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7/11/07
11:10 am

THE IMPACT OF THE BOLL WEEVIL, 1892-1940

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Prepared for NBER-DAE Summer Institute Meetings, July 2007

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The boll weevil is America's most celebrated agricultural pest. Using a newly created county-level panel data-sets on the spread of the boll weevil, local cotton production, and weather during the crop season, we investigate the impact of this pest on the southern economy between 1892 and 1940. Our study provides sharper estimates of the full time path of production both before and after its first arrival. We show that the initial effect on production was small compared to the decline over the 3-5 years and that the recovery was slow even after improved means to combat the pest became known. Much of the decrease in production is due to declining yields rather than reductions in cotton acreage. We also investigate how southern farmers adjusted in anticipation of the insect's arrival. Using county-level data from the Censuses of Agriculture and Population, we trace out the time path of alternative crop yields and acreage, farm values, and population in the wake of the cotton planters' worst enemy.

THE IMPACT OF THE BOLL WEEVIL, 1892-1940

The boll weevil, with its entourage of songs and folklore, is enshrined in many popular accounts as America's most destructive agricultural pest. Testifying before Congress in 1903, B. T. Galloway, chief of the USDA's Bureau of Plant Industry, referred to the insect's advance as "the wave of evil."[1] Two years later in a speech before both Houses of Congress (what is now termed the State of the Union Address) President Theodore Roosevelt discussed biological warfare when he alerted anxious cotton producers that USDA scientists had imported a predatory ant from Guatemala that fed on the weevil.[2] The weevil was indeed a headline grabber.

In line with the testimony of contemporaries, many social scientists have viewed the arrival of the boll weevil in 1892 as unleashing a revolution. In *One Kind of Freedom*, Roger Ransom and Richard Sutch wrote: "It required a shock nearly equal to emancipation to jolt the agrarian South out of the routine it followed for the four post-emancipation decades. That shock was the coming of the boll weevil…. The impact of the cotton boll weevil on southern agriculture was immediate…. the boll weevil heralded the end of the era the Civil War had introduced."[3] Although it is unlikely that Ransom and Sutch still hold this view, many historians do. Carolyn Merchant argued that the arrival of the boll weevil reduced "cotton yields by about 50 percent… the entire economy of the South was at risk."[4] The arrival of the pest is commonly seen as one of the triggers of the "Great Migration" of African-Americans to the North after 1915.[5]

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[1] Testimony of B. T. Galloway, Hearings, U.S. House Agriculture Committee, p. 16.
[2] See http://www.infoplease.com/t/hist/state-of-the-union/116.html for T. Roosevelt's address. The weevil-killing ant proved to be a humbug.
[3] Ransom and Sutch, *One Kind of Freedom,* pp. 171-72, 174.
[4] Merchant, *Columbia Guide,* p. 55. Merchant continues (p. 56) "Although the new methods were helpful, they were also expensive, and the combination of declining yields and higher costs drove many farmers out of business."
[5] Crew, "Great Migration," 34-36. The article summarizes material for the exhibit, *Field to Factory: Afro-American Migration 1915–1940,* at the Smithsonian's National Museum of American History.

James Street termed the weevil's invasion was a "disastrous experience." Peter Daniel took a more balanced approach, but nevertheless concluded that "the boll weevil invasion further undermined the precarious economic situation of southern farmers by destroying part of the crop, increasing the cost of production, and making cotton farming more attractive to growers in western areas."[6]

Other scholars, including Robert Higgs, Kent Osband, Douglas Helms, and Gavin Wright see the insect as changing little or nothing. For example, Higgs concluded that "the boll weevil infestation was neither a necessary nor a sufficient condition underlying the Great Migration."[7] And in *Old South, New South,* Wright argued that given the elasticity of demand for cotton, "the South as a whole did not suffer as a result of the boll weevil…. Each new attack simply caused the price received by all the other areas to be raised, thus serving, if anything, to keep cotton culture strong in older areas of the East longer than it otherwise would have been." While the weevil did have "a lasting effect on cultivation practices… most parts of the South worked it into their routine and returned to 'normal.' What it did not do was to trigger a major diversification of southern agriculture or a new shift of resources out of agriculture into industry or other pursuits."[8] As James Giesen observed, southerners were growing more cotton in 1921 than in 1892.[9]

The existing literature has largely taken a macro approach, focusing on the effect on the South as a whole, or investigated the pest's impact across the 13 southern states. Such an approach, while valuable for addressing certain questions, does not identify the effect of the shock of the pest's arrival on local economies, including its effects of land values and migration behavior. This paper assembles and analyzes two new county-level data sets, including information of annual cotton production activity, to offer a fresh assessment of the impact of the boll weevil invasion on Southern economic development.

[6] Street, *New Revolution*, pp. 38-39; Daniel, *Breaking the Land*, p. 163.
[7] Higgs, "Boll Weevil," p. 350.
[8] Wright, *Old South, New South*, p. 122. For how this passage fits into the literature, see Wright "Reflections ," p. 44. DeCanio, *Agriculture* implicitly takes a "no-effect" position because he uses county-level census data from 1880, 1890, 1900, and 1910 to estimate production functions for cotton in the southern states, but contains no reference to the impact of the boll weevil.
[9] Brown, *Cotton,* 2nd ed. pp. 345, Osband, "Boll Weevil," pp. 627-43; Giesen, "South's Greatest," p. 2. Comparisons between production in 1892 and 1921 are problematic because both had short crops. But taking a longer view also indicates rising cotton acreage and output. Giesen, "South's Greatest," pp. 1-2, 211-12, 346-50 seeks to debunk the "myth" linking the boll weevil and the Great Migration.

The paper has the following form: The next section documents the coming of the boll weevil and describes briefly its life cycle, migration patterns, and means of damaging cotton to inform our investigation of the impact of the insect. The second section discusses the limited methods – by altering cultural practices and applying chemicals—available to farmers to combat the pest threat. The chief control method available was to plant earlier maturing cotton at the cost of crop yield, fiber quality, and a more concentrated harvest season. The third section explores the existing literature on the costs imposed by the weevil. Section Four describes the two new county-level panel data sets we have constructed to investigate the impact of the weevil. Section Five presents and interprets our results. Section Six concludes.

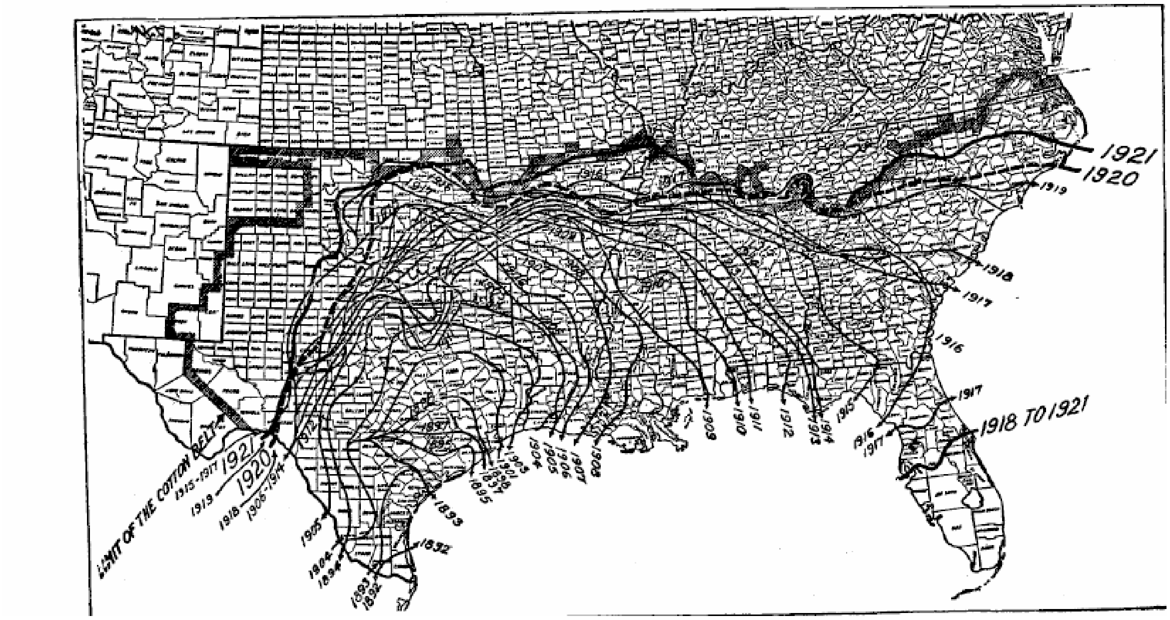
I. The Coming of the Boll Weevil

The boll weevil, *Anthonomus grandis* Boheman, is a small beetle-- ¼ inch long and 1/3 inch wide--with wings and a very pronounced snout. It was native to Mexico and Central America.[10] Most accounts assert that it entered the United States in 1892 near Brownsville, Texas and thereafter advanced 40 to 160 miles a year.[11] By 1922 it had swept up the Atlantic seaboard and infested over 85 percent of the Cotton Belt. See Figure 1 illustrating the weevil's spread from 1892 to 1921.

[10] Substantial parts of this and the next two sections are drawn from Olmstead and Rhode, *Biological Innovation*.

[11] See Giesen, "South's Greatest Enemy," pp. 24-25, for an account of the insect's activities in Mexico. Scientists had collected specimens near Veracruz as early as 1840. The USDA set 1892 as the date when the insect became officially established in the United States, and this has sense been taken as the date of entry. But the first USDA entomologists on the scene concluded in 1895 "that the boll weevil had probably been present in the Brownsville area for as long as 10 years." Stavinoha and Woodward, "Texas Boll Weevil History," pp. 453-54; Burke. et al., "Origin and Dispersal," pp. 228-38.

Figure 1: USDA Map of Spread to Boll Weevil, 1892-1921



In the environment of the American South, the weevil fed almost exclusively on the cotton plant. Weevils could survive on seedling cotton but reproduce only on fruiting cotton. Cotton was planted in March and April and the seedlings first emerged after about two weeks. Beginning about one month after the seedling emerged, the plant formed flower buds or squares. The squares provided the weevil larvae with a protected place to grow into pupae and then adults. Each viable square grew about three weeks and then opened into an individual flower for a single day. But flowering of different squares was spaced over a two-month period from June to August. This was the period when the boll weevil inflicted its greatest damage. Warm, wet, cloudy summers were associated with the greatest infestations. Very hot, dry summers limited damage by killing off the weevil's larvae and pupa in the squares and young bolls. The cotton plant's bolls opened and were ready to harvest from late August through early January. One consequence of the build-up of boll weevil population over the summer was that the late-season crop, that appearing on the top of the plant, suffered the greatest losses. The weevils continued to feed until the cotton plant was destroyed or killed by frost.

The weevil damaged the plant in a wide variety of ways, beginning in the Spring and extending to the Fall. Adult weevils punctured the squares to lay their eggs and to eat the pollen. Early in the season they also fed on the leaves, and later in the season they attacked the young bolls. The female deposited her eggs in the squares and young bolls. The larvae and pupae fed on the inside of the squares and bolls, causing them to shed, fall to the ground, and release the adult insect. The remaining bolls are often stained or otherwise damaged. Female weevils could produce 100 to 300 eggs and typically deposit only one egg to a square. Depending on the weather, weevils can produce two to eight generations per year during their period of reproductive activity. The result could be truly devastating to the growing cotton crop.

Adult weevil survived the winter without food by going into hibernation (the diapause, which a weevil enters after gaining fat and having its sex organs atrophy). Cold weather and standing water could kill the overwintering adults, but yard and field trash, nearby woods, and Spanish moss provided protection. Much of the control efforts were devoted to denying the weevil a safe place to survive the winter. A few weevils began to seek hibernating places as early as July, but most did so in the Fall. The weevils surviving the winter emerged during the warm days from March until July. Even a small number of survivors could cause serious problems. One pair of weevils could generate 12 millions of progeny in a single season, although 2 million was more typical.[12]

During most of the year, weevils would fly only short distances. But in August, its seasonal migration began. Through a series of short flights, weevils could travel about one hundred miles. The direction of travel was random, but the most rapid flows followed the prevailing wind. Weather events such as the great Galveston hurricane of September 1900 carried the boll weevil far beyond the strength of its wings.

The significance of the boll weevil's life habits is that farmers could do little to prevent the boll weevil from entering their territory. The timing of arrival was largely independent of the behavior of individual cotton growers. Once the insect hit, it could be driven out by unfavorable weather as illustrated by the retreating frontiers in the maps and was subject to some control by cultivation practices as discussed below.[13] First

[12] Brown, *Cotton,* 2nd ed., pp. 339-46; Gains, "Boll Weevil," pp. 501-04; Oosterhuis and Jernstedt, "Morphology and Anatomy of the Cotton Plant," pp. 175-206.

[13] Population density appears to have an inverted U-shaped relationship with damage. The weevils needed cotton to survive and reproduce, but they also required a safe environment to overwinter. The worst damage occurred in cotton producing areas characterized by small fields, nearby woods especially those with hardwoods, and rolling or hilly terrain. Alluvial areas with large blocks of land completely cultivated

contact usually occurred during the August seasonal migration, that is, after the weevil could do much initial damage that year. The weevils were not like a plague of locust consuming all in their path. Maximum damage occurred after the local weevil population grew. Thus, the classic USDA maps detailing the spread of the weevil present excessively pessimistic picture of the area being ravaged by the insect.[14]

The invaded territory in such maps creates a somewhat misleading impression for another reason. Many counties initially attacked, for example in southern Texas, were not producing much cotton. The same is true of many of counties on the fringes of the cotton belt that were never infested. A large swath of west Texas appears free of the weevil but this is not prime cotton country at that time. To address these problems, we have assembled data showing when the weevil invaded each county in the Cotton Belt weighted by the county's cotton acreage and production as reported to the 1900 census.[15] The series are graphed in Figure 2 which also shows the land area covered - the usual measure of the boll weevil's progress. As the figure shows, after 1905 the traditional land area measurement significantly understates the weevil's importance in the Cotton Belt. As an example, those areas still free from the weevil in 1922 accounted for 13 percent of the landmass, but produced less than 1.5 percent of the 1900 crop.

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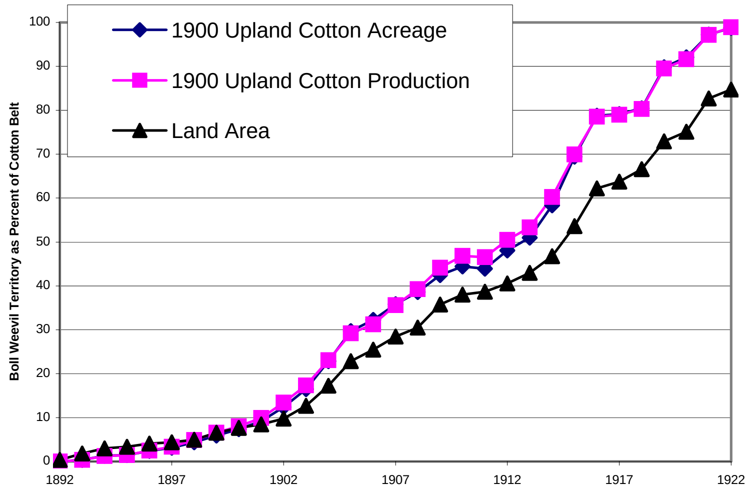
in cotton land and cleaned properly after harvest (especially if the fields were covered with standing water over part of the winter and the nearby trees did not bear Spanish moss) might suffer only spot infestations. Contrary to popular opinion, monoculture was not the problem. Regions on the fringes of the cotton belt with very little production could also escape serious damage. High rates of infestation did encourage the weevil to move on to look for additional sources of food. Brown, *Cotton,* 1st ed., pp. 295-97; Brown and Ware, *Cotton* 3rd ed., pp. 202-06.

[14] These widely-publicized maps did allow farmers and local authorities further east to form expectations about when the weevil would strike.

[15] The use of the 1900 census may understate the insect's effect in southern Texas where it was already reducing yields. Adding two-three years to the date listed provides a better sense of land area under the weevil's thrall. (The figure does take into account back-tracking of the weevil territory over the 1910-14 period.)

Figure 2: Spread of the Boll Weevil, 1892-1922



Our new production- and acreage-weighted series of the weevil's spread generally fit the standard S-shaped diffusion curve, with an acceleration in diffusion in the 1898-1905 period. This was the period when the insect's path of destruction made its eastward turn. By 1907, the weevil crossed the Mississippi River. Thereafter, it advanced from east to west along a front with a slight tilt running from the northwest to the southeast. (See the regressions in Appendix B for the latitudes and longitudes of the weevil front.) Weather conditions in 1915 and 1916 were exceptionally favorable for the insect's spread as the pest engulfed most of Georgia and leaped into the Florida cotton fields to the south and threatened the Carolinas to the north. The advance slowed the next two years, and it was not until 1921-22 that the boll weevil finished its geographical conquest. There was a brief period between 1908 and 1913 when the production and acreage series diverge. In these years, the weevil attacked the Mississippi Delta where yields were relatively high, pushing the production series above the acreage series.

II. Control Methods

From the 1894 on, the USDA, various state agencies, private companies, amateur scientists, farmers, and numerous quacks sought ways to limit the insect's damage. Insecticides proved ineffectual. Efforts to erect quarantine buffers also came to naught. An early proposal in Texas to establish a 50-mile wide cotton-free zone ran into legislative resistance.[16] By 1904 when Georgia adopted quarantine measures, the weevil was too well established in the South to pause for long.

Many ideas on how to coexist with the weevil diffused rapidly. Entomologists' recommended the adoption of early maturing varieties, destruction of stalks and brush, use of fertilizers to hasten ripening, early planting, and more thorough cultivation.[17] It did not take farmers long to switch to earlier maturing varieties. The boll weevil entered Robertson County, Texas between 1898 and 1901. By 1901 farmers in that county were importing seed from northern Texas, and by early 1904 the Dallas Jobbers' Cotton Association had imported 19 carloads of seed from North Carolina. According to Douglas Helms, "One estimate held that Texas farmers 'imported thousands of car loads of short staple cotton seed' in the rush to adjust to weevil destruction." As the weevil spread, so did the transition in varieties, with some farmers such as those in the Yazoo-Mississippi Delta apparently switching in advance of the destruction.[18] In addition to adopting earlier ripening varieties, farmers sought other means to promote earlier crop development. Farmers in southern and central Texas soon moved their planting date up by three to four weeks.[19]

Figure 3 offers a quantitative indication of the movement to earlier ripening varieties by charting the dates of cotton ginning. In the early years (1902-07) of the twentieth century, less than 45 percent of U.S. cotton was ginned before the 18th of October. By 1934-39, almost 70 percent was ginned by that date. Over the period of the weevil's spread, cotton production was moving onto the High Plains of Texas and Oklahoma as well as shifting to the irrigated fields of Arizona, California, and New Mexico. The spread of the boll weevil accelerated this trend, because the Far West was weevil free.[20] But in Arizona, California, Oklahoma, and New Mexico ginning occurred

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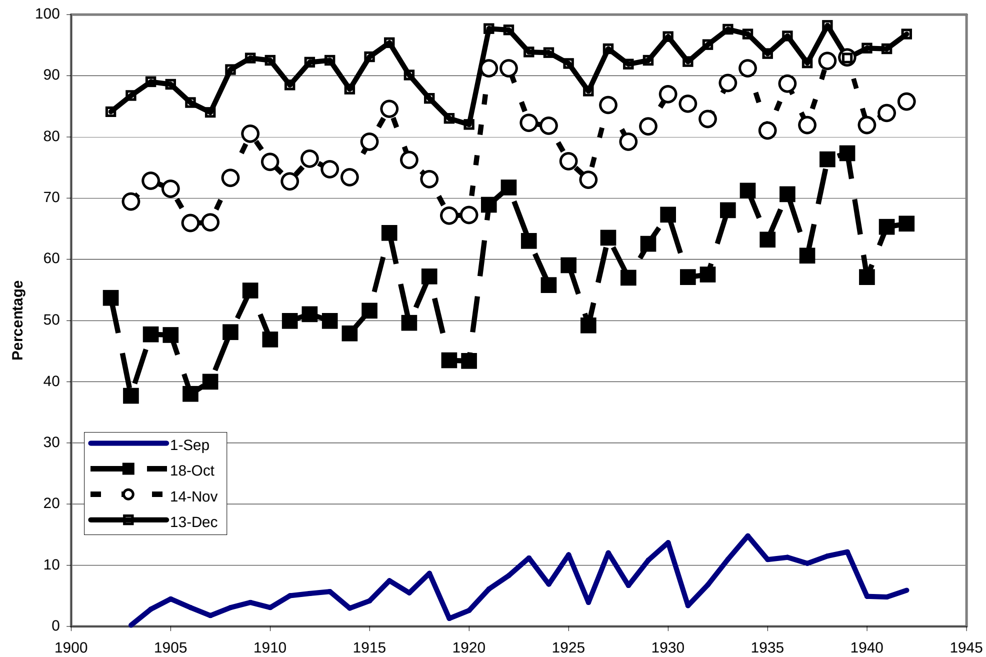
[16] Helms, "Just Looking for a Home," pp. 56-57.
[17] These recommendations advanced in the 1890s are very similar to what agricultural scientists were still proposing in 1938. Brown, *Cotton,* 2nd ed,, pp. 347-53; Howard, "Insects Affecting," pp. 1-31; Hunter, "Methods of Controlling the Boll Weevil," pp. 1-15.
[18] Helms, "Revision and Revolution," pp. 109-11; Giesen, "South's Greatest," Ch. 4 and 5 provide a detailed account of the adjustment process in the Delta.
[19] Brown, *Cotton,* 2nd ed,, pp. 351-53; Helms, "Revision," pp. 112-14. In other areas, farmers attempted to plant later in hopes of depriving food from the weevils emerging from hibernation.
[20] Kent Osband downplays the impact of the weevil on the westward expansion of cotton production. In fact the weevil greatly accelerated this movement. The USDA's research program in the western states was

much later than the national average, and consequently the regional shift of production meant that the trend toward early ginning in the Cotton South was even more rapid than implied in Figure 3. The move to early varieties was also apparent within individual states. For example, our regression analysis of state level data using fixed effects (not reported here), reveals that over the 1902-40 period the arrival of the boll weevil led to a 17 percent increase in the share of cotton ginned before the 18th of October.[21]

Figure 3: Percentage of US Cotton Ginned by Selected Dates, 1902-42



A swatch of fertile cotton lands from Texas to the Carolinas was denuded of long-staple cottons. For over a hundred years breeders had selected and acclimated cottons for specific areas. Over few years this work was lost. Characteristics such as fiber quality, picking ease, and storm resistance lost importance in the face of one overriding concern - early maturation. Picking efficiency and quality suffered as large areas abandoned 1

dedicated to breeding and promoting varieties that would help offset the loss of the longer Cotton Belt varieties. Osband, "Boll Weevil," pp. 627-43.

[21] The advent of the boll weevil and the shift to earlier maturing varieties altered the picking season. It reduced demands for labor late in the Fall (November and especially in December) and likely increased demands in September. These changes likely have effects, not explored here, on the attendance behavior of children enrolled in southern schools. It is also beyond the scope of the present paper to consider the impact of the infestation on health, as in recent study by Banerjee, et al.. "Long Term," of phylloxera in 19th Century France.

1/8th inch "Big Boll" cotton to grow varieties with small bolls and very short 5/8th inch staples. About 50 long staple varieties ceased to be commercially viable and in most cases became extinct.[22] Many high-quality mid-staple varieties were lost as well.

Among the most important measures in the integrated pest management (IPM) system recommended by cotton scientists was to burn or plow under the cotton stalks immediately after harvest to reduce the number of weevils before they hibernated. Repeated experiments showed that destroying the stalks significantly reduced the next year's damage and generated higher yields. In one USDA experiment an isolated group of Swedish cotton farmers followed the prescribed stalk destruction policy and, relative to control test--plots, harvested an extra 600 pounds of seed cotton. But according to Helm's careful investigation of this issue, the practice was not widely adopted. There were drawbacks. It required much labor to cut the stalks while green rather than waiting for them to die and dry out. Furthermore, weevils could migrate to nearby fields, meaning that an individual farmer who destroyed his green stalks would not capture the full benefit of his investment nor be fully protected unless his neighbors followed suit. Success required a community effort. USDA scientists understood this externality problem and in 1896 urged Texas state officials to enact legislation to establish mandatory stalk destruction dates. The individualistic Texans turned a deaf ear. Other control recommendations-- destroy volunteer cotton, clean up trash, locate fields away from the woods, and use more fertilizer to hasten ripening -- had the same motivation: invest resources to lessen the weevil's chances of surviving the winter.[23]

The measure that would later become the main line of defense -- effective poisons -- was not available during the first wave of destruction. This was not for want of trying, as both farmers and entomologists experimented unsuccessfully with the bromides used against others insects. Poisons such as Paris Green gained popularity even though USDA tests showed they were not cost--effective. The grubs feeding inside the squares were well protected from poisons and the foliage gave the adults considerable shelter from

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[22] Brown, *Cotton*, 2nd ed., pp. 339-55; Helms, "Revision," pp. 110-11; Ware, "Origin," pp. 50-81, 95-97. The extinction was nearly complete. A long-staple cotton named Sunflower was the only variety of "the old Mississippi Valley series" to survive the devastation. Sunflower became a parent for most of the important long staple varieties later developed. Ware, "Origin," p. 67.

[23] Brown, *Cotton,* 2nd ed., pp. 351-54; Helms, "Revision," pp. 118-20. Destroying the bolls that shed off the plant and contained the larvae, pupae, and young adults was also considered advantageous.

contact poisons. In 1908 William Newell experimented with dusting (as opposed to spraying) the plants with a powdered lead arsenate formulation.

The first really effective poison arrived in 1918 when the USDA's B. R. Coad developed a calcium arsenate mixture for dusting. The calcium helped the poison adhere to the plant, making it more accessible to the weevils. The discovery of an effective poison was only part of the story because application methods also had to be perfected. After numerous experiments, the USDA recommended that farmers raise a large dust cloud at night or in the early morning and let it settle while dew was still on the plants. In addition, there were trials with dusting machinery ranging from hand dusters, to mule and tractor towed devices, to airplanes. Calcium arsenate was costly and beyond the reach of many farmers.[24] In the period under consideration, farmers had limited means, besides shifting to lower-yielding earlier-maturing varieties or more radically abandoninging cotton production, to combat the bug.

III. Financial Impacts of the Boll Weevil

There is considerable controversy about the financial magnitude of boll weevil damage. The conventional view is that the weevil was devastating, destroying "between one-third and one-half of the crop in newly infested areas."[25] USDA studies generated large estimates of the aggregate losses, often in the range of $300 million current dollars annually. The Bureau of Agricultural Economics (BAE) began estimating annual boll weevil losses from full yield in 1909 (see Table 1). Over the 1909 to 1940 period, the estimated reduction in yield for the United States (excluding the weevil-free Far West) ranged from a high of 31.0 percent in 1921 to a low of 1.3 percent in 1911 and averaged about 10.5 percent overall.[26]

[24] Brown, *Cotton,* 2nd ed., pp. 348-52; Helms, "Technological Methods for Boll Weevil Control," p. 291; Haney, Lewis, and Lambert, "Cotton Production and the Boll Weevil," pp. 8-11.
[25] Manners, "Persistent Problem," p. 25.
[26] U. S. Bureau of Agricultural Economics, *Statistics,* pp. 67-80.

Table 1: Bureau of Agricultural Economics Estimates of Weevil Damage

Percentage Losses from Full Yield Due to Boll Weevil

	VA	NC	SC	GA	FL	AL	TN	MS	LA	MO	AR	OK	TX	All
1909	0	0	0	0	0	0	0	4	42	0	6	3	12	6.1
1910	0	0	0	0	1	0	0	15	40	0	7	1	7	5.1
1911	0	0	0	0	0	0	0	5	11	0	2	0	1	1.3
1912	0	0	0	0	0	2	0	18	14	0	2	1	3	3.5
1913	0	0	0	0	12	4	0	33	25	0	3	0	7	6.7
1914	0	0	0	0	0	6	0	24	18	1	3	1	8	5.9
1915	1	1	0	0	13	16	1	25	20	0	5	3	16	9.9
1916	0	0	0	3	21	28	2	32	24	0	7	4	19	13.4
1917	0	0	0	9	27	29	0	22	12	2	10	4	7	9.3
1918	0	0	0	11	24	12	0	10	10	7	3	1	4	5.8
1919	0	0	3	19	40	29	0	20	25	0	5	1	14	13.2
1920	0	0	13	31	32	36	1	32	26	0	9	9	20	19.9
1921	0	4	31	45	28	32	7	30	35	0	22	41	34	31
1922	0	13	40	44	32	26	9	38	25	0	18	26	16	24.2
1923	0	13	27	37	33	33	21	31	23	4	16	19	10	19.5
1924	0	7	16	15	28	12	2	7	5	0	4	4	8	8
1925	0	8	12	7	6	5	0	3	10	1	2	2	2	4.1
1926	0	3	4	5	4	3	2	6	9	2	3	8	11	7.1
1927	2	16	27	18	9	15	3	16	12	0	11	31	20	18.5
1928	10	12	15	14	9	12	2	14	18	0	15	26	12	14.1
1929	4	21	18	15	14	14	2	16	17	0	6	11	13	13.3
1930	3	17	13	7	14	4	1	3	3	0	2	3	4	5
1931	0	8	8	7	10	8	2	15	11	0	3	6	9	8.3
1932	12	14	15	22	25	21	9	25	15	0	13	14	11	15.2
1933	7	8	14	8	9	12	8	15	11	0	9	10	6	9.1
1934	4	7	11	12	18	11	2	14	9	0	4	6	4	7.3
1935	2	9	15	12	15	9	4	9	11	0	4	6	7	8.1
1936	1	4	5	6	7	4	1	3	5	0	1	1	8	4.9
1937	10	11	11	10	7	5	1	4	6	0	2	2	5	5.3
1938	21	26	16	18	13	10	1	11	9	0	5	4	8	9.9
1939	32	23	8	14	14	18	3	13	8	0	3	4	5	8.7
1940	2	1	4	10	14	12	1	10	10	0	2	2	7	6.5
Mean	3.5	7.1	10.2	12.5	15.0	13.4	2.7	16.3	16.2	0.5	6.5	7.9	9.9	10.3
Sdev	7.0	7.6	10.4	12.2	11.1	10.6	4.2	10.2	9.9	1.5	5.3	10.1	6.7	6.5

Source: U. S. Bureau of Agricultural Economics, *Statistics on Cotton and Related Data*, Statistical Bulletin No. 99 (Washington, DC: 1951), pp. 67-80.

Taking a different approach, a Bureau of Entomology and Plant Quarantine (BEPQ) study conducted across the South compared “the yield in plots where the boll weevil was controlled with that in untreated plots. . . .”[27] The results, summarized in Table 2, suggest that average physical losses were in the range of 11-33 percent, which were higher than the average BAE estimates.

Table 2: Bureau of Entomology and Plant Quarantine Estimates of Weevil Damage

Locality	Period	Yield Reduction
Talluah, LA	1920-34	32.2 percent
Florence, SC	1928-35	23.6 percent
Oklahoma (eastern)	1928-35	32.8 percent
Mississippi (hill section)	1934-36	10.8 percent

Source: Hyslop, “Losses Occasioned by Insects, Mites, and Ticks,” pp. 4-5.

In *One Kind of Freedom*, Roger Ransom and Richard Sutch present even larger estimates of the short-run losses caused by the boll weevil. Using annual state-level data from the USDA for Louisiana, Mississippi, Alabama, Georgia, and South Carolina, they compare average cotton acreage and yields for the four years before the weevil first entered each state with the four years after the weevil had completely crossed through. (Adopting these wide time frames was necessary because damage increased for several years after contact as the weevil population built up. The weevil typically required about 6 years to cross a state, making the mid-points of the periods under comparison roughly a decade apart.) These calculations reveal the infestation reduced cotton acreage by an average of 27.4 percent and yields by 31.3 percent.[28]

By way of contrast, Kent Osband, one of Sutch’s students, presents considerably smaller estimates of the financial (as opposed to physical) losses. There was no doubt that in the two or three seasons after the weevil arrived in an area, the local farm and business communities were hit hard. Osband noted that for all the damage done after the weevil arrived in a particular locale, the Cotton South as a whole was resilient.

[27] Hyslop, “Losses Occasioned by Insects, Mites, and Ticks,” pp. 4-5. Hyslop also raises the question of increased cost of production, but only gives a rough estimate of dusting for 1926--30. On average in this period farmers dusted over 3.2 million areas. At an estimated cost of $2 per acre and assuming one-half of the dusting was directed at the boll weevil, meant about $3.2 million a year spent to dust the weevil.
[28] Ransom and Sutch, *One Kind of Freedom*, pp. 174-76.

> Cotton farmers learned to cut their losses to the weevil: They changed their cultivation methods, harvested sooner and applied poisons. After the initial shock, every state witnessed a decline in weevil losses and resurgence of cotton production …. the weevil seems a symbol less of King Cotton's collapse than of its perseverance.[29]

The key observation was that the South as a whole faced a downward-sloping demand for cotton with an elasticity close to unitary. As a result, weevil-induced reductions in cotton output led to offsetting increases in cotton prices. Based on his assumptions about the elasticities of demand and supply (including foreign supply), Osband estimated that the aggregate revenue loss to southern cotton producers was a modest 2 percent. From this macro perspective, the higher cotton prices greatly benefited foreign producers and hurt consumers everywhere. Even within the South, some producers initially benefited while others suffered. Osband argues that taking into account the low elasticity of cotton demand, the micro-level evidence that "the weevil triggered a transition out of cotton" is consistent with macro-level evidence of little long-term impact. [30]

This analysis downplays the importance of quality changes, assuming the elasticity of demand is unaffected by product adjustments made in response to the boll weevil. But by shifting to early-maturing shorter-staple cotton to lessen damage, U.S. farmers dropped out of the higher-end long-staple markets and entered the market segment competing with India and other low-end cotton producers. The shift also opened up the greater prospect of competing with non-natural fibers such as rayon. Rayon, which is made from cellulose, was developed in France in the 1890s and manufactured in the United States from 1910 on. Initially rayon was "of low tensile strength and highly irregular in quality… (b)ut these properties.., improved steadily" over a period when cotton fiber quality was declining.[31]

Osband's macro-level findings that price changes largely offset output losses for the region as a whole adds significantly to our understanding. But it tells us little about

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[29] Osband, "Boll Weevil," p. 628.

[30] Osband, "Boll Weevil," p. 627. His analysis uses the state-level USDA production data to estimate the supply functions of each state and assumes the weevil reduced yields in line with the BAE estimates. He then simulates the changes in cotton acreage, outputs, and prices as the boll weevil spreads across the South. The model does assume that land taken out of cotton earned a smaller return in other uses.

The argument regarding southern resilience in response to the boll weevil should not be exaggerated. Yields were permanently decreased (until the advent of the modern eradication campaign) and the use of extra fertilizer and pesticides increased costs. The main thrust of Osband's case is that increased prices compensated from the reduced production.

[31] Wright, "Competitive Outlook," p. 259.

how the local economy in areas just experiencing weevil's invasion were affected by this great shock to production. His study does not reveal how farmers adjusted either before or after the weevil's arrival nor how migration patterns and land values were affected. While the boll weevil infestation in distant areas (along with other market forces) may have gradually increased a cotton-growing region's prosperity, most accounts suggests that when the boll weevil hit a community, it acted like a tsunami, causing large and immediate changes in production relationships. Investigating how these local economies responded to such great shocks to their staple commodity promises to advance understanding the region's institutions and long-run performance.

IV: Two New Data Sets

This study departs from previous research by assembling and analyzing new county-level panel data sets to investigate the magnitude and timing of the effects of the boll weevil. A county-level approach avoids many of the aggregation problems plaguing state-level studies and, obviously, increases by orders of magnitude the number of degrees of freedom. We utilize two new sets of data:

a. The first (which we call the "census" data) uses information from the Census of Agriculture for the years *1889, 1899, 1909, 1919, 1924, 1929*. This data set contains county level data on production and acres and allows constructing a measure of yields. This data-set also has county-level characteristics from the Census of Agriculture and Population, among other sources.

b. The second data (which we call the "commerce" data) contains annual data on cotton ginned within each county from *1899* to *1940*. We inputted these statistics from a set of surveys of local ginners conducted by the U.S. Department of Commerce. Local ginning is not a direct measure of local production, but the two series are close. For example, the correlation coefficient across counties in the 1899 census is 0.99. The ginning data do not allow calculating yields. However, they have the great advantage of being available annually.[32]

Both data sets make use of the same data on the time the boll weevil arrived in a county. We have coded the year when the weevil first arrived in any part of each county, when it passed completely through as well as the years of various retreats and returns from the classic USDA boll weevil maps. The frontier lines were drawn for the end of the crop year, after the weevil's period of seasonal migration. In the analysis below, we use the average of the start and through years to indicate the weevil's presence in a county. To provide for weather controls at the local level, we have created selected temperature and precipitation variables from two historical climate data sets. Specifically, we construct variables for each county's mean temperature in January and its precipitation in May, June and July based on data from nearby weather stations. See Appendix A for a fuller description of all the data.

To create our panels, we must address the problem that numerous southern counties (N=138) changed the boundaries over the period between 1890 and 1940. For example, new units were frequently created out of one or more old units. One option would be simply to exclude those counties experiencing boundaries changes but this is unsatisfactory because the changes were likely non-random. As an alternative, we have formed multi-county aggregates (N=44) for those counties experiencing boundaries changes to be used in their place. We use these multi-county aggregates together with the counties with consistent boundaries (N=1165 in the full data set).[33] We will call these geographical units "counties" from now on, even though of course some are aggregated out of several counties.

Sample Selection

We have adopted a sample selection procedure with the goal of creating a balanced panels of uniform, consistently defined geographic units with continuous

[32] The historical literature has referred these ginning data when reporting stories about the impact of the weevil in selected counties. We subject the series to the first systematic investigation.

[33] The full data set includes all of the counties in Alabama, Arkansas, Georgia, Florida, Louisiana, Mississippi, Missouri, North Carolina, Oklahoma, South Carolina, Tennessee, Texas, and Virginia. Note that only a handful of counties in Missouri and Virginia reported cotton and that many in Tennessee and Texas were also marginal producers.

measures of activity (production and acreage in the census sample and ginning in the commerce sample) as well as of the presence of the weevil for the entire time period, (1889-1929) and furthermore a simple temporal pattern for the presence of the boll weevil. This latter requirement leads us to drop those counties that saw a temporal disappearance of the weevil. These counties were largely at the edge of the cotton growing zone. We also exclude counties with minimal initial cotton acreage/production and include the multi-county aggregates together with the cotton-producing counties with consistent boundaries. Many of our specifications have log production, log acres or log yields as their dependent variables. Thus, we are wary of putting undue weight on tiny producers. We drop some observations that have very small production in some years.

The next two paragraphs describe the sample selection for each of the samples:

Census data: We have 1,201 geographical units in the data with consistent boundaries throughout 1889-1929. Across 6 years with census data, this makes for a total of 7,206 observations. We drop 529 counties for which the first year of boll-weevil presence is missing. Most were in Missouri, Virginia, and western Texas. This leaves 818 counties. To avoid putting undue weight on small producers, we remove all those counties who have fewer than 100 acres of cotton production or missing acres in any of the years. This step removes an additional 62 counties with 372 observations. We drop another 81 counties that experience retrenching and re-entering of the weevil and are left with 671 counties and a total of 4,026 observations. We thus drop 45 percent of the counties with consistently defined boundaries.

Commerce data: For the commerce data we start by using the period 1899-1929. For now, we drop the data 1930-1940 to maintain comparability with the census data (even though the ginning data does not have 1889-1898). The data has 1,240 'counties' with consistent geographic boundaries throughout the entire period 1899-1929. 400 counties have missing values for the first appearance of the weevil. After dropping these we retain 840 counties for 26,041 observations over the entire 1899-1929 period. Again, we eliminate marginal counties by dropping those with cotton acres less than 100 as reported in the Census of Agriculture in 1889. This drops 62 counties and 1,922 observations. 86

out of the remaining 778 experience retrenching of the weevil and dropping these leaves us with 692 counties and 21,452 observations. Finally 145 counties have either missing cotton_ginning data or cotton_ginning<100 at some point. This leaves the commerce sample with 547 counties and 16,958 observations.

V: Impact of Boll Weevil

To provide a first look at the impact of the boll weevil, Table 3 reports results from a simple specification – a regression of various cotton production measures on Year and County fixed effects as well as a measure of whether the weevil was currently present in the county and local weather variables.

Specification:

$$y_{it} = \beta\text{*bw} + aW_{it} + \theta_i + \theta_t + \varepsilon_{it} \tag{1}$$

Columns 1-3 show the results estimated on the census data and the time period 1899-1929. Column 4 shows the estimates for the commerce data and covers the years 1899-1929.

Table 3: Impact of Boll Weevil on Cotton Production

	(1) Log Bales	(2) Log Acres	(3) Log Yield	(4) Log Ginning
1889	-0.988	-0.793	-0.195	
	(0.061)**	(0.055)**	(0.029)**	
1899	-0.948	-0.813	-0.135	
	(0.066)**	(0.059)**	(0.032)**	
1909	-0.312	0.007	-0.319	
	(0.055)**	(0.049)	(0.026)**	
1919	-0.309	-0.281	-0.029	
	(0.045)**	(0.040)**	(0.021)	
1924	-0.376	-0.579	0.204	
	(0.064)**	(0.057)**	(0.031)**	
Jan Temp	-0.036	-0.085	0.049	0.001
	(0.010)**	(0.009)**	(0.005)**	(0.002)
Summer Rain	-0.391	-0.156	-0.235	-0.318
	(0.063)**	(0.057)**	(0.030)**	(0.018)**
Is Weevil present?	**-0.480**	**-0.190**	**-0.290**	**-0.391**
	(0.047)**	**(0.042)****	**(0.022)****	**(0.014)****
Observations	3618	3618	3618	24068
R-squared	0.81	0.83	0.47	0.75

Standard errors in parentheses

significant at 5%; ** significant at 1%
Col 1-3 on census data for 1889, 1899, 1909, 1919, 1924, and 1929. Col 4 on annual ginning from the commerce data 1899-1929.
All Specifications with year and county fixed effects; 1929 is the omitted year.

These numbers suggest that the impact of the weevil on overall production was huge. These (within county-) estimates imply that the weevil was associated with a decline of total output by 40-50 percent. Much of this decline is due to a decline in yields. At the same time the year fixed-effects imply that there has been a secular increase in production by about 60-80 percent over this time period, most of which was due to expanding production area for cotton.

The potential for reverse causation is an obvious and important concern. To address this issue, we adopt the approach of instrumenting for the presence of the boll weevil using latitude and longitude. This reflects the observation that the weevil advanced across the South in a front. Table 4 displays the results for the second stage of the regressions on bales, acres, yields, and ginning (The first stages for presence of boll weevil has an F-statistic (48 numerator dfs) of 124.78 for the annual data. For the census data, the F has 6 numerator dfs and a value of 209.80.) If anything, the effects in the IV regressions are stronger than in the OLS regressions.

Table 4: IV-regression using longitude and latitude

	(1) log bales 1889-1929	(2) log acres 1889-1929	(3) log yield 1889-1929	(7) log ginning 1899-1940
Is BW present?	**-0.660** **(0.062)****	**-0.134** **(0.055)***	**-0.526** **(0.030)****	**-0.452** **(0.020)****
Observations	3,618	3,618	3,618	24,068
R-squared	0.81	0.83	0.45	0.75

Standard errors in parentheses
* significant at 5%; ** significant at 1%
With Year and County Fixed Effects and weather controls.
IV are quadratics in longitude and latitude interacted with Year dummies for with a boll weevil presence in more than 0% and less than 100% of counties.

We now turn to an analysis allowing a better understanding of the timing of the impacts. We replace the variable for the boll weevil's presence with 10 leads and 10 lags for the weevil's arrival. The specification retains the local weather variables as well as the County and Year fixed effects.

Specification:

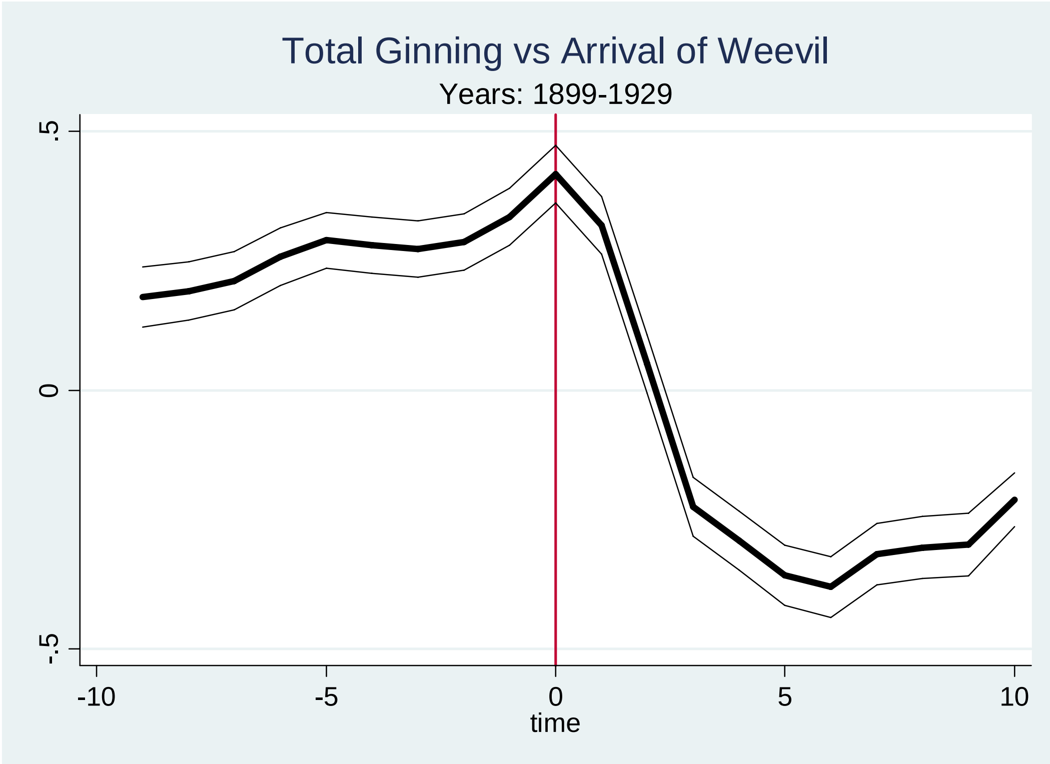
(2) $$y_{it} = \beta_k \sum_{k>-10}^{k\leq 10} 1[t - h_i = k] + \alpha W_{it} + \theta_t + \theta_i + \varepsilon_{it}$$

where h_i is the year that county i is first hit. The omitted timing category is 10 or more years before being hit. The years 10 or more after being hit are also combined into a single final category.

To save the reader the trouble of staring at large tables of coefficients appearing in small font, we will present the results as a series of graphs. Appendix C provides the regression table for the cotton production regressions corresponding to these graphs. In addition to the evidence on cotton ginning, production, acreage, and yield, we present also graphs showing the estimated impact of the boll weevil's arrival on corn production, acre, and yields, total land in farms, the constant-dollar value of farm real estate, total population, and black population derived using the same regression framework. Each of these new variables is in logs and is part of the census data set. The coefficients displayed in these graphs are measured against the value 10 years or more prior to the arrival of the weevil.

We begin with the annual ginning series.

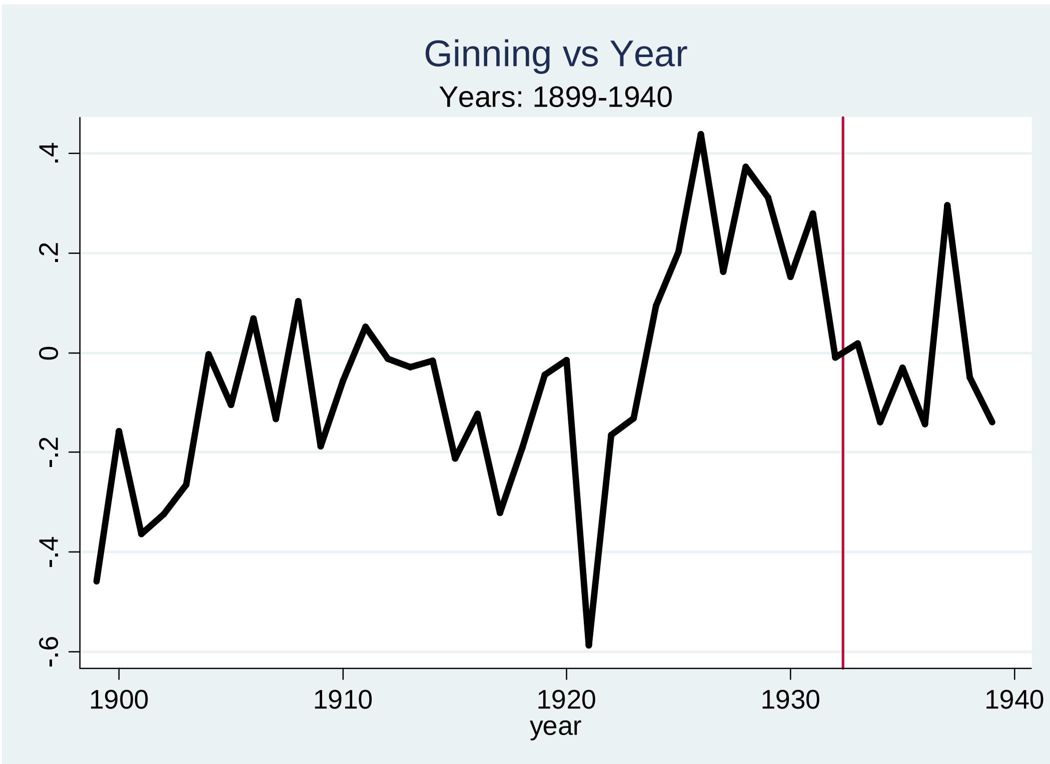
Total Ginning



The total ginning graph puts the destructive impact of the weevil into sharp relief. Ginning fell by about 0.1 log points in the year after first contact and average of 0.25 log points for the next two years. By the year six after the county is hit, ginning is 0.8 log points below the levels of year zero. Thereafter, activity rebounds slightly, in accordance with expectations that farmers in infected counties learned to adapt to the pest.

One might expect that in anticipation of the weevil's arrival, southern farmers would have adjusted to lessen their dependence on cotton. But our results show the cotton crop in the year of contact was higher in the decade prior to the arrival of the weevil. Furthermore, cotton production increased again in last year prior to the arrival of the weevil compared to the two or three years before contact. The magnitude of the effect is statistically significant and economically large, with the crop 0.13 log points higher.

Several possible explanations come to mind. The first is that this relationship is not the product of human intention. For example, good cotton-growing weather covering a large region might encourage both a big crop and a large population of fast migrating weevils. The regressions include partial controls for local weather but some omitted variable bias may remain. A second, more intriguing alternative is that the rise in production both in the decade but also immediately before impact was a conscious human choice. Helms states "farmers too often attempted to grow that last 'big crop' after the boll weevil arrived…."[34] It might be economically rational to seek to depreciate cotton-specific assets (equipment and soils) before the insect's attack lowered their productivity. It might also be a response to enlarged local labor pools swollen by cotton hands moving back east to escape the wave of destruction to the west.[35] One consequence of the built up is that the subsequent decline starts from an abnormally high peak.

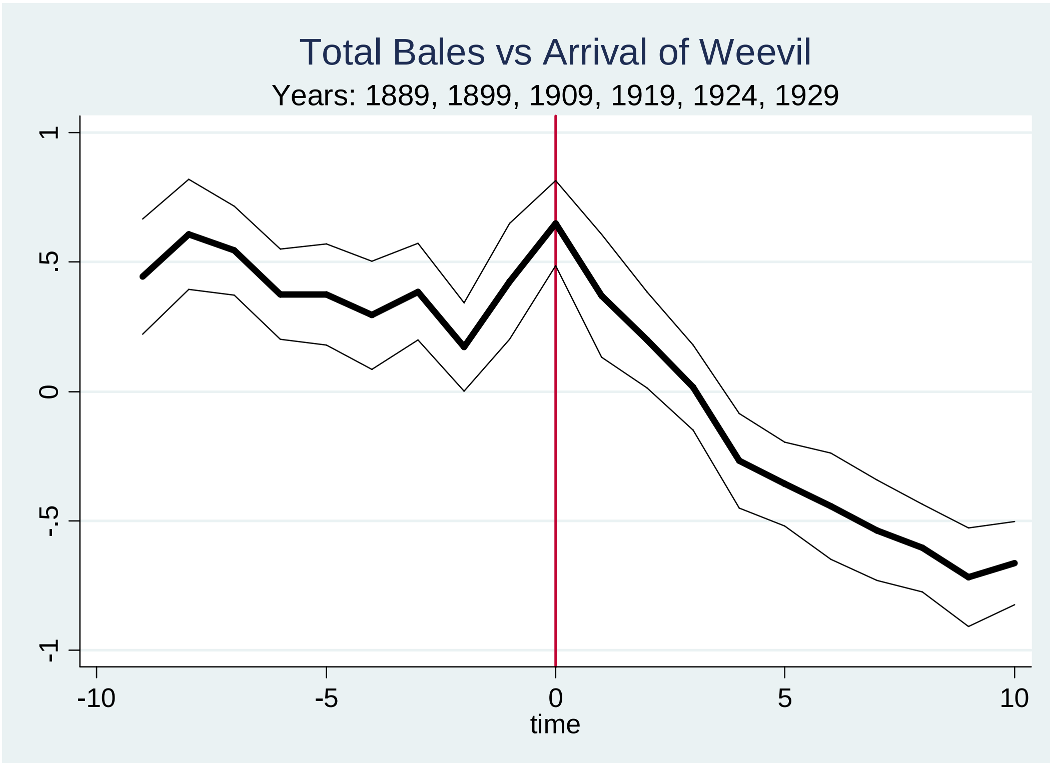


The ginning results also reveal an interesting pattern of Year dummies displayed in the graph below. These coefficients reflect southern-wide effects including the state of cotton market, government policies, regional weather, the general state of knowledge about how to combat the weevil, and many of macro-level effects that Osband emphasized. The effects of World War One and of the New Deal crop programs are

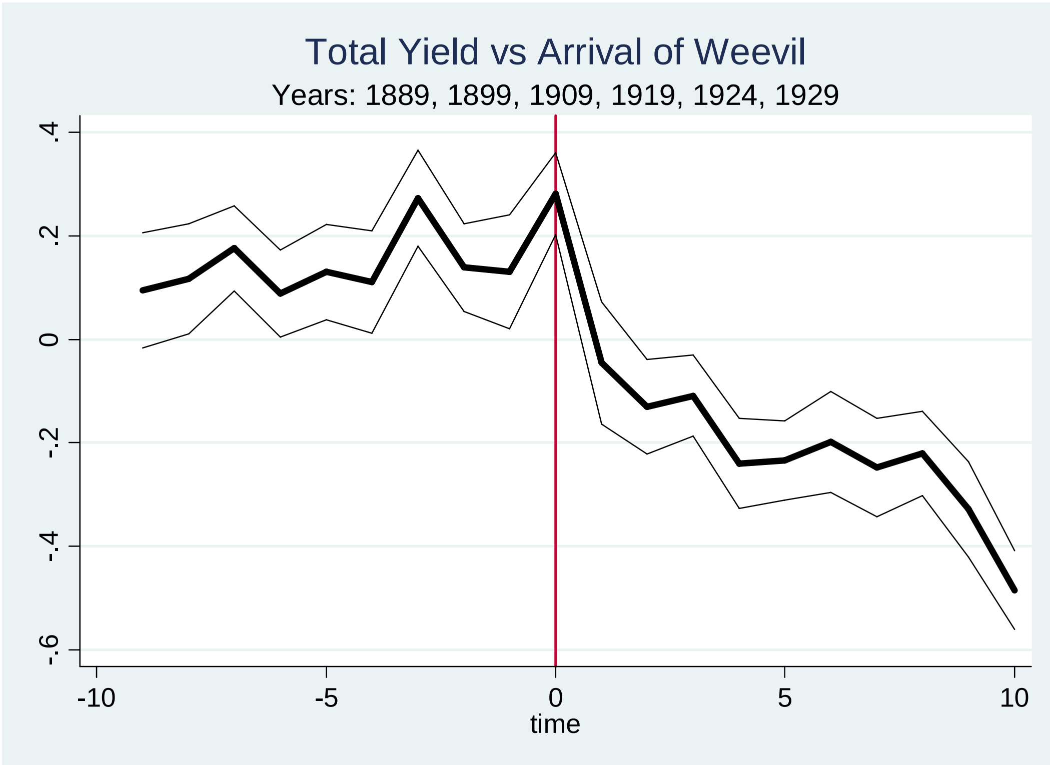
[34] Helms diss, p. 399 citing the *Southern Cultivator*, Dec. 1 1916, p. 2
[35] Giesen, p. 137 recounts that in the late 1900s several thousand of African-Americans entered the Delta region to escape the ravages of the weevil further west.

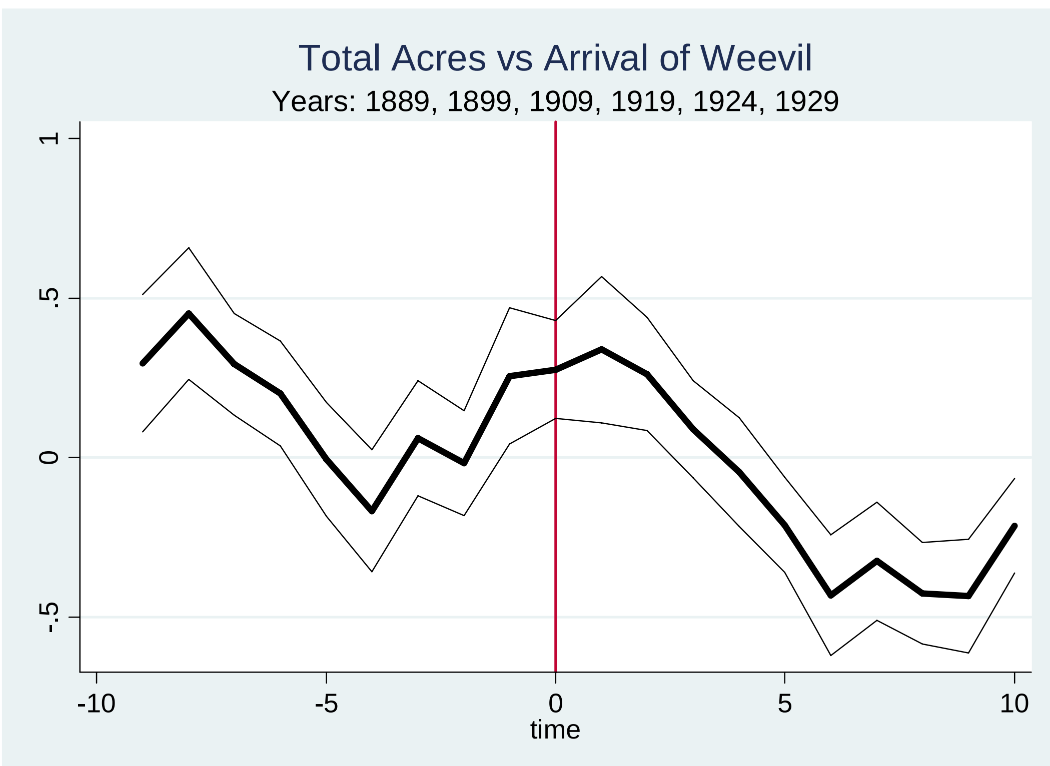
clearly evident in these results. But note that 1921 which was thought to be a bad crop year for weevil damage across the South shows a large negative shock.

Total Cotton Bales, Yields, and Acreage

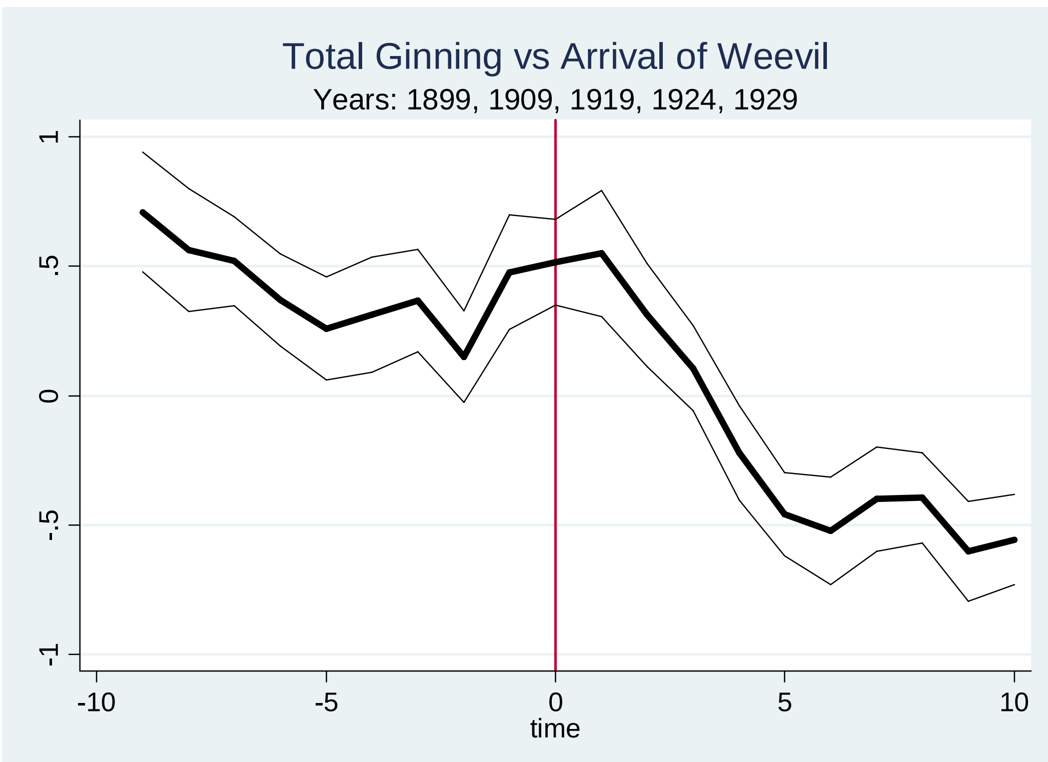


The results from the census sample for total bales display broadly similar patterns to those from the commerce data. Output also rises in the years immediately before the county is hit. Then a substantial decline begins, of larger magnitude and longer duration than in the commerce sample. The availability of acreage and yield information in the census allows us to decompose the sources of the output changes. Cotton yields fall sharply in the first year after contact, and continue to decline over the entire post-infestation period. By way of contrast, the acreage results show an increase in the first year after contact, continuing a growth trend from the previous years. There is only a small decline in the second year. Thereafter, cotton acreage declines to a level about 0.2 log points below the pre-arrival level.


Total Yield vs Arrival of Weevil
Years: 1889, 1899, 1909, 1919, 1924, 1929
.4
.2
0
-.2
-.4
-.6
-10
-5
0
5
10
time

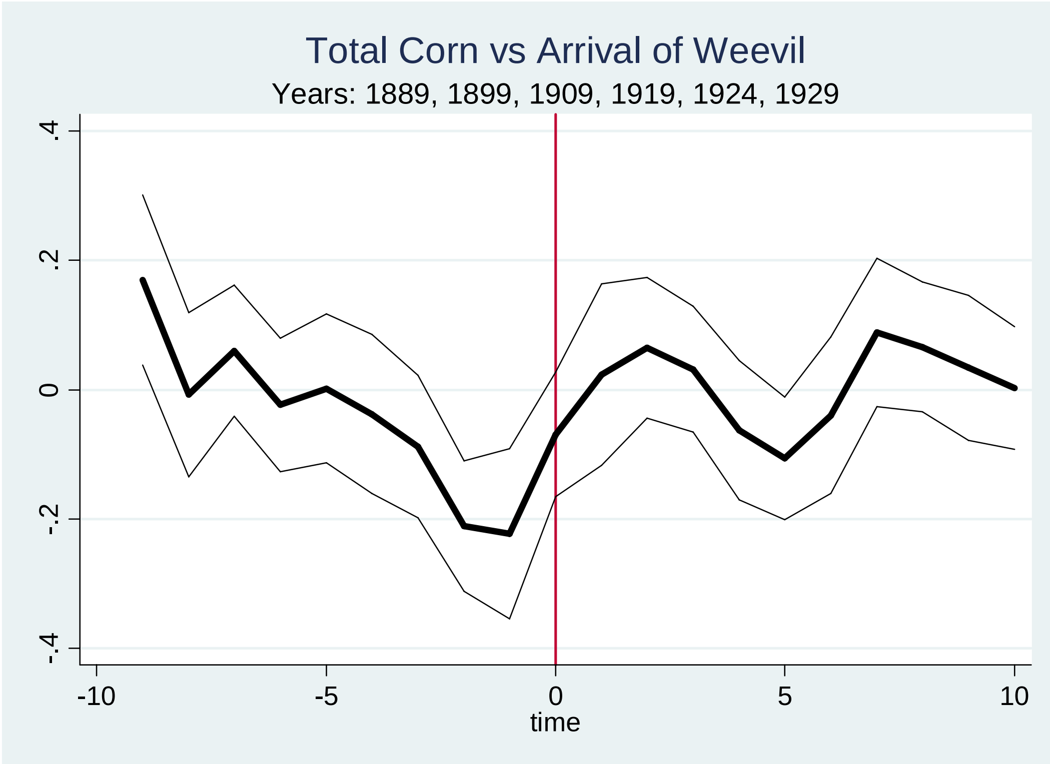

Total Acres vs Arrival of Weevil
Years: 1889, 1899, 1909, 1919, 1924, 1929
.1
.5
0
-.5
-10
-5
0
5
10
time

The next figure uses the annual ginning data to link to the regressions employing census. These results identify the effect of the boll weevil using only the information of the census years 1899, 1909, 1919, 1924, and 1929. We can see that although the coefficients bounce around, they have the same pattern as those using all the census data. Instead of displaying a slow increase in the cotton production prior to the arrival of the weevil, we observe a less regular pattern prior to arrival. This is, we believe, entirely spurious and only driven by the particularities of the census years. The lesson is clear: temporary patterns in the effect of the boll-weevil estimated from the census data are to be interpreted with caution.

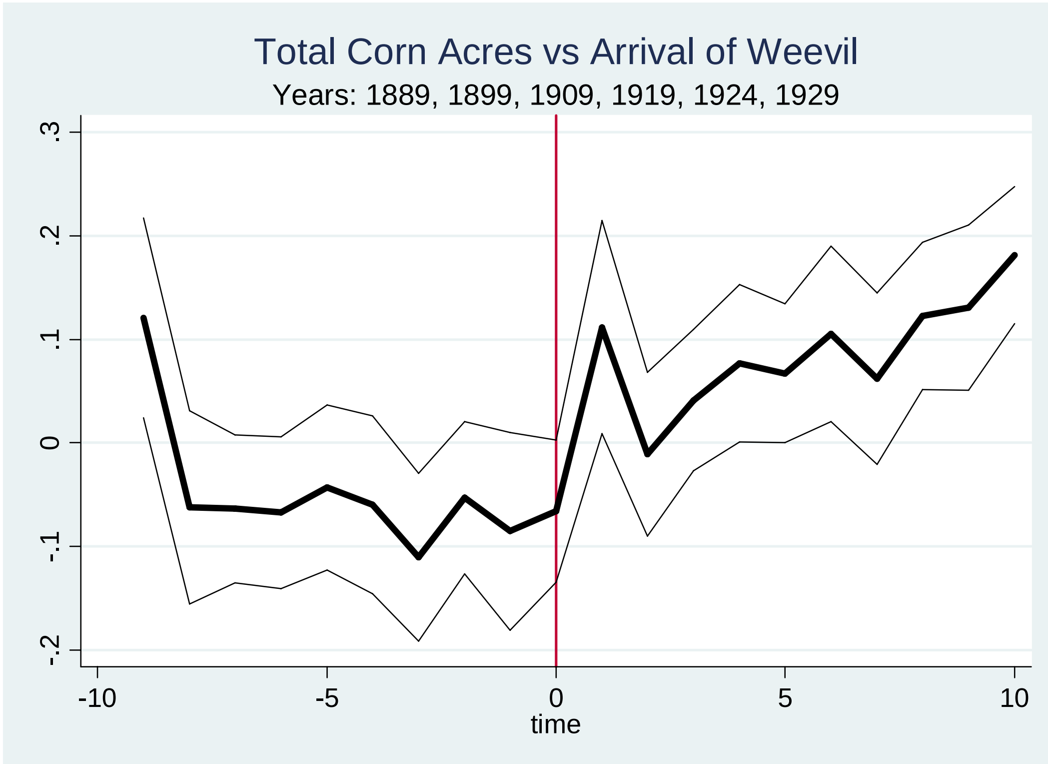


Total Corn Bushels, Yields, and Acreage

The decline in cotton acreage raises the question of what southern farmers did with the released land. Examining changes in production of corn, the other major crop, provides part of the answer. The graphs below show the time patterns for corn output, acreage, and yields.

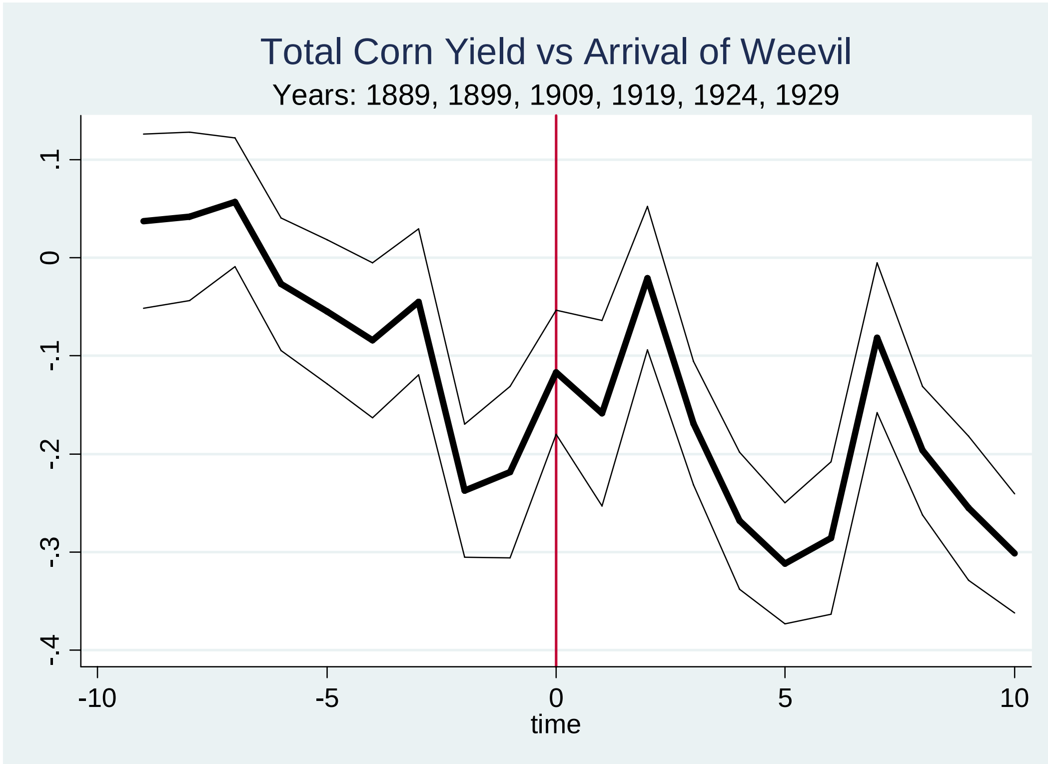


Total corn shows a declining trend before the weevil's arrival. As the insect approaches the county, corn output begins to grow. By two years after contact, corn bushels return to the range prevailing at the opening of our window of analysis. The series remains at the level at the close of the window. As with cotton, the census data allow us to decompose the output changes into acreage and yields.



The results of corn acreage are quite clear. There is little trend in the period before the boll weevil's arrival. In the year after contact, acreage jumps by about 0.17 log points. In the next year, corn acreage falls back.[36] Thereafter corn acreage grows, reaching a level about 0.25 log points higher at the close of the window than at the year of first contact. This represents an impressive reallocation of land.

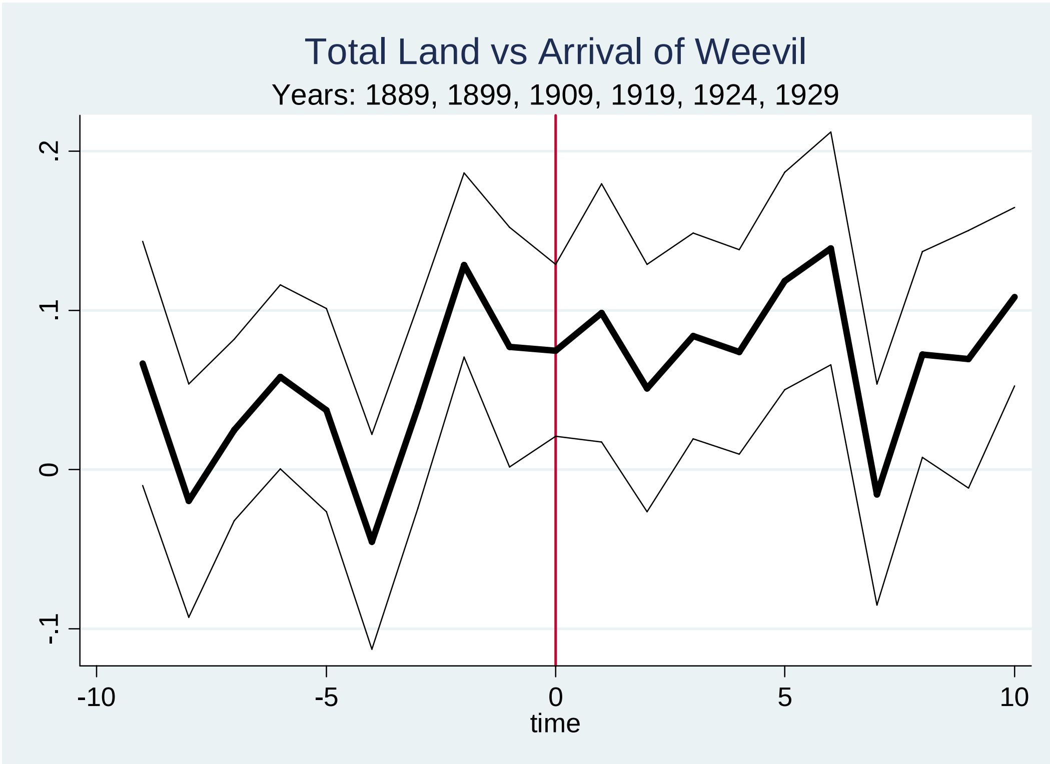
[36] It is difficult to know whether the jump up and back is a general phenomenon or specific to the counties whose timing identifies this effect. It does echo the change in period nine years before impact.

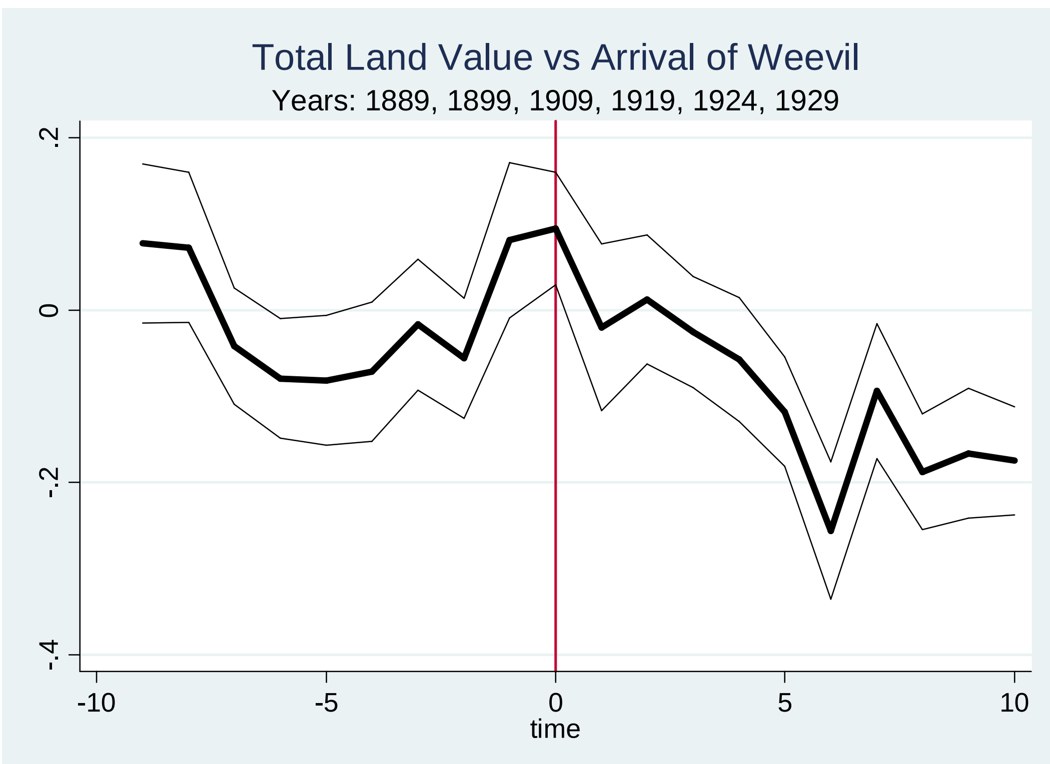


By way of contrast, the results for corn yields are noisy. They show a downward movement in the years before impact and then a sharp recovery. The pattern for yields is consistent with farmers initially shifting the better lands out of cotton and into corn and then ending up either returning the poor lands to corn or utilizing rotations that sapped corn yields. Overall the corn data indicate a greater movement to alternative crops than suggested in the traditional literature which downplays the boll weevil's effects on diversification suggest.

All Farm Land and Real Estate Values

Parts of the boll weevil literature contend that large tracts of land were completely abandoned in its wake. Examining the impacts of total farm land indicate such accounts are exaggerated. Total land farmed changed little immediately after impact and is within the same range at the end of the window of analysis as at year zero and at the beginning of the window.

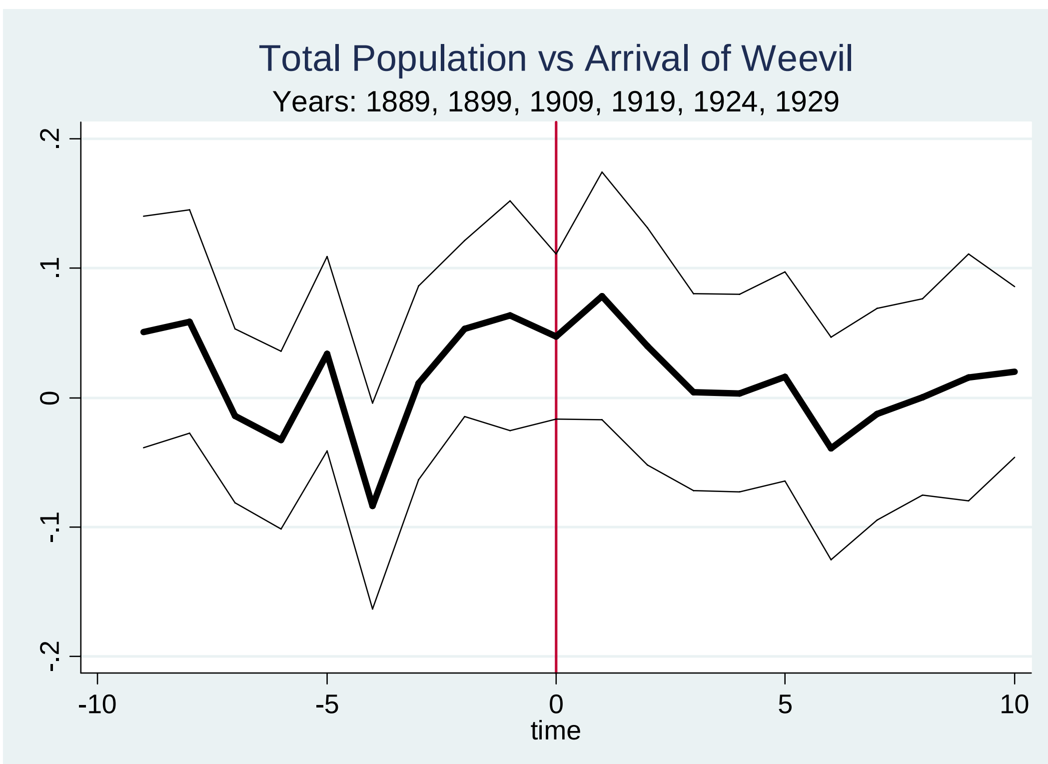

Total Land vs Arrival of Weevil
Years: 1889, 1899, 1909, 1919, 1924, 1929
.2
.1
0
-.1
-10
-5
0
5
10
time

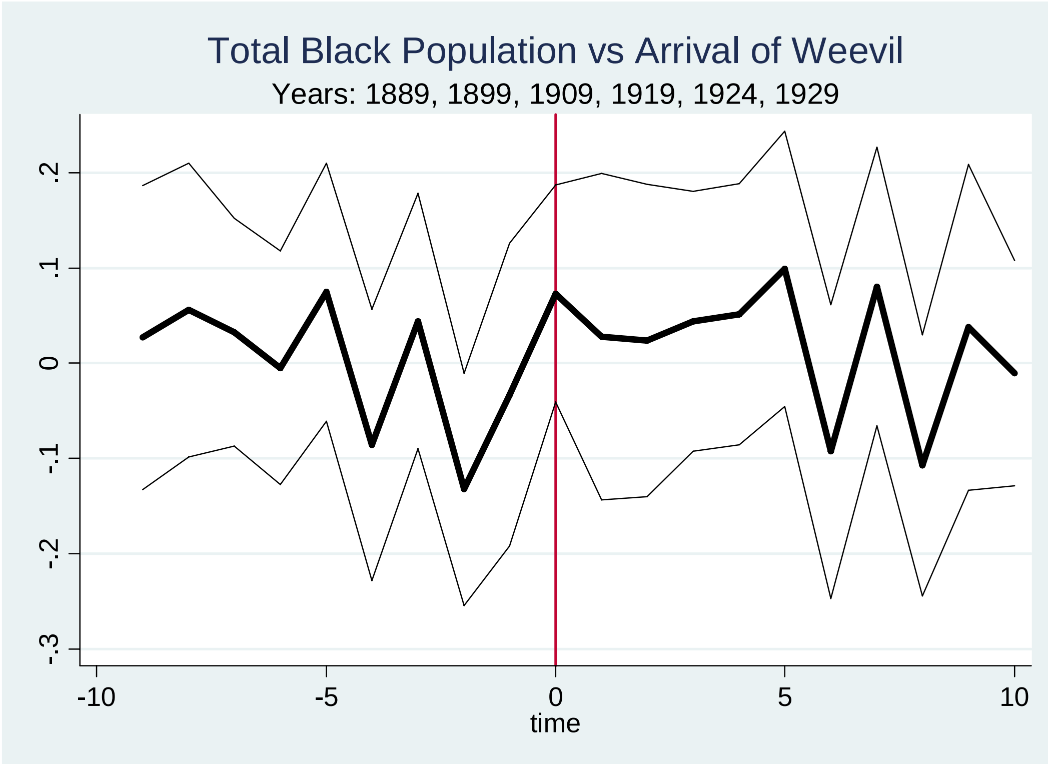

Total Land Value vs Arrival of Weevil
Years: 1889, 1899, 1909, 1919, 1924, 1929
.2
0
-.2
-.4
-10
-5
0
5
10
time

Nor are the effects on land values as great as often suggested. The land value results largely mirror those for cotton bales. They show little anticipation of boll weevil's arrival and, in fact, are rising immediately before contact. The coefficients then begin to fall, reaching a level about .1-.15 log points lower in year 5 following the arrival of the weevil compared with the land values preceding the arrival of the weevil. These are large impacts, but not of the magnitudes consistent with stories of the weevil drastically reducing farm land values and undermining local financial institutions..

Population

Examining the series on population also paint a picture of small changes, especially in comparison of the impact on cotton production. There appears to be little change in overall population, in the black population specifically, or in the racial composition of the population.





Preliminary Summary.

Our preliminary findings may be summarized a following. The boll weevil had large and rapid negative effects on cotton production, the South's great staple. Cotton production in counties hit by the weevil declined significantly and show little recovery even 10 years after the weevil arrived. Cotton acreage declined by a smaller magnitude and acreage in corn, the major alternative crop, rose. Most of the decline in cotton was due to declines in yields. Farm values fell measurably but not drastically after the boll weevil arrived. There is little evidence this key asset price moved in anticipation of the threat – instead declines in farm values tracked the declines in overall cotton production and yields. Finally, there is no evidence that labor relocated following the arrival of the weevil. Both the size and racial composition of the population seems unaffected by the arrival of the pest.

VI: Conclusion

This paper examines the county-level evidence on the effects of the spread of the boll-weevil through the cotton-growing areas of the United States between 1892 and 1922 on U.S. cotton production. This event is of specific interest due to the importance of cotton for the economy of the American South in this period. We show the boll-weevil significantly reduced the production of cotton in the years immediately after its arrival. We examine the time-path of effects on total acreage and on yields, thus revealing the effect on total production. We also trace out the time-path of effect on annual cotton ginning. Further we examine to what extent the effect of the weevil is capitalized into land values. This gives an independent measure of the effect of the weevil.

We also see the spread of the boll weevil as a prism through which to examine other important questions in the development of the American South. In the future, we want to study how local economies dealt with this negative event on local productivity, on its relationship to tenancy and to out-migration. These aspects of the research would greatly benefit from suggestions. Finally, we desire to compare the impact of the boll weevil in the American South to similar episodes in other times and places to enhance our understanding of the general question of how economies respond to severe negative shocks to productivity.

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Appendix A:
Data Description and Sources

Extent of Boll Weevil Infestation

The extent of boll weevil infestation was based on the map appearing in the USDA, *Yearbook of Agriculture, 1921* (Washington, DC: GPO, 1922), p. 350.
Several dates are relevant:
Start_year=Weevil first appeared in a county;
Thru_year=Weevil infects whole county;
Retreat_year=Weevil pushes out of county (e.g. in upper belt by unfavorable weather);
Return_year=Weevil reappears;
Final_year= Weevil infects county "permanently."

Ginning Data

Annual county-level data on cotton ginning are available beginning in 1899 from the U.S. Bureau of the Census, *Quantity of Cotton Ginned in the United States* (Washington, DC : GPO, 1900-1904); *Cotton Production in the United States* (Washington, DC : GPO, 1905-1970). The data including both the upland and Sea Island crops (exclusive of linters) are in number of 500-pound equivalent bales. Local agents collected the data based on a comprehensive canvas of southern ginneries.
County-level ginning is very closely correlated to county-level production; the R-squared equaled 0.99 in the 1899 Census data.

Production and Farm Characteristics

US Census of Agriculture collected data on acreage, production, and thus yields for cotton, corn, and other crops by county for 1889, 1899, 1909, 1919, 1924, 1929. It also has number of farms by tenure status -- owner-occupier, cash tenant, share tenant, share cropper. Census data based on ICPSR Study No.2896, Historical, Demographic, Economic, and Social Data: The United States, 1790-2000, Michael R. Haines, Colgate University , Inter-university Consortium for Political and Social Research.
Value of Land and Buildings per Acre from ICPSR No. 9 and is in round numbers.

Weather

The weather data come from two sources: (a) United States Historical Climatology Network (USHCN): http://www.ncdc.noaa.gov/oa/climate/research/ushcn/ushcn.html; and (b) National Oceanic and Atmospheric Administration, Nineteenth Century U.S. Climate Data Set Project (based primarily on records kept at US forts): http://lwf.ncdc.noaa.gov/oa/climate/onlinedata/forts/forts.html. The USHCN data extend further into the 19th century, but early coverage is much better in the NOAA 19th Century Dataset. The USHCN data is described as a "data set of monthly averaged maximum, minimum, and mean temperature and total monthly precipitation developed to assist in the detection of regional climate change. The USHCN is comprised of 1221 high-quality stations from the U.S. Cooperative Observing Network within the 48 contiguous United States." The NOAA forts data set is described as "*In situ* monthly temperature and precipitation data for the United States from the Nineteenth Century ... the temperature data begins in 1822; The precipitation data begin in 1837.….[The] monthly station data [were collected] by the U.S. Department of the Army Medical Departments and Signal Corps, the U.S. Patent Office, the Smithsonian Institution, and from the Department of Agriculture's Voluntary Observers and Weather Bureau." We merge these data sources to estimate the temperature and precipitation variables for each county.

Appendix B:
Logit Regressions of Boll Weevil Presence, 1907-1918 in Southern United States

South of Latitude 35 degrees and East of 95 degree Longitude

		latd	longd	latd_sq	longd_sq	latdXlongd	cons	Pseudo_R2
1907	b	243.4	373.5	-2.176	-1.779	-1.145	21488.3	0.95
	se	(121.30)	(178.80)	(0.81)	(1.07)	(1.28)	(8456.70)	
1908	b	199	205.6	-3.652	-1.138	0.362	-12973.3	0.958
	se	(65.63)	(92.42)	(1.21)	(0.52)	(0.42)	(4915.00)	
1909	b	-7.808	166.7	3.903	-0.322	-2.878	-7847.7	0.957
	se	(119.30)	(45.93)	(2.61)	(0.86)	(3.24)	0.00	
1910	b	77.6	-4.096	0.259	0.257	-1.115	-1242.4	0.963
	se	(32.50)	(43.40)	(0.82)	(0.15)	(0.82)	(2212.60)	
1911	b	253.5	111	1.038	0.111	-3.701	-9378.4	0.953
	se	(85.62)	(50.01)	(0.68)	(0.12)	(1.38)	(3566.90)	
1912	b	-8.49	48.56	-0.952	-0.389	0.755	-2134.3	0.99
	se	(19.34)	(53.35)	(0.55)	(0.27)	(0.40)	(2267.30)	
1913	b	751.3	893.8	8.672	-1.86	-15.69	-52875.9	0.951
	se	(310.90)	(118.90)	(4.18)	(1.94)	(6.62)	0.00	
1914	b	92.89	-51.98	-0.464	0.48	-0.777	566.3	0.931
	se	(28.29)	(40.48)	(0.45)	(0.18)	(0.47)	(1867.00)	
1915	b	149.8	25.31	0.0739	0.244	-1.872	-3689.7	0.865
	se	(33.93)	(25.51)	(0.36)	(0.12)	(0.53)	(1377.90)	
1916	b	153.7	-41.42	-1.411	0.423	-0.789	-849.8	0.999
	se	(30.98)	(16.99)	(0.24)	(0.13)	(0.28)	(622.80)	
1917	b	75.65	-8.07	-1.92	-0.0409	0.54	-929.7	0.904
	se	(19.63)	(15.07)	(0.35)	(0.10)	(0.25)	(672.60)	
1918	b	72.8	-53.02	-1.185	0.335	-0.00396	998.7	0.889
	se	(19.94)	(21.27)	(0.20)	(0.15)	(0.21)	(778.20)	

No. of Obs.=599 in each logit regression

Appendix C

Timing of Impact of Boll Weevil on Cotton Production

Time to/from Weevil Arrival	(1) Log total Bales	(2) log Acres	(3) log Yield	(4) log Ginning	(5) log Ginning (restr)
-9	0.391	0.296	0.095	0.180	0.710
	(0.117)**	(0.108)**	(0.056)	(0.029)**	(0.115)**
-8	0.570	0.453	0.117	0.192	0.563
	(0.112)**	(0.103)**	(0.053)*	(0.028)**	(0.119)**
-7	0.469	0.293	0.176	0.211	0.520
	(0.087)**	(0.080)**	(0.041)**	(0.028)**	(0.086)**
-6	0.291	0.202	0.089	0.258	0.370
	(0.089)**	(0.082)*	(0.042)*	(0.028)**	(0.089)**
-5	0.125	-0.006	0.130	0.290	0.260
	(0.097)	(0.089)	(0.046)**	(0.027)**	(0.099)**
-4	-0.056	-0.167	0.111	0.280	0.313
	(0.104)	(0.096)	(0.049)*	(0.027)**	(0.112)**
-3	0.334	0.061	0.273	0.272	0.368
	(0.098)**	(0.090)	(0.046)**	(0.027)**	(0.099)**
-2	0.122	-0.017	0.139	0.286	0.151
	(0.090)	(0.082)	(0.042)**	(0.027)**	(0.089)
-1	0.386	0.256	0.131	0.335	0.477
	(0.116)**	(0.107)*	(0.055)*	(0.028)**	(0.111)**
Hit 0	0.558	0.276	0.282	0.418	0.515
	(0.084)**	(0.077)**	(0.040)**	(0.028)**	(0.083)**
+1	0.294	0.339	-0.045	0.319	0.549
	(0.125)*	(0.115)**	(0.059)	(0.028)**	(0.122)**
+2	0.132	0.262	-0.130	0.051	0.312
	(0.096)	(0.089)**	(0.046)**	(0.028)	(0.100)**
+3	-0.020	0.089	-0.109	-0.226	0.106
	(0.083)	(0.076)	(0.039)**	(0.028)**	(0.082)
+4	-0.284	-0.045	-0.240	-0.291	-0.221
	(0.092)**	(0.085)	(0.044)**	(0.029)**	(0.091)*
+5	-0.445	-0.211	-0.234	-0.358	-0.459
	(0.081)**	(0.075)**	(0.039)**	(0.029)**	(0.081)**
+6	-0.629	-0.431	-0.198	-0.381	-0.524
	(0.103)**	(0.095)**	(0.049)**	(0.029)**	(0.104)**
+7	-0.571	-0.324	-0.247	-0.317	-0.400
	(0.101)**	(0.093)**	(0.048)**	(0.030)**	(0.101)**
+8	-0.646	-0.425	-0.220	-0.304	-0.395
	(0.086)**	(0.079)**	(0.041)**	(0.030)**	(0.087)**
+9	-0.762	-0.433	-0.328	-0.298	-0.601
	(0.097)**	(0.089)**	(0.046)**	(0.030)**	(0.096)**
>=10	-0.697	-0.213	-0.485	-0.212	-0.557
	(0.081)**	(0.074)**	(0.038)**	(0.026)**	(0.087)**
Observations	3618	3618	3618	24068	2885
R-squared	0.83	0.84	0.54	0.76	0.79

Standard errors in parentheses
* significant at 5%; ** significant at 1%
All specifications with Year and County Fixed Effects and climate variables
Col 4 on ginning data for 1899-1929. Col 5 on ginning data for 1899, 1909, 1919, 1924, and 1929.