects on IP

Why did cotton harvests affect U.S. IP in the postbellum era but not in the antebellum era, when raw cotton was a larger share of U.S. national income? Why did wheat and corn harvests fail to affect IP even though their shares of national income were similar to cotton's? In the remaining sections of the paper, we briefly consider and reject a "real" explanation of these patterns suggested by the literature on oil-price shocks. At greater length, we propose and test a monetary explanation.

V. A) A 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 depicted 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 expected productivity of current or future inputs. There is no sense in which a large cotton harvest could boost nonagricultural output by releasing labor from the agricultural sector: it took more labor to bring in a larger crop (Parker 1991, pp. 61-63).

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 cotton as an input to the textile industry. A test of this approach is to observe the relation between U.S. cotton harvests and *British* IP. Recall that American cotton was 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, there should be similar effects on British IP. To check this, we examine the relation between U.S. cotton harvests and Hoffman's (1955) index of British IP, defining IP gaps as for the U.S. We observe no cotton harvest effect on British IP in the postbellum era analogous to the U.S. effect. Therefore, we do not view this real channel as promising.

Table IX 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

[7] This is not surprising, because the geographic location of wheat production changed substantially from the 1870s to the 1900s (Olmstead and Rhode 2002, p. 937) and the prior studies guiding our wheat weather variable selection date from the twentieth century.

U.S. IP gap on the left-hand side, the cotton harvest coefficient is practically zero in the antebellum era; but positive and significant at one percent in the postbellum samples. With the British IP gap on the left-hand side, the cotton coefficient is very small in magnitude and not significantly different from zero for either postbellum sample, though it is positive and significant at around the ten percent level for the antebellum era.

V. B) Monetary explanation

In their *Monetary History of the United States,* Friedman and Schwartz (1963, pp. 97-99, 107, 140-41) argue that wheat harvest fluctuations contributed to business cycles in the period from 1879 to the First World War, through a monetary channel created by the U.S. monetary regime of the period. In January 1879, the U.S. Treasury began to redeem legal-tender currency dollars ("greenbacks") in gold, placing the U.S. within the international gold standard that had developed over the 1870s (Meissner 2005) and which remained in force until the beginning of the First World War, when most countries suspended gold convertibility. Under the international gold standard, a country's monetary authorities exchanged domestic high-powered money for gold at a fixed rate. Monetary gold flows balanced the difference between net exports and international capital outflow. The U.S. had no central bank. High-powered money consisted of monetized gold, and nongold currency that the Treasury promised to redeem in gold. The high-powered money supply to banks and the public was proximately determined by international gold flows reflecting the balance of payments; the rate of growth of nongold currency; and the change in the stock of gold held in Treasury vaults, removed from banks and the public (Friedman and Schwartz 1963, pp. 124-134). As a bumper crop harvest boosted U.S. export revenues it could boost potential money growth, unless this effect were counteracted by slower growth in nongold high-powered money or an

[8] Da-Rocha and Restuccia (2006) show that a large farm sector can amplify real effects of nonagricultural productivity shocks in an RBC model, by increasing elasticity of labor supply to nonagricultural sectors.

increase in the Treasury gold stock. In fact there is no reason to believe Treasury policy tended to counteract the potential effects of crop export revenues in this way.[9] Table X shows results of regressing growth in nongold high-powered money and the Treasury gold stock on harvest fluctuations: no coefficient is significant at conventional levels. Thus, Friedman and Schwartz argued that wheat harvest fluctuations affected high-powered money-supply growth through net exports, and hence contributed to business cycles through a general effect of money-supply shocks on real activity. Fels (1959, pp. 60, 87, 181, 220) makes a similar argument.

Oddly, neither Fels nor Friedman and Schwartz mention cotton in this context. But pre-1914 contemporaries mentioned cotton along with wheat harvests as affecting financial conditions through international gold flows (e.g. Sprague 1903, p. 50; 1915, p. 500; Andrew 1906). Both crops' fluctuations were positively related to export revenue in the postbellum era, as was indicated by Table III. Within the post-1879 gold standard period, volatility in both crops' export revenues was large enough to affect high-powered money supply growth. Table XI shows statistics on high-powered money growth, gold inflow across the twelve months from the July preceding a harvest season to the following July, and annual crop-related export revenues, all expressed as fractions of the preceding July's money stock. For both cotton and wheat revenues, standard deviations and maximum-minimum spreads are large relative to volatility in gold flow or money growth.

A channel from cotton harvests to U.S. IP through international gold flows is consistent with the *absence* of a cotton-harvest effect on British IP. Britain and major European countries had central banks that could sterilize the effects of transitory gold

[9] Nongold money consisted of greenbacks, silver notes, national banknotes and silver coins. 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 (Myers, 1931, p. 403; Cagan, 1965, p. 91). On occasion, Treasury officials deliberately managed Treasury vault cash to

flows on money supplies, but often responded to persistent gold outflows with actions that tended to reduce the money supply and raise interest rates (Sayers 1976). Harvest-related gold inflows to the U.S. must have been matched by outflows from the outside gold-standard world. These may not have been large enough relative to the world gold stock to provoke *tightening* by European central banks, but there is no reason they should cause monetary *loosening* abroad.[10] Table XII shows results of regressing the change in British short-term interest rates (July-to-June averages) and the British high-powered money supply (July-to-June averages or July-to-July) on U.S. harvest fluctuations: no coefficient is significant at conventional levels.

A channel through export revenues is also consistent with the absence of a cotton harvest effect on U.S. IP in the antebellum era. In that era, the U.S. and most other countries active in international trade and investment tied their currencies to gold, silver, or both.[11] Friedman (1990) and Flandreau (1996) argue that these various standards amounted to a single specie standard essentially similar to the later gold standard. If so, the U.S. money supply was linked to export revenues before 1860 as after 1879. However, as we showed in section II, within the antebellum era export revenues were *unrelated* to cotton harvest fluctuations, perhaps because cotton prices were more sensitive to U.S. harvests than in the postbellum era.

Finally, a gold-standard monetary channel is consistent with our tentative conclusion that cotton harvests began to affect the IP gap at a point prior to the beginning of the 1880s, but subsequent to the early 1870s. From 1862 through 1878, legal-tender currency dollars traded at a floating rate against gold and specie-linked currencies; their supply was unaffected by the trade balance (Friedman and Schwartz, 1960, 54-55).

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affect money-market conditions (Myers, 1931, pp. 370-86), but no accounts suggest that they did so in a way that would pre-empt the effects of harvest fluctuations.

[10] Friedman and Schwartz (1963, p. 89 footnote) guessed that the U.S. held less than twenty percent of the world monetary gold stock in the late nineteenth century. A theoretical attempt to quantify the possible effect of U.S. money-demand variations on world interest rates would be interesting but dubious.

[11] The American dollar was officially bimetallic but effectively silver until 1834, gold after that (Friedman, 1990).

Legislation passed in 1875 promised that gold redemption at the antebellum rate would resume in January 1879; this event took place as scheduled. Thus, the straightforward gold-standard link between net exports and the high-powered money supply came into effect at the end of the 1870s. That does not rule out the possibility of a different monetary channel before 1879. Even before 1879, the U.S. stock of monetary gold, which *was* affected by the trade balance (p. 79), served a number of purposes ordinarily associated with high-powered money: Friedman and Schwartz (1960) argue that gold was "a second species of money" (p. 58) "used for monetary purposes alongside greenbacks" (p. 83), and that as 1879 approached gold became a better way to hold funds for domestic purposes because the future dollar-gold exchange rate became more certain (p. 79).[12] Calomiris (1988) argues that already by 1876 resumption was nearly certain and gold flows were related to the money supply, broadly defined. Even on these arguments, however, one would not expect a monetary channel to operate until the *later* 1870s.

There is one obvious puzzle: why did wheat harvests *fail* to affect IP? We argue that this can be explained as a result of another essentially monetary phenomenon. Harvest fluctuations were also positively related to high-powered money *demand*, so the effect of a crop's harvest on economic activity depended on the strength of its export-revenue effect *relative to* its money-demand effect. Money-demand effects of wheat harvest fluctuations were stronger relative to the crop's export revenue effects, so wheat harvests failed to affect IP even though they were positively related to export revenue.

We illustrate this point in a standard Keynesian open-economy model tailored to fit the pre-1914 U.S. The model has implications for a variety of available data which we test in the final section of the paper.

Before presenting the model, we explain why money-demand effects of harvests

[12] "Gold dollars" - the quantity of gold corresponding to a dollar at the antebellum parity - served as the medium of exchange for nearly all purposes in the far West; many bond payments were fixed in gold dollars; banks offered gold dollar accounts and held gold reserves (Friedman and Schwartz, 1960, pp. 26-27, 58, 83) before 1879. Unfortunately, it is difficult to analyse the domestic monetary role of gold before

are plausible, and describe some characteristics of the pre-1914 U.S. economy that guide the model's particular assumptions.

Harvest effects on money demand

It is well-known that, in the gold standard period, demand for high-powered money was subject to a regular seasonal peak during the fall harvest months, falling off to seasonal lows in the summer just before the next harvest season (Kemmerer 1910). A modern economics literature has examined the corresponding seasonals in gold flows, interest rates and financial market conditions (Goodhart 1968, pp. 51-52; Miron 1986; Clark 1986; Barsky, Mankiw, Miron and Weil 1988). Apart from harvests' seasonal effects on money demand, there is reason to believe that the size of a harvest could affect the magnitude of the associated money-demand shock.

High-powered money was held by banks for payments and reserve requirements, and by households and nonbank businesses as cash. Compared with later eras, fewer households held bank deposits; cash was a larger share of high-powered money or standard monetary aggregates (Cagan 1965, pp. 119-123). To bridge the gap between periodic income payments and day-to-day expenses, households without bank accounts held cash hoards and used "book" credit extended by merchants (Fisher 1913, p. 81).

Rural households were especially unlikely to hold bank deposits or make payments with checks (Fisher 1913, p. 51; James 1978, pp. 32-33). Contemporaries observed that in the harvest season "Farmers require payment very largely in cash to pay labourers and frequently for their own use where, as often happens, they have no account with a business bank" (Sprague 1903, p. 36). Farmers and laborers used cash hoards along with book credit to cover expenses between harvest seasons, including spring planting costs and mortgage payments (e.g. Wright 1922, pp. 71, 92; Young 1925, p. 21). Farm mortgages were short-term (five years or less); paid off when a farmer's income was high, renewed or allowed to fall into arrears when income was low; payments were

1879 because banking data from the period do not distinguish between greenback dollar and gold dollar assets (Kindahl, 1961).

made just once a year, usually around May (Murray 1933, p. 381; Hinman and Rankin 1933, pp. 30-35; Bogue 1955, pp. 53, 66, 72). The Indianapolis Monetary Commission (1898, p. 313) described farmers' use of cash hoards:

> 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...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.

The seasonal pattern in rural cash demand was an obvious cause of the seasonal in high-powered money demand. Data on inter-regional cash shipments show massive flows to the rural midwest and south from the urban northeast from August through December, and return shipments over the following months through the early summer (Kemmerer 1910, pp. 128-129).

Given the cash-intensity of rural economic activity, we propose that large harvests tended to boost rural cash demand, not only within the harvest season but also through following months. A larger crop might cause farmers to hire more wage labor to bring it in, resulting in larger cash wage payments and laborers' cash-holdings. The behavior of commodity-market prices (Table III) suggests that harvest fluctuations were also positively related to farmers' harvest-season income, at least for postbellum wheat and cotton. Harvests of these crops could thus be positively related to farmers' cash-holdings – for example, as farm owners made bigger mortgage payments in a high-income year.

There is also reason to believe money-demand effects could be stronger for wheat than for cotton harvests. Inter-regional cash-shipment data indicate that southern cash demand fell off sharply after the harvest season, while midwestern cash demand remained high through early summer (Kemmerer 1910, pp. 224-227). Many factors that appeared to boost rural cash demand were weaker in the cotton-growing South.

Compared with the midwest, a smaller fraction of farms (by number or land area) were mortgaged (U.S. Bureau of the Census 1914, pp. 159, 162-163). Cash wages of hired labor were a smaller fraction of crop value in cotton than in wheat (U.S. Bureau of the Census 1900, Part II, p. cxxix) and wages were less likely to be paid in cash: "scrip" redeemable at a local store was used "especially..in country districts throughout the South. These are issued in payment of wages, and reduce the amount of money paid out in wages as well as in retail payments" (U.S. Comptroller of the Currency 1894, p. 21; see also Woodman 1968, p. 302). "Crop lien" laws, unique to the southern states, allowed tenant farmers to finance most expenditures with store credit as they gave a merchant creditor a first claim on a tenant's standing crop (Ransom and Sutch 1977, p. 123). A typical northern farmer sold his crop to grain dealers or grain-elevator operators (U.S. Industrial Commission 1901, pp. 50, 62-63). A cotton-growing farmer or tenant often sold his crop to the same enterprise that furnished him credit between harvests (a factor, local merchant or plantation) so that little if any cash changed hands: the sale merely reduced a debt or created a credit on the books of the enterprise (Ransom and Sutch 1977, p. 123; Brooks 1898, p. 242; Brown 1927, pp. 374-375; Hammond 1896, p. 382; Woodman 1968, pp. 288, 302, 308). 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).

Given these differences between wheat and cotton regions, we propose that the money-demand shock associated with the wheat harvest was larger relative to its effect on export revenue, not only because wheat crop sales were larger relative to export revenue (Table II), but also because of the cotton belt's peculiar farm credit and tenancy institutions.

Unfortunately, there are no data to directly indicate effects of harvest fluctuations on rural cash demand. Measures of inter-regional cash flows are available for only a few years in the 1900s. For most postbellum years there is no way to estimate cash held by the nonbank public (Friedman and Schwartz 1970, p. 208-211), let alone cash held by rural households. But money-demand effects can be inferred from the behavior of observable variables, given a few more features of the gold-standard economy.

Other features of the pre-1914 U.S. economy

Under the gold standard, rates of exchange between financial centers were tied to the "parity" value defined by currencies' gold content. An exchange rate could not remain outside the bounds – the "gold points" - that just covered costs of transporting gold between the locations. In the U.S. most international payments were negotiated through "sight" exchange claims to London sterling funds (even if the ultimate counterparty was outside England) purchased from, or sold to, financial institutions in New York City (Myers 1931, pp. 338-350). Thus, the effective foreign exchange rate was the New York dollar price of London sight exchange, for which data are available from January 1879 on. The New York-London gold points were narrow enough to hold this rate within a range that was too small to make a difference for the relative price of foreign goods. At the same time, the exchange rate did vary measurably within the gold points. Thus, the direction of international gold flow over a span of months could be reflected in the average value of the exchange rate over those months, as the rate was driven to (or perhaps just beyond) the gold point for a larger fraction of days.[13]

As the exchange rate was practically fixed for purposes of foreign trade, dollar prices of internationally-traded commodities such as cotton and wheat may have been directly determined on international markets. But most U.S. prices were not tied down by purchasing-power parity except in the very long run (Diebold, Husted and Rush 1991; Lothian and Taylor 1996). Empirical studies of price inflation in the pre-1914 U.S. (e.g. Gordon 1990; Backus and Kehoe 1992) generally find a positive relation between real

[13] Canjels, Prakash-Canjels and Taylor (2004) observe that from 1879 through 1913 the largest deviation from parity in the New York-London rate on any *day* was 1.06 percent (p. 870). They also argue that the marginal costs of shipping gold at a particular point in time increased with the amount of gold shipped. If so, the average exchange rate over a period could indicate the direction of gold flow not only because the rate was driven to a gold point, but also because the rate on a particular day could range further from parity – in effect, the gold points widened - when the gold flow was bigger.

activity and the rate of price inflation along the lines of the original Phillips curve, in contrast to the "accelerationist" Phillips curve apparent in post-1950s data. The pre-1914 Philips curve matches a standard expectations-augmented aggregate supply function, assuming prices were expected to return to a PPP level in the long run (Alogoskoufis and Smith 1991). Thus, the inflation rate could be positively related to output fluctuations caused by aggregate demand shocks.

The central U.S. financial market, New York, was tightly linked to London, the central European market.[14] Financial institutions and individual investors 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). In London, the benchmark short-term liquid asset was bank-backed bills of exchange, for which open-market rate data are available starting in the early nineteenth century. As bills of exchange and banker's acceptances were not traded in the U.S., the most comparable American asset was perhaps commercial paper, which was actively traded in New York with rate data available from the late 1850s on. Thus, the difference between rates on New York commercial paper and London bills indicates the international interest-rate spread in this era.

The weight of empirical evidence suggests capital flows to the U.S. were sensitive to expected rate-of-return differentials, but not *infinitely* sensitive: uncovered interest-rate parity did *not* hold between New York and London.[15] Thus, it is possible that

[14] Bordo and MacDonald (2005) show that short-term interest rates in continental financial centers were tightly linked to London's, less tightly linked from one continental center to another.

[15] Studies have examined whether New York-London interest-rate spreads were related to probable future change in exchange rates in a manner consistent with uncovered interest-rate parity. At times, the spread obviously exceeded the range of possible future exchange-rate variation *assuming* the dollar remained tied to gold (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 clear evidence against uncovered interest-rate parity in seasonal patterns: month to month, New York interest rates were relatively low just when 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 business-cycle frequencies (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).

international capital mobility to the U.S. was imperfect, in the sense that the spread between expected returns on U.S. commercial paper and London bills (accounting for expected future exchange-rate movements) was positively related to the volume of capital flow to the U.S. Before 1896, the spread was also affected by a perceived risk that the dollar would again be devalued or floated. This perception largely disappeared after the 1896 presidential election, which was taken to signal a firm U.S. commitment to the gold standard: the long-run trend value of the London-New York spread was narrower after the election than it had been over 1879-1896 (Friedman and Schwartz 1982, pp. 515-517).

For American banks and investors outside New York, commercial paper was the most important (often the *only*) traded short-term asset: 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, 174-98). Thus, commercial paper rates can be taken to indicate the opportunity cost of holding high-powered money, and also banks' opportunity costs of making loans to local borrowers (Sylla 1969).[16]

The bank-credit channel, that is the cost and availability of bank loans as distinct from rates on traded assets such as commercial paper, may have been more important before 1914 than in later eras (Miron, Romer and Weil 1994). To the degree that credit-channel disturbances are triggered by changes in market rates (as discussed by Romer and Romer 1990, p. 187; Bernanke and Gertler 1995, p.28), this could have tended to amplify standard IS effects of interest rates on output. Certainly, the pre-1914 U.S. was extraordinarily subject to bank panics, which must have affected the supply of bank loans at any given level of short-term market rates. Unfortunately, there are no pre-1914 data that indicate changes in required returns to bank lending or the degree of credit rationing

[16] Another money-center asset held by banks all across the U.S., and which might represent banks' opportunity cost of local loans, was correspondent bank accounts in New York. But the return to holding these accounts is unobservable, as it included the value of various services provided by the correspondent bank (James, 1978, pp. 103, 109-111).

in a straightforward way.[17]

Model

To describe the pre-1914 U.S. economy we rely on a textbook "old Keynesian" model rather than a "new Keynesian" model, because at least two key features of the pre-1914 economy for harvests' possible monetary effects are at odds with simplifying assumptions that make New Keynesian models tractable. One is imperfect international capital mobility: in standard New-Keynesian open-economy models (e.g. Clarida, Gali and Gertler, 2002), uncovered interest-rate parity holds. Another is the nature of rural cash demand, in our view essentially related to limited financial-market participation: new Keynesian models (including those that allow for money-demand shocks such as Ireland [2004]) assume households have access to perfect capital markets and complete consumption insurance. Of course, such models may be appropriate to analyse other aspects of the pre-1914 U.S. economy.

In our model, variable levels are average values over a period covering the harvest season and following months, ending before the next harvest season. First-differences are changes across the same span of time. Variables subscripted (-1) are dated to the preceding period. Variables other than interest and inflation rates are logs or deviations of logs from long-run trends. Parameters' signs are positive except where noted.

The nonagricultural output gap over the post-harvest period, as indicated by the IP gap, is:

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

where the real interest rate ($i - E\pi$) is normalized to trend, and the nominal interest rate i corresponds to the period's average New York commercial paper rate. $E\pi$ is the average expected rate of price inflation over corresponding maturities. The disturbance term ε_y reflects all other factors affecting nonagricultural output. To the degree that credit-

[17] A number of studies (e.g. Bodenhorn 1995) have used pre-1914 bank call reports to calculate the ratio of reported earnings from loans to outstanding loan balances. This figure can indicate long-term trends in the return to bank loans. Its relation to cyclical-frequency movements is doubtful.

channel shocks are triggered by high interest rates, they would boost the magnitude of the interest-rate coefficient in (1).

Realized inflation over the post-harvest period is:

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

where Δp is the change in the (log) price level across the period and ε_p reflects "cost-push" shocks.

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

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

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

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

g is international gold inflow as a fraction of the pre-harvest money supply and ε_{ms} reflects other factors affecting the high-powered money supply (changes in the supply of nongold currency and/or the quantity of money held in Treasury vaults).

Gold inflow is reflected in the exchange rate:

$$(5) \qquad e = -\eta g + \varepsilon_e$$

where e is the post-harvest period's average dollar price of London sight exchange. Gold inflow is also 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:

$$(6) \qquad g = \theta_{CF} (i - i^* - E\dot{e}) - \theta_y y - \theta_p p + \varepsilon_{bop}$$

The first term on the right-hand side of (6) describes capital flow, determined by the spread between the domestic interest rate and the expected return to foreign short-term assets. i^* denotes the London open-market bill rate. $E\dot{e}$ is the expected future 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).

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

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

and exchange-rate expectations in (6) can be related to the average exchange rate:

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

Making some substitutions gives nonagricultural output and gold inflow as functions of the domestic interest rate:

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

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

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

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

We must assume $\beta_1 > 0$: an exogenous increase in the domestic interest rate tends to reduce output. This condition is consistent with, but not limited to a case where $\varphi_\pi \geq 0$, which holds if the price level is believed to be mean-reverting or a random walk – a plausible assumption for the gold standard era. We must also assume that $\beta_2 > 0$: an exogenous interest-rate hike tends to draw in gold. This condition is consistent with, but not limited to a case where $\varphi_e > 0$, which holds if a relatively low exchange rate is accompanied by expectations of a future rise – again plausible under the gold standard.

Under these assumptions, variations in the model's disturbance terms have the standard effects in Keynesian models. "IS shocks" ε_y create output fluctuations that are positively related to the domestic interest rate and the international interest-rate spread; under gold-standard conditions they are also positively related to gold inflow and money-supply growth. "Money-demand shocks" ε_{md} create output fluctuations that are positively related to gold inflow and money-supply growth, but negatively related to the domestic interest rate and the international interest-rate spread. Both types of shocks, along with exogenous variations in the foreign interest rate i^*, create positive relations between output and inflation. "Cost-push" shocks ε_p create negative correlations between output growth and inflation. Overall the model has no *general* implications for correlations between IP gaps and other variables.

Effects of harvest fluctuations enter the model through the disturbance terms. "Real" effects on production costs or spending correspond to relations between harvest fluctuations and ε_y in (1) and/or ε_p in (2). We focus instead on effects on net exports and money demand, which affect output and inflation through the interest rate i.

Denoting a crop's harvest fluctuation by h, a positive effect on net exports means $\partial \varepsilon_{bop} / \partial h > 0$. By itself, this would create a positive relation between the harvest and nonagricultural output growth. For example, a positive balance-of-payments disturbance associated with a bumper harvest must be accompanied by some combination of a smaller international interest-rate spread and larger gold inflow (or smaller outflow) in expression (6). In (4), larger gold inflow means faster money-supply growth. From (3) and (1), faster money-supply growth must be accompanied by a decrease in the U.S. interest rate (matching the decrease in the international interest-rate spread) and an increase in nonagricultural output.

A positive effect of a crop's harvest fluctuation on rural cash demand means a positive relation between the harvest and total demand for high-powered money at a given interest rate and level of nonagricultural output: $\partial \varepsilon_{md} / \partial h > 0$. Allowing for this money-demand effect along with the balance-of-payments effect gives:

(11) $\partial \Delta y / \partial h = (1/\beta_3)\,[\,(1/\beta_2)\, \partial \varepsilon_{bop}/\partial h \;-\; \partial \varepsilon_{md}/\partial h\,]$ *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) $\partial g / \partial h = \partial \Delta m / \partial h = \partial \varepsilon_{md}/\partial h + (\alpha + \mu_y + \beta_1 (\mu_i / \gamma_r))\; \partial \Delta y / \partial h$

(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 a crop harvest is positively related to nonagricultural production only if its balance-of-payments effect is strong enough *relative to* its money-demand effect. It is plausible that this could be true for cotton and not for wheat. For the cotton crop, export revenue was larger relative to crop sale income (Table 2). Also, the cotton belt's peculiar credit institutions appear to have reduced the use of cash relative to credit, so southern rural cash demand may have been smaller relative to crop sale income.

We hypothesize that cotton harvest fluctuations affected IP because their money-demand effects were weak relative to their export-revenue effects. Wheat harvests failed to affect IP because their money-demand effects were relatively strong.

Testable implications

If cotton harvests affected IP through this monetary channel, then cotton harvest fluctuations and cotton-caused variations in IP growth should be positively correlated with gold inflow and money-supply growth (expression 12); negatively correlated with the exchange rate (expression 13); negatively correlated with the international interest-rate spread and the change in the short-term interest rate (14); and positively correlated with price inflation (15) reflecting the interaction between an aggregate-demand shock and the Phillips curve. Importantly, these patterns need *not* hold for IP growth fluctuations due to causes *other* than the cotton harvest. These could appear uncorrelated with monetary quantities and interest rates, for example, if they reflected a mix of IS and money-demand shocks. Thus, one test of our explanation is to observe relations between IP growth and measures of the model's other variables, comparing IP fluctuations most likely due to the cotton harvest with *other* IP fluctuations.

Another test of our explanation is to observe relations between variables and harvests of cotton, wheat and corn. If wheat harvest fluctuations failed to affect IP because their associated money-demand shocks were strong relative to their effects on net exports, then wheat harvests should appear unrelated to inflation, the international interest-rate spread and the change in the domestic interest rate. But wheat harvests should be *positively* related to gold inflow and money-supply growth. Corn harvests should be unrelated to any of these variables.

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

VI.A) Cotton-caused IP fluctuations versus other IP fluctuations

To observe relations between variables and IP changes most likely due to cotton, we ran 2SLS regressions on the first-difference of log IP, with IP change instrumented in the first stage by the preceding autumn's cotton harvest fluctuation (deviation from quadratic trend). To observe relations between variables and IP changes more likely due to other causes, we ran OLS regressions on the *residual* from the first-stage regression of IP change on cotton. Finally, we ran OLS regressions on IP changes in general.

As left-hand side variables, for gold inflow we use total net gold imports over the months from July of the harvest season through the following June, as a fraction of the initial July's high-powered money supply. High-powered money supply growth is the July-to-July change in the log of high-powered money. The exchange rate is the average New York dollar price of London sight exchange across months from harvest July through the following June. The international interest-rate spread is the average July-through-June value for the New York commercial paper rate *minus* the London bill rate. The change in the domestic interest rate is the change in the average commercial paper rate from the July-to-June period preceding the harvest to the following July-to-June. For the change in the price level we use the July-to-July change in the log of wholesale price indexes, which are the only reliable cyclical-frequency measures of the price level in this period (Hanes 1999). 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. Therefore, in addition to the standard series we use a special WPI constructed from the standard series' components *excluding* raw farm products and foods (but *including* cotton textiles). Samples begin with 1879-1880, the first harvest season of the gold standard period. When the left-hand side variable is the international interest-rate spread, we add a dummy variable for post-1896 years, to allow for the change in the spread associated with the decreased probability of dollar devaluation.

Results for cotton-caused IP changes (2SLS regressions) are shown in Table XIII, row (a). All coefficients have signs consistent with the hypothesized monetary channel and are significantly different from zero at the five percent level or better. Results from regressions on other IP changes (residual from first stage of (a)), shown in (b), are different: coefficients are not significantly different from zero and some differ in sign from (a). Coefficients on IP changes in general, in (c), have magnitudes between those in (a) and (b). Estimated coefficients with inflation on the left-hand side (columns 6 and 7) are an exception: across (a), (b) and (c) all are positive, significant at 2 percent and about the same magnitude. This suggests *all* causes of IP fluctuations tended to create positive relations between output and inflation (cost-push shocks were unimportant). Coefficients on the post-1896 dummy variable for the international interest-rate spread, shown at the bottom of the Table, are all negative and significantly different from zero at one percent.

VI. B) Cotton versus wheat and corn harvests

Table XIV shows results of regressing the same LHS variables on cotton, wheat and corn harvest fluctuations (quadratic trends). We add one more LHS variable: 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. This is the closest one can get to cash held by the nonbank public, but it includes cash held by financial institutions other than national banks (see data appendix). In addition to OLS regressions we ran three sets of 2SLS regressions, one for each crop, using Table VIII's weather variables. OLS estimates are most efficient if harvest fluctuations generally were caused by exogenous events. But 2SLS regressions are a useful check for wheat, given

Table IV's evidence of a positive relation between wheat harvest fluctuations and IP in the same year.

OLS results in panel A are consistent with predicted differences across crops. For growth in cash outside national banks, gold inflow or 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. 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, not significantly different from zero. For inflation, results depend somewhat on the price index. For the standard WPI 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, suggesting that the corn harvest's negative effect on the standard WPI merely reflects its direct effect on corn prices (which have heavy weight in the standard WPI). For either WPI, the cotton harvest coefficient is positive and significant at five percent. In 2SLS results, panel B, cotton coefficients are similar in magnitude to their OLS counterparts, as are wheat coefficients for monetary quantities and exchange rates. They generally have larger standard errors, so some are not significant at conventional levels.

VII. Conclusion

From about 1880 to the First World War, fluctuations in the cotton harvest due to weather, crop diseases and other factors exogenous to the industrial economy caused most major American business cycles, including the depressions of 1884, 1893, 1895 and 1910. This phenomenon is apparent in the relation between harvest fluctuations and measures of industrial production (IP). Wheat and corn harvests did not affect IP. Cotton harvests did not affect IP in the antebellum era.

We explain the unique postbellum effect of cotton harvests on IP as the outcome of interactions between harvests, export revenues and high-powered money demand. Under America's gold-standard regime of 1879-1914, a positive export-revenue shock tended to boost nonagricultural output as it allowed for larger gold inflows, faster growth in the high-powered money supply and lower U.S. interest rates. A positive money-demand shock tended to depress nonagricultural output as it boosted high-powered money supply through gold inflows but increased U.S. interest rates. In the 1879-1914 period, cotton harvests affected IP because they were positively related to export revenue and their money-demand effects were relatively weak. Wheat harvests failed to affect IP because their money-demand effects were stronger relative to their export-revenue effects. In the antebellum era, cotton harvests failed to affect IP because they were not positively related to export revenue.

Data on international gold flows, interest rates, exchange rates and inflation are consistent with our monetary explanation of the cotton harvest's effect on IP. Large cotton harvests boosted gold inflows, money-supply growth and the foreign exchange value of the dollar, while they decreased American short-term interest rates and American interest rates relative to London rates. Large wheat harvests boosted gold inflows, the money supply and the dollar's exchange value but did *not* decrease U.S. interest rates. Of course, we have left many aspects of this mechanism unexplored in this paper, including the role of financial panics in the transmission of the cotton harvest's monetary shock to industrial output, and the possibility that a variant of the mechanism was already at work in the later 1870s.

We believe that alternative explanations based on real channels may prove difficult to reconcile with 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 cotton harvests on price inflation, which is consistent with interactions between a Phillips curve and aggregate demand shocks, rather than supply shocks. But whether or not we are correct about the channel from the cotton harvest to nonagricultural production, our results leave little doubt that cotton harvest fluctuations were the ultimate, exogenous cause of many pre-World War I business cycles.

Data appendix

General note: "NBER series" refers to National Bureau of Economic Research Macro History database (http://www.nber.org/databases/macrohistory/)
Values of crop-related exports: Export values starting 1851 are from USDA, Bureau of Statistics (1910) and USDA *Yearbook* (1913, 1916). Value of cotton exports for earlier years from USDA, Bureau of Statistics (1912). Wheat (and flour) and corn (and meal) exports for the earlier years from the U.S. Department of Treasury (1848, 1849, 1850, 1851). All of these figures are 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. Annual figures for years before 1843 are for twelve-month spans ending September 30th. After 1843, figures 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.

Commodity market 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 (04001, 04005).

U.S. high-powered money supply and components: Monthly data on components of the high-powered money stock begin with June 1878 (Friedman and Schwartz 1970, pp. 205-211): high-powered money outside the Treasury (NBER 14135); gold held in the Treasury (NBER 14137). Nongold money outside the Treasury calculated as money outside the Treasury minus gold (gold coins and gold certificates) outside the Treasury (14131). Total monetary gold, in or outside the Treasury, is NBER 14076.

U.K. high-powered money supply: Capie and Webber (1985), Table I.1, "Monetary Base."

International gold inflow to U.S.: Monthly net gold export from NBER 14112.

New York – London exchange rate: Neal and Weidenmier (2003) collected weekly-frequency New York bid and ask prices for London exchange from the New York *Commercial and Financial Chronicle*. Weidenmier kindly provided 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 (Myers 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, sight exchange rates taken from Schneider, Schwarzer and Zellfelder (1991, p. 330).

Interest rates: New York commercial paper rate is NBER series 13002. London open-market bill rate is NBER series 13016.

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).

Cash outside national banks: For national banks only, 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 occurring 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.

Weather variables: 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 (lwf.ncdc.noaa.gov/oa/climate/onlinedata/forts/forts.html). Temperature data are available beginning in 1822; precipitation data in 1838. To create a monthly weather variable for the cotton belt, we used observations of all weather stations located in North Carolina, South Carolina, Georgia, Florida, Tennessee, Alabama, Mississippi, Louisiana, Arkansas, and Texas; for the grain belt, Ohio, Indiana, Michigan, Illinois, Wisconsin, Minnesota, Iowa, Missouri, North Dakota, South Dakota, Nebraska, and Kansas. For each variable and region, we ran a fixed-effect regression with dummies for each year and weather station. Estimated coefficients on year dummies are our measure of the monthly weather variable.

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Table I: 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 II: Statistics on staple crops 1840-1910

	Per cent 1840-1860	1869-1913	1880-1913
Exports/U.S. merchandise exports			
Cotton	51.7	29.3	25.6
Wheat and wheat flour		14.0	13.0
Corn and corn meal		3.9	3.6
Value of harvested crop/GNP			
Cotton*	3.6	2.4	2.3
Wheat		3.0	2.6
Corn		6.3	5.9
Farmers' income from crop sales/GNP			
Cotton	3.6	2.4	2.3
Wheat		2.5	2.2
Corn		1.3	1.2
Export revenues/farmers' income from crop sales			
Cotton	91.7	71.4	71.4
Wheat and wheat flour		35.0	37.1
Corn		18.7	18.9
Cotton consumed (value)/GNP			
U.S.**	0.8	1.1	0.9
Britain***	3.6	3.1	2.7
Cotton consumed (value)/Nonagricultural GNP			
U.S.**	1.4	1.4	1.2
Britain***	4.5	3.4	2.9
Imports of U.S. cotton by Britain (value)			
/GNP***	3.0	2.8	2.4
/Nonagricultural GNP***	3.8	3.1	2.6

* 1840-1860 average of values for 1839, 1844, 1849, 1854, 1859.
**Averages of values for 1840, 1850, 1860, 1870, 1880, 1890, 1900.
***Averages of values for 1841, 1851, 1861, 1871, 1881, 1891, 1901, 1907.

Sources:
Crop exports/ merchandise exports: Historical Statistics of the United States, Millennial Edition (2006): Series Ee366, Ee571, Ee576. Corn exports valued at Chicago prices in *Agricultural Statistics, 1936*, pp. 32-33.
Value of harvest crop/GNP: 1840-1860 is cotton's value added from Gallman (1960, pp. 46-47) over GNP from Gallman (1966, p. 26). 1869-1913 and 1880-1913 are calendar-year crop farm value from Strauss and Bean (1937, pp. 36, 39-40, 64-65) over GNP from Balke and Gordon (1989, pp. 84-85).
Farmers' income from crop sales/ GNP: 1840-1860 are cotton's value added from Gallman (1960, pp. 46-47) over GNP from Gallman (1966, p. 26). 1869-1913 and 1880-1913 are calendar-year crop "gross income" from Strauss and Bean (1940, pp. 36, 39-40, 64-65) over GNP from Balke and Gordon (1989, pp. 84-85).
Cotton consumption as share of national income: U.S. GNP from *Historical Statistics* (2006) series Ca10. Nonagricultural GNP calculated using 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* (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, 334, 760, 822).

Table III: 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 [0.295] *0.95*	0.640 [0.168] *0.00*	0.534 [0.137] *0.00*	1.333 [0.133] *0.00*	1.062 [0.050] *0.00*	-0.868 [0.303] *0.01*	-0.500 [0.148] *0.00*		
Wheat(-1)			0.589 [0.132] *0.00*					-0.151 [0.193] *0.44*	
Corn(-1)			0.210 [0.115] *0.08*						-0.815 [0.151] *0.00*
Pre-harvest WPI	0.862 [0.292] *0.01*	0.325 [0.300] *0.29*	0.312 [0.243] *0.20*			0.703 [0.323] *0.04*	1.053 [0.265] *0.00*	0.581 [0.355] *0.11*	2.003 [0.320] *0.00*
Time	0.034 [0.058] *0.56*	0.021 [0.018] *0.26*	0.020 [0.015] *0.19*	0.106 [0.025] *0.00*	0.051 [0.002] *0.00*	-0.094 [0.063] *0.15*	-0.025 [0.016] *0.14*	-0.010 [0.022] *0.64*	0.067 [0.020] *0.00*
Time Sqr / 1000	0.135 [0.451] *0.77*	-0.045 [-0.333] *0.99*	0.014 [0.269] *0.96*	-0.418 [0.190] *0.04*	-0.373 [0.040] *0.00*	0.728 [0.489] *0.15*	0.508 [0.294] *0.09*	0.196 [0.394] *0.62*	-0.979 [0.356] *0.01*
R2	0.90	0.79	0.87	0.98	0.99	0.41	0.88	0.52	0.76

*Excluding 1843 Sources: see data appendix

Table IV: 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 [0.317] *0.85*	-0.084 [0.322] *0.80*	0.471 [0.279] *0.10*	-0.141 [0.318] *0.66*	0.018 [0.361] *0.96*	-0.045 [0.334] *0.89*	0.581 [0.266] *0.03*	-0.222 [0.323] *0.50*
IP(-1)	-0.321 [0.325] *0.33*	0.011 [0.302] *0.97*	-0.412 [0.275] *0.14*	-0.153 [0.319] *0.63*	-0.383 [0.363] *0.30*	0.069 [0.303] *0.82*	-0.132 [0.267] *0.62*	-0.228 [0.327] *0.49*
Crop(-1)	-0.223 [0.183] *0.23*	-0.186 [0.184] *0.32*	-0.002 [0.157] *0.99*	-0.130 [0.154] *0.40*	-0.241 [0.181] *0.19*	-0.259 [0.184] *0.17*	-0.218 [0.154] *0.17*	-0.208 [0.152] *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 V: IP Gaps Regressed on Lagged Harvest Fluctuations

Coefficient
[standard error]
p-value

A)

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 VI: 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 VII: Harvest fluctuations and weather variables

	1871-1913 (harvests 1870-1912)				1880-1913 (harvests 1879-1912)			
	R2	Rbar2	F-stat	p-value	R2	Rbar2	F-stat	p-value
Cotton harvest on								
cotton weather	0.43	0.32	3.812	0.00	0.61	0.51	5.824	0.00
wheat weather	0.17	-0.06	0.726	0.68	0.26	-0.02	0.943	0.51
corn weather	0.21	-0.00	0.993	0.46	0.28	0.02	1.063	0.42
Wheat harvest on								
cotton weather	0.12	-0.052	0.705	0.67	0.20	-0.02	0.930	0.50
wheat weather	0.29	0.09	1.469	0.20	0.60	0.45	3.988	0.00
corn weather	0.23	0.018	1.087	0.40	0.33	0.08	1.339	0.27
Corn harvest on								
cotton weather	0.19	0.03	1.188	0.33	0.22	0.00	1.019	0.44
wheat weather	0.18	-0.05	0.790	0.63	0.19	-0.11	0.629	0.76
corn weather	0.67	0.58	7.381	0.00	0.65	0.52	4.920	0.00

Table VIII IV estimates, Harvest effects on IP

A) 2SLS regressions, IP gap on harvest fluctuations and lagged IP gap

1871-1913

LHS variable	IP gap, quadratic			ΔLn(IP)		
	Cotton	Wheat	Corn	Cotton	Wheat	Corn
	(1)	(2)	(3)	(4)	(5)	(6)
Crop(-1)	0.444	0.101	0.006	0.502	0.035	0.041
	[0.121]	[0.166]	[0.097]	[0.134]	[0.182]	[0.106]
	0.00	*0.55*	*0.95*	*0.00*	*0.85*	*0.70*
IP(-1)	0.669	0.572	0.597			
	[0.111]	[0.131]	[0.129]			
	0.00	*0.00*	*0.00*			
R2*	0.52	0.37	0.36	0.25	0.00	0.01

1880-1913

LHS variable	IP gap, quadratic			ΔLn(IP)		
	Cotton	Wheat	Corn	Cotton	Wheat	Corn
	(1)	(2)	(3)	(4)	(5)	(6)
Crop(-1)	0.467	0.088	-0.011	0.517	0.038	-0.019
	[0.108]	[0.127]	[0.108]	[0.124]	[0.146]	[0.125]
	0.00	*0.49*	*0.92*	*0.00*	*0.79*	*0.88*
IP(-1)	0.585	0.442	0.478			
	[0.123]	[0.159]	[0.154]			
	0.00	*0.01*	*0.00*			
R2*	0.52	0.27	0.24	0.37	0.00	0.00

*Using TSLS coefficient estimates on actual harvest fluctuations (structural residuals)

B) Corresponding OLS estimates

1871-1913

LHS variable	IP gap, quadratic			ΔLn(IP)		
	Cotton (1)	Wheat (2)	Corn (3)	Cotton (4)	Wheat (5)	Corn (6)
Crop(-1)	0.321	0.081	0.014	0.353	0.034	0.050
	[0.076]	[0.088]	[0.079]	[0.084]	[0.097]	[0.087]
	0.00	*0.36*	*0.86*	*0.00*	*0.73*	*0.56*
IP(-1)	0.648	0.576	0.599			
	[0.106]	[0.127]	[0.128]			
	0.00	*0.00*	*0.00*			
R2	0.55	0.37	0.36	0.30	0.00	0.01

1880-1913

LHS variable	IP gap, quadratic			ΔLn(IP)		
	Cotton (1)	Wheat (2)	Corn (3)	Cotton (4)	Wheat (5)	Corn (6)
Crop(-1)	0.372	0.125	-0.001	0.421	0.032	0.009
	[0.080]	[0.099]	[0.087]	[0.093]	[0.113]	[0.101]
	0.00	*0.22*	*0.99*	*0.00*	*0.78*	*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 IX: Cotton harvests and British *versus* American IP, 1880-1913

(quadratic trends)

Coefficient
[Standard error]
p-value

	1829-1860		1870-1913		1880-1913	
LHS variable	IP US (1)	IP UK (2)	IP US (3)	IP UK (4)	IP US (5)	IP UK (6)
Cotton(-1)	-0.083 [0.110] *0.46*	0.115 [0.060] *0.07*	0.292 [0.079] *0.00*	0.036 [0.049] *0.46*	0.340 [0.087] *0.00*	0.067 [0.057] *0.25*
IP (-1)	0.754 [0.126] *0.00*	0.214 [0.179] *0.24*	0.616 [0.113] *0.00*	0.390 [0.133] *0.01*	0.534 [0.124] *0.00*	0.295 [0.057] *0.25*
Other country IP	0.406 [0.328] *0.23*	0.096 [0.068] *0.17*	0.217 [0.235] *0.36*	0.140 [0.071] *0.05*	0.266 [0.270] *0.33*	0.089 [0.092] *0.34*
R2	0.60	0.15	0.56	0.33	0.56	0.28

Table X: Harvests and Treasury money supply factors
1880-1913

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

Coefficient
[Standard error]
p-value

	(1)	(2)
Cotton(-1)	0.032 [0.039] *0.42*	0.004 [0.236] *0.98*
Wheat(-1)	0.046 [0.037] *0.22*	0.095 [0.224] *0.67*
Corn(-1)	0.015 [0.032] *0.64*	0.202 [0.196] *0.31*
R2	0.10	0.04

Sources: see data appendix

Table XI: Volatility in high-powered money supply, international gold flow and crop export revenue, 1880-1913

	Percent of preceding July's high-powered money supply				
			Crop-related export revenue		
	ΔMoney supply	Gold inflow	Cotton	Wheat	Corn
Mean	4.4	2.9	16.8	8.8	2.5
Standard deviation	4.7	4.0	3.3	5.6	1.5
Maximum *minus* minimum	24.4	17.2	13.8	26.1	5.9

Sources: see data appendix

Table XII: Harvests and British interest rates or money supply
1880-1913

LHS variables:
(1) Change in London bill rate (average of months from July to June)
(2) Change in log (U.K. high-powered money, average of months from July to June)
(3) Change in log (U.K. high-powered money, July to July)

Coefficient
[Standard error]
p-value

	(1)	(2)	(3)
Cotton(-1)	-1.321	-0.053	-0.029
	[1.225]	[0.042]	[0.063]
	0.30	*0.21*	*0.66*
Wheat(-1)	-0.312	0.009	-0.007
	[1.166]	[0.040]	[0.060]
	0.79	*0.83*	*0.91*
Corn(-1)	1.277	-0.023	-0.037
	[1.200]	[0.035]	[0.053]
	0.22	*0.52*	*0.49*
R2	0.08	0.07	0.03

Sources: see data appendix

Table XIII: Cotton-caused IP fluctuations *versus* other IP fluctuations, 1880-1913

Left-hand side variables:

Δg Net gold imports/ money supply (previous July)
Δm Change in high-powered money stock (outside the Treasury), July to July
e Exchange rate, annual average ending June
$(i - i^*)$ 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) Two-stage least squares with cotton harvest deviation as instrument for Δy
(b) OLS with residual variation in Δy as RHS variable
(c) OLS with 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)	0.284	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*
(b)	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*
(c)	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*

Post-1896 dummy for $(i - i^*)$: Coefficients [standard error]

(a) –1.256 [0.188]

(b) –1.263 [0.191]

(c) –1.258 [0.181]

Sources: see data appendix

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

Left-hand side variables:
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

	Δ*Cash*	*Δg*	*Δm*	*e*	*(i – i*)*	*Δi*	*Δp* WPI	*Δp* WPI exc.
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Cotton(-1)	0.148	0.095	0.120	-0.027	-1.883	-3.592	0.192	0.205
	[0.063]	[0.044]	[0.058]	[0.011]	[0.779]	[1.247]	[0.093]	[0.096]
	0.03	*0.04*	*0.05*	*0.02*	*0.02*	*0.01*	*0.05*	*0.04*
Wheat(-1)	0.132	0.103	0.124	-0.036	0.781	2.182	0.071	0.122
	[0.060]	[0.042]	[0.056]	[0.011]	[0.742]	[1.187]	[0.088]	[0.092]
	0.04	*0.02*	*0.03*	*0.00*	*0.30*	*0.08*	*0.43*	*0.20*
Corn(-1)	0.049	0.048	0.058	-0.009	-0.186	1.220	-0.135	-0.002
	[0.052]	[0.037]	[0.049]	[0.009]	[0.650]	[1.038]	[0.077]	[0.080]
	0.36	*0.20*	*0.24*	*0.35*	*0.78*	*0.25*	*0.09*	*0.98*
R2	0.32	0.35	0.31	0.44	0.66	0.28	0.21	0.20

B) 2SLS results

	Δ*Cash*	*Δg*	*Δm*	*e*	*(i – i*)*	*Δi*	*Δp* WPI	WPI exc.
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Cotton(-1)	0.179	0.064	0.085	-0.023	-1.683	-2.654	0.232	0.338
	[0.084]	[0.062]	[0.080]	[0.017]	[0.942]	[1.646]	[0.119]	[0.123]
	0.04	*0.31*	*0.30*	*0.18*	*0.08*	*0.12*	*0.06*	*0.01*
Wheat(-1)	0.153	0.122	0.145	-0.041	0.264	1.604	0.003	0.039
	[0.081]	[0.057]	[0.074]	[0.015]	[0.972]	[1.663]	[0.121]	[0.124]
	0.07	*0.04*	*0.06*	*0.01*	*0.79*	*0.34*	*0.98*	*0.76*
Corn(-1)	-0.027	0.032	-0.027	0.007	-0.961	0.423	-0.247	-0.116
	[0.078]	[0.057]	[0.072]	[0.015]	[0.829]	[1.442]	[0.105]	[0.111]
	0.73	*0.58*	*0.71*	*0.66*	*0.26*	*0.77*	*0.02*	*0.31*

Post 1896 dummy for *(i – i*)*: Coefficients [standard error]

OLS: -1.252 [0.181]
TSLS, cotton: -1.245 [0.178]
TSLS, wheat: -1.264 [0.192]
TSLS, corn: -1.237 [0.196]

Sources: see data appendix

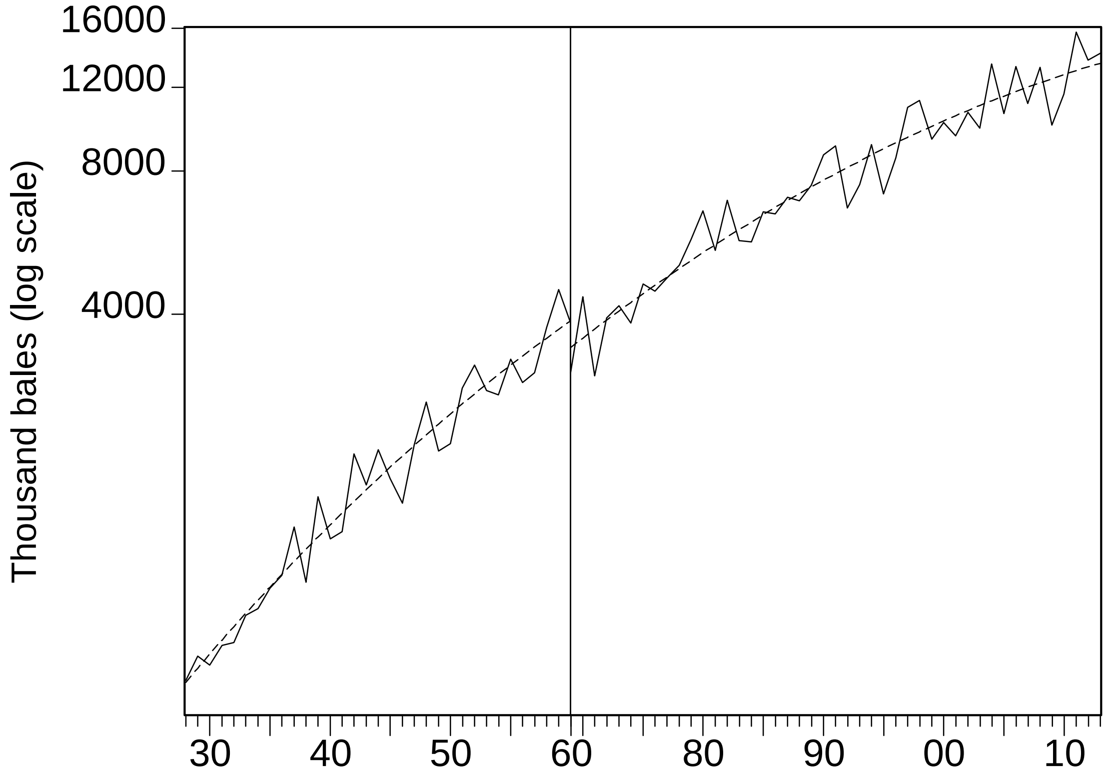


FIGURE I A)

Cotton Production and Quadratic Trends, 1828-1860, 1869-1913

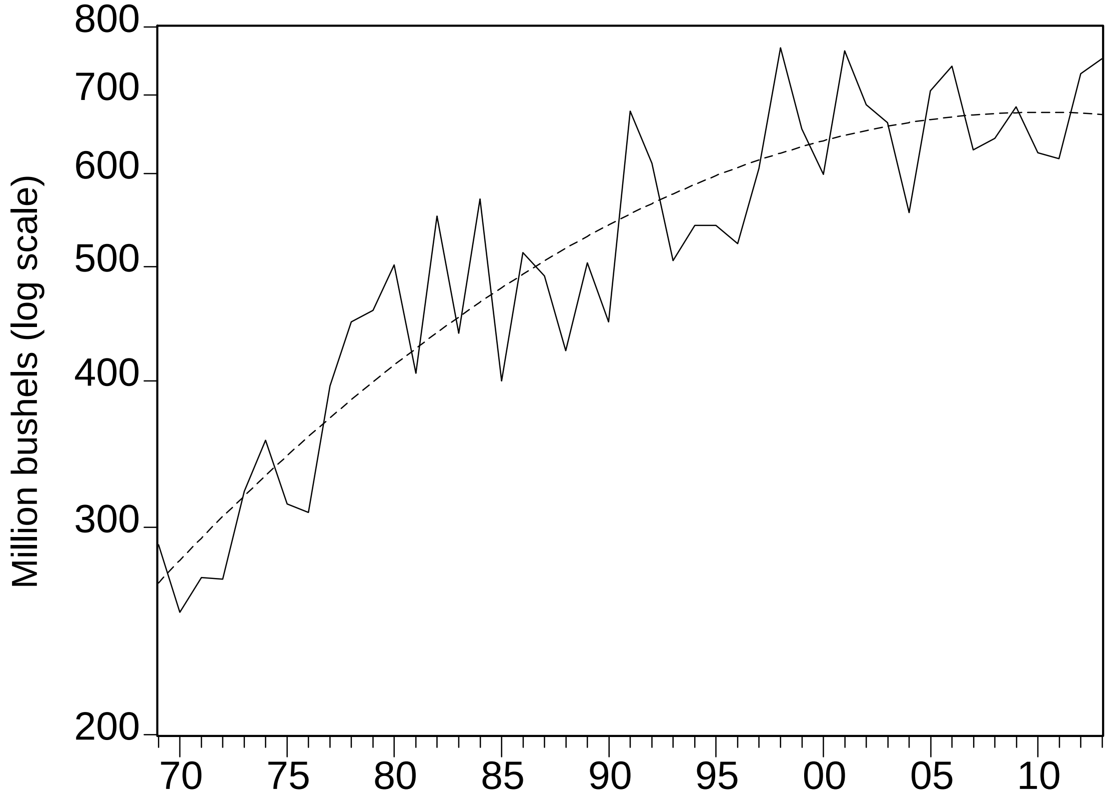


FIGURE I B)

Wheat Production and Quadratic Trend, 1869-1913

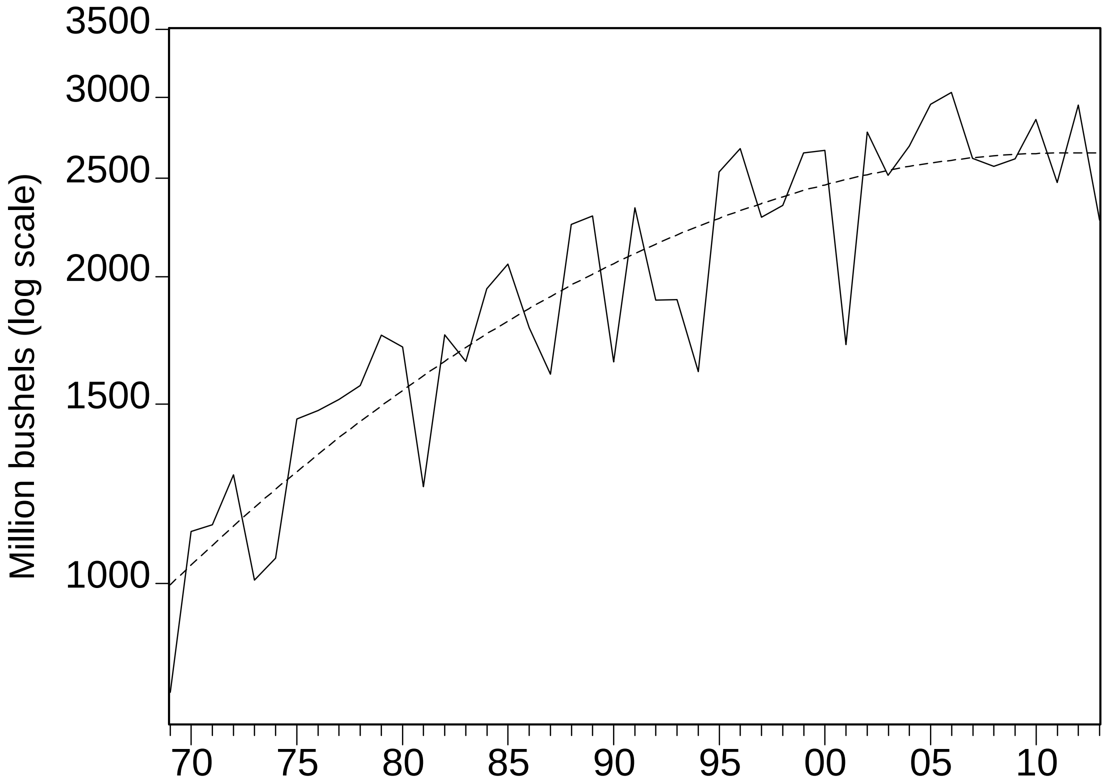


FIGURE I C)

Corn Production and Quadratic trend, 1869-1913

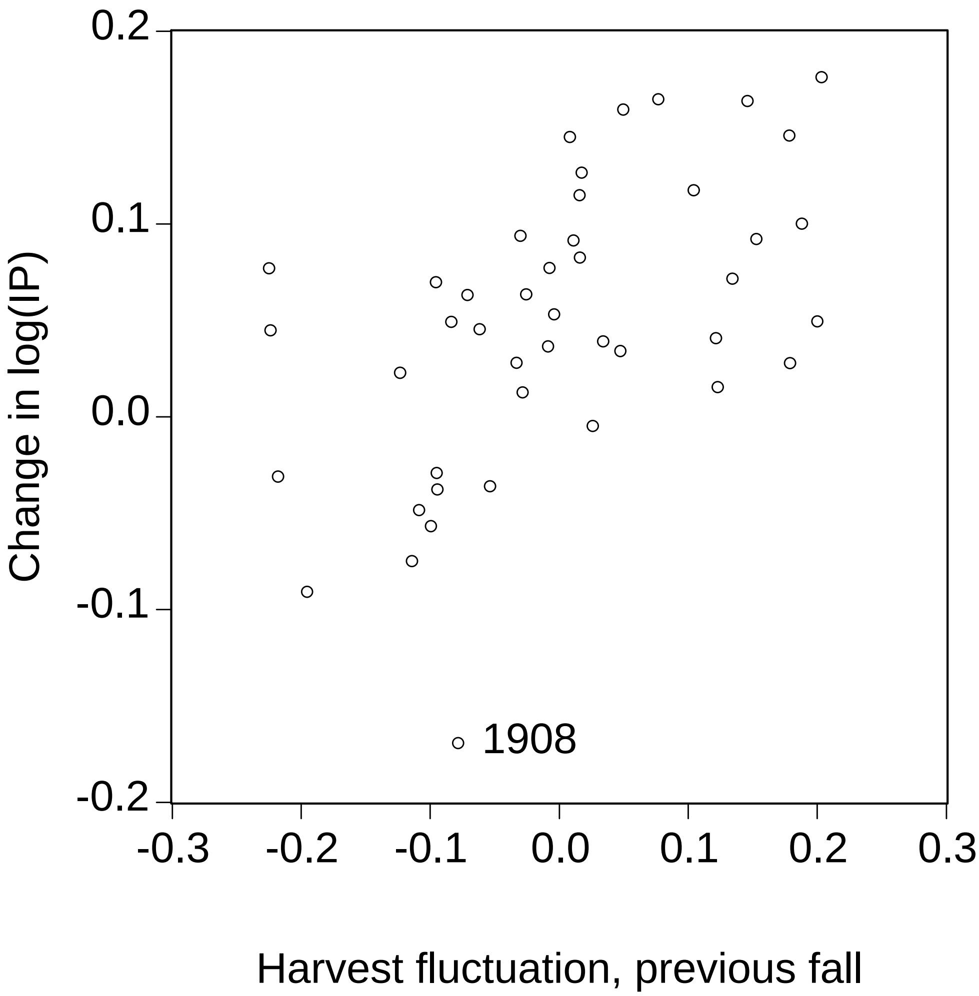


FIGURE II A)

ΔLn(IP) and Cotton Harvest Fluctuation, 1870-1913

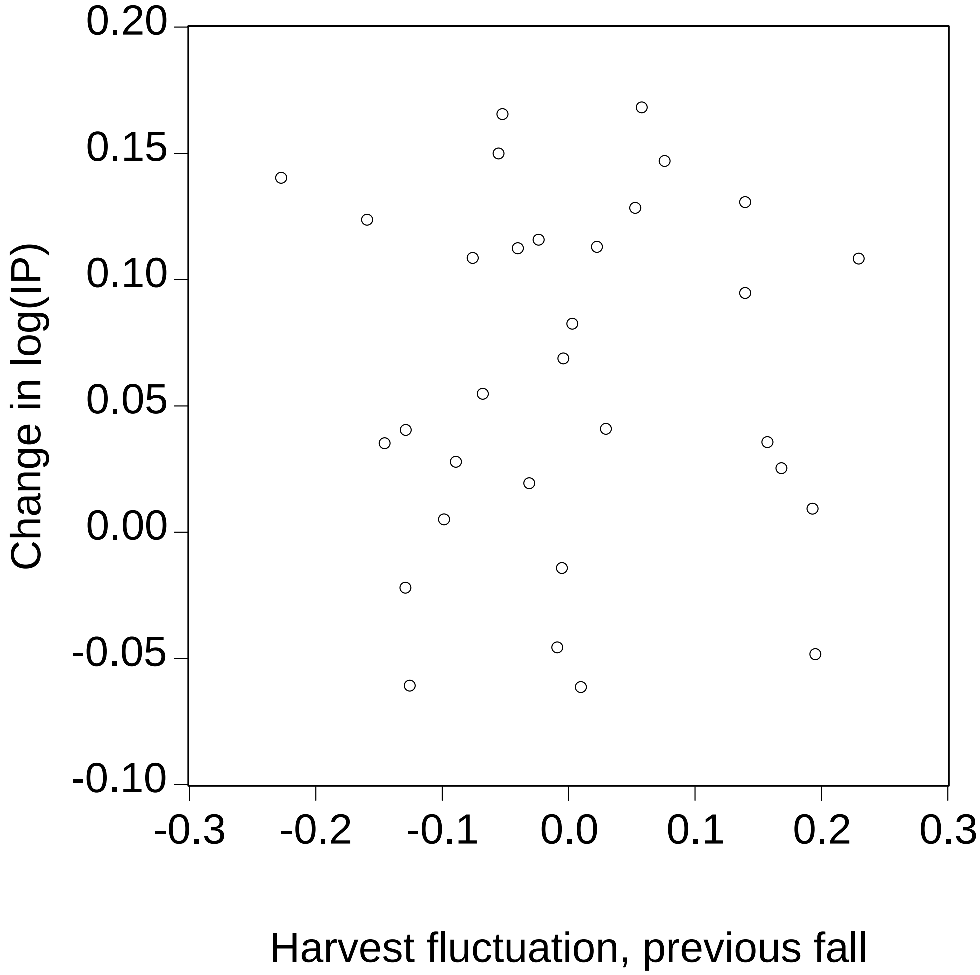


FIGURE II B)

ΔLn(IP) and Cotton Harvest Fluctuation, 1829-1860

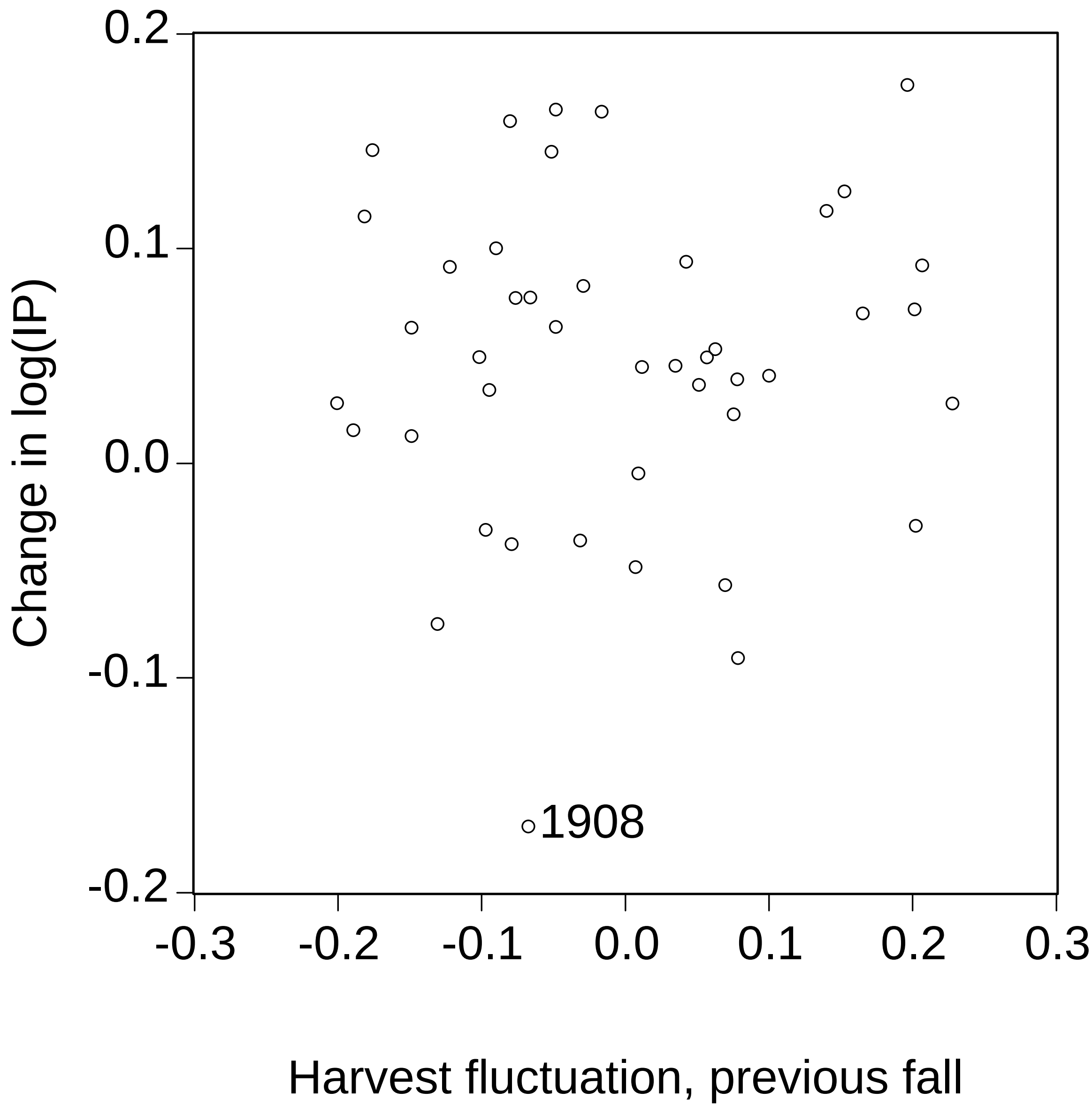


FIGURE II C)

ΔLn(IP) and Wheat Harvest Fluctuation, 1870-1913

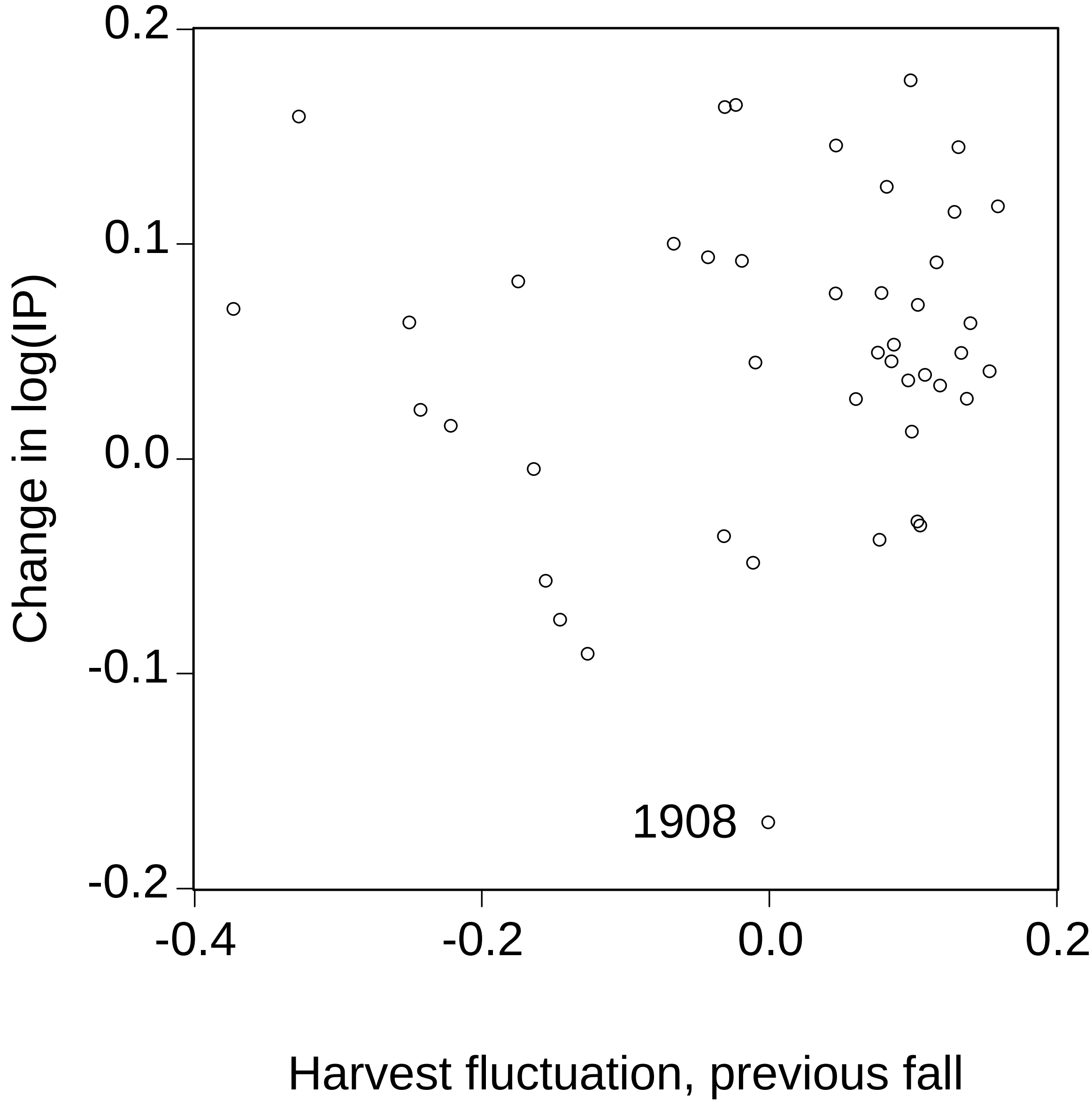
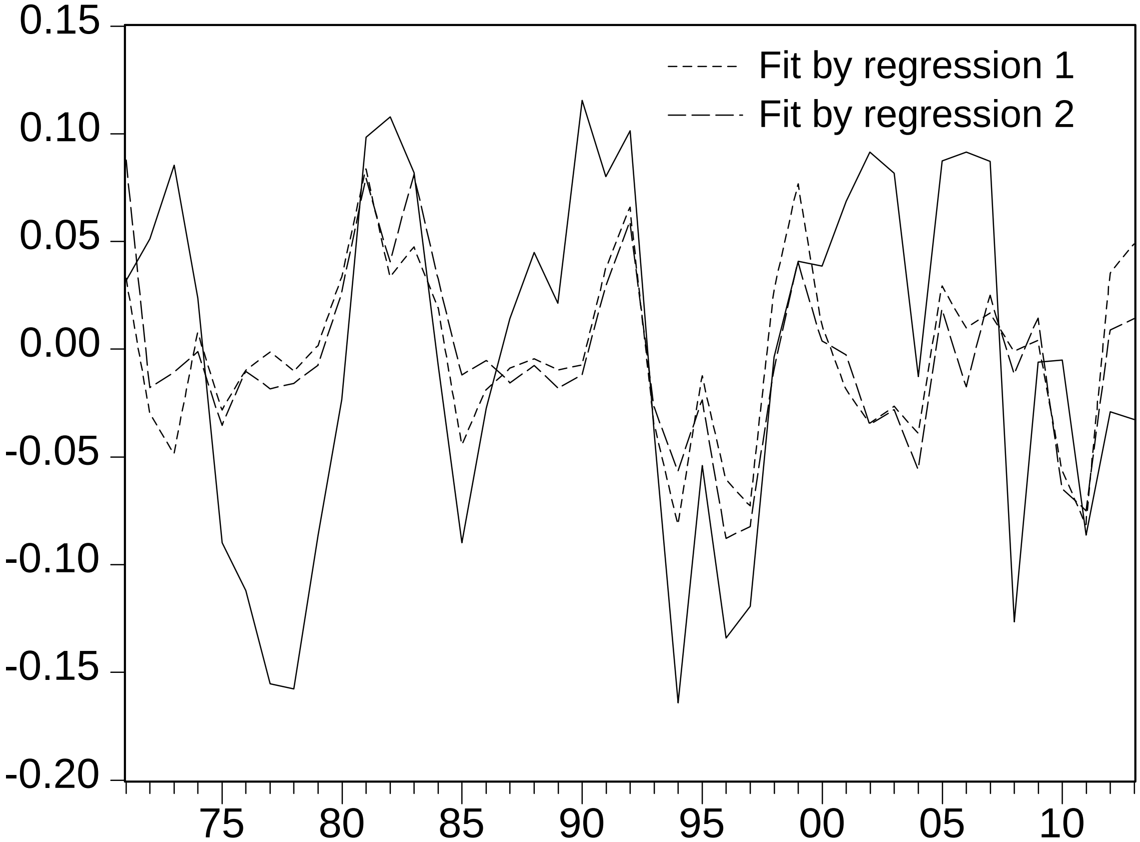


FIGURE II D)

ΔLn(IP) and Corn Harvest Fluctuation, 1870-1913

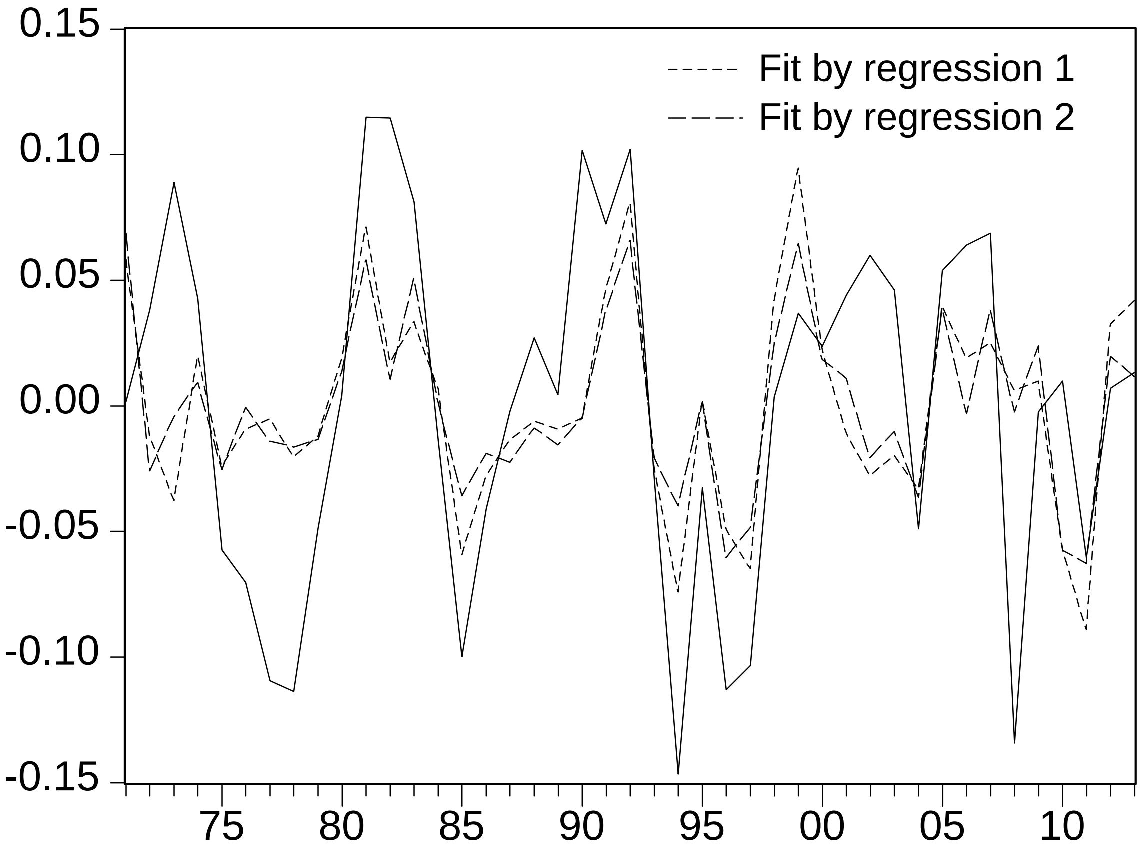


Regression 1 RHS: two lags cotton
Regression 2 RHS: one lag cotton, one lag IP gap

FIGURE III A)

IP Gaps Forecast by Cotton Harvest Fluctuations, 1871-1913

Quadratic trends



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

FIGURE III B)

IP Gaps Forecast by Cotton Harvest Fluctuations, 1871-1913

HP trends

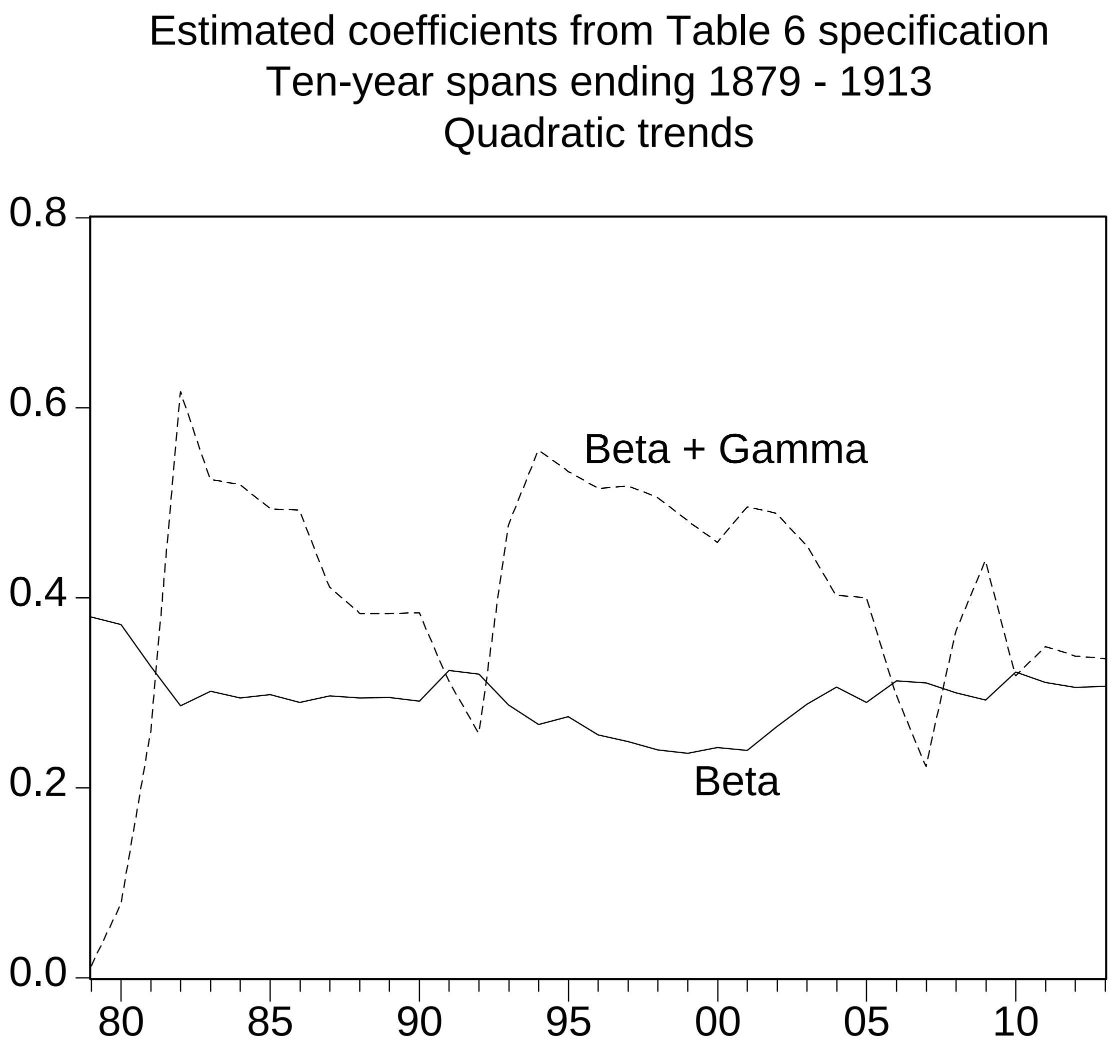

Estimated coefficients from Table 6 specification
Ten-year spans ending 1879 - 1913
Quadratic trends
0.8
0.6
0.4
0.2
0.0
Beta + Gamma
Beta
80
85
90
95
00
05
10

Figure IV A)

Estimated coefficients from Table 6 specification
Ten-year spans ending 1879 - 1913
HP trends

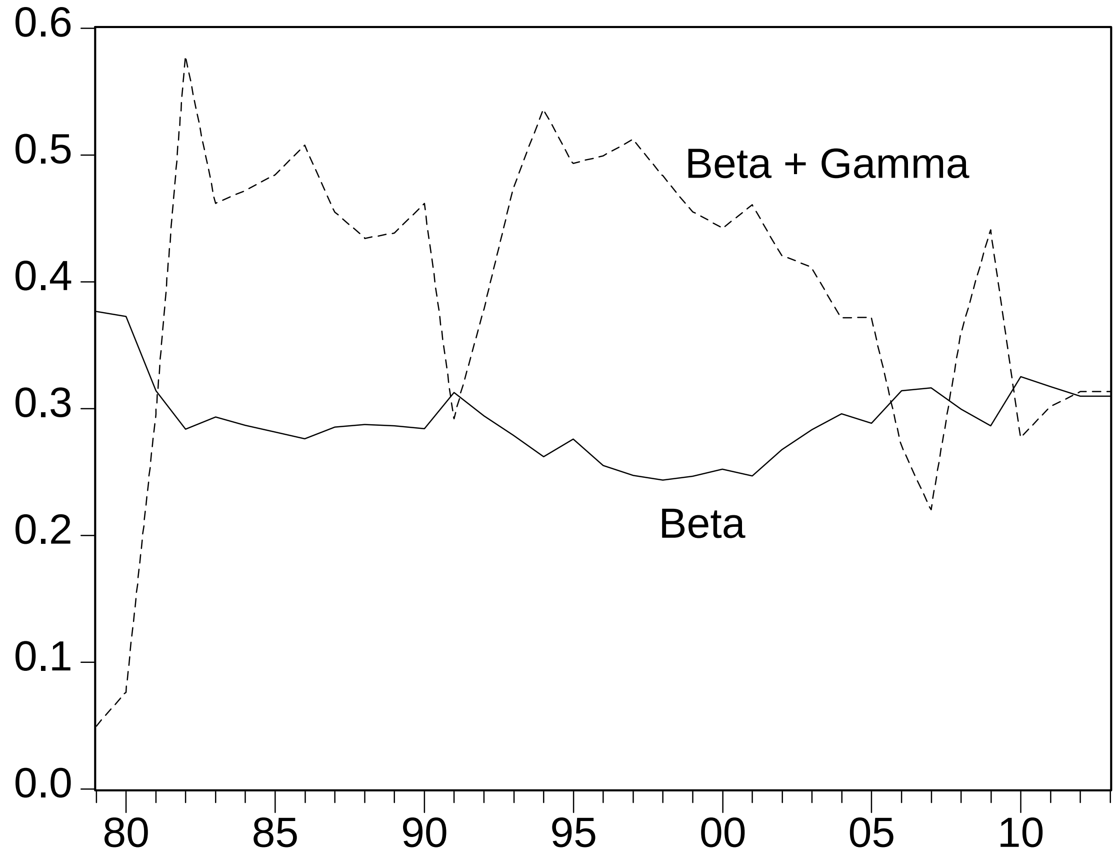


Figure IV B)