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Evidence from the Boll Weevil Plague in
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Effects of Agricultural Productivity Shocks on Female Labor
Supply: Evidence from the Boll Weevil Plague in the US South

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Abstract: In the beginning of the 1890s, counties located in the Cotton Belt of the American South were hit by an agricultural plague, the boll weevil, that adversely affected cotton production and hence the demand for labor. We use variation in the incidence of the boll weevil multiplied with counties' initial cotton share to construct instrumental variables estimates of the labor supply curve. Controlling for county and state-by-time fixed effects, we find a significant positive response of labor supply to changes in labor income. The effect is particularly large for females, consistent with evidence that females had a comparative advantage in picking cotton.

Keywords: Labor Supply, Female Labor Force Participation, Agricultural Productivity Shocks, US South, Boll Weevil.

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1 Introduction

The response of labor supply to changes in labor income is of fundamental importance for many policy relevant questions at the intersection of macro, labor, and public economics (Blundell and Macurdy, 1999; Mankiw, 2014; Keane and Rogerson, 2012). For example, it affects the answer to a much heated debate between liberals and conservatives on what is the impact of a change in labor income tax rates on labor supply (Keane, 2011; Manski, 2012).¹ In this regard, female labor supply is of particular interest since women’s increased involvement in the economy was the most significant change in the US labor market and other developed countries during the past century (Killingsworth and Heckman 1986; Goldin, 1990; 2006).

In this paper we use an instrumental variables approach to estimate the causal response of labor supply along the extensive margin (participation into the labor force) to changes in labor income. The instrumental variables approach exploits variation in the timing of the incidence of the boll weevil – an agricultural pest – that adversely affected cotton production in Southern US counties towards the end of the 19th and the beginning of the 20th century. Cotton production was a significant part of aggregate output of Southern US counties, accounting for 35 percent of the value of all crops produced, 28 percent of agricultural output, and 17 percent of total output in 1900 (US Bureau of the Census, 1904).² Importantly, the spread of the boll weevil was determined by geographic conditions, in particular, temperature and wind directions (Hunter and Coad, 1923; Lange et al., 2009) so that variation in the timing of the boll weevil is exogenous to counties’ economic conditions.

The impact of the boll weevil’s incidence on output per worker varied across US counties depending on the initial importance of cotton production in a particular county. Counties with a greater initial cotton share experienced a significantly larger drop in output per worker due to the incidence of the boll weevil: a one standard deviation higher initial cotton share reduced output per worker due to the incidence of the boll weevil by an additional 7 percent. We exploit this heterogeneity in effect to construct an instrumental variable as the incidence of the boll weevil times the initial cotton share. The constructed instrument is in the spirit of an intensity-to-treat effect (see e.g. Nunn and Qian, 2011; Hornbeck and Naidu, 2014) and delivers a highly significant first-stage effect. Because the instrument captures shocks to agricultural productivity it should be interpreted as shifting the demand for labor (see the technical appendix for more details).

¹Unfortunately, economic theory makes no clear prediction regarding the sign (or magnitude) of the labor supply response to changes in labor income. The reason is that the answer depends on whether the substitution effect dominates the income effect; and economic theory is silent on the relative magnitude of the two effects as they depend on the particular utility function specified.

²In the main cotton producing states Alabama, Georgia, Louisiana, Mississippi, South Carolina and Texas – the so-called Cotton South (Ransom, 1989) – cotton production accounted for 59 percent of the value of all crops produced, 50 percent of agricultural output and 37 percent of total output in 1900 (US Bureau of the Census, 1904).

In the reduced form we find that upon arrival of the boll weevil the labor force participation rate decreased significantly more in US counties with a higher initial share of cotton. Controlling for county and state-by-time fixed effects, we find that a one standard deviation higher initial cotton share reduced the labor force participation rate of all working age people by 2 percentage points; for females the effect goes up to 3 percentage points. With 6 percentage points the impact is particularly large for black females. This is consistent with anecdotal evidence that (black) females had a comparative advantage in cotton cultivation (Metzer, 1975; Goldin and Sokoloff, 1984). Indeed, when regressing the share of females employed in a household on the cotton share of US counties in 1880 we find a significant positive coefficient on the latter variable. This result also holds if we instrument the cotton share with geographic cotton suitability.

Two-stage least squares estimation that uses boll weevil incidence interacted with the initial cotton share as an instrument yields a significant positive effect of output per worker on labor force participation: a one percent increase in output per worker increased the labor force participation rate by 0.2 percentage points.³ For females the effect goes up to 0.4 percentage points; for black females it is 0.8 percentage points. These estimates are significantly larger than those produced by least squares regressions. An explanation for the larger two-stage least squares estimates is a reverse causal effect that downward biases the least squares estimates. While the difference is small for men, it is very large for women implying that the least squares estimates are subject to a strong reverse causality bias. The negative reverse causal effect arises in the least squares regressions because increases in labor supply decrease output per worker as well as wages (under the standard assumption of decreasing returns to scale in labor).

In terms of other labor related adjustment mechanisms, we find that there are significant effects on immigration, emigration, as well as on non-market labor. Decreases in output per worker due to the boll weevil lead to significant decreases in immigration, significant increases in emigration, and significant increases in the share of housekeepers.

Our work relates to research following Lindsey (1987) that relies on natural experiments – mostly changes in tax law – to identify the labor supply curve (e.g. Pencavel 1986; Blundell and Macurdy 1999; Keane 2011).⁴ In that literature there exists considerable uncertainty and disagreement about the elasticity of labor supply. While there is a consensus that females have a more elastic labor supply than men, existing studies come up with a wide range of elasticities (e.g. Killingsworth and Heckman 1986; Blundell and Macurdy 1999; Keane 2011). For example, the extensive margin (Hicksian) wage elasticities for married

³The size of the estimate is in line with the point estimates of extensive margin steady-state (Hicksian) labor supply elasticities from macro and micro studies (see Chetty et al., 2013, Table 2)

⁴For the US, for example, a significant number of studies have exploited several tax changes in the 1980s, in particular the US 1986 Tax Reform Act (TRA) and the expansion of the earned income tax credit (EITC) for identification (e.g. Eissa 1995; Feldstein 1995; Eissa and Liebman 1996; Meyer and Rosenbaum 2001; Meyer 2002).

women from cross-city studies range between 0.26 and 2.03 (see Goldin, 1990, Table 5.2) while Chetty et al. (2013, Table 1) report extensive margin (Hicksian) wage elasticities from quasi-experimental studies that range between 0.17 and 0.43 for women. When using natural experiments for estimating the labor supply curve, a main problem is the definition of a valid control group. A popular approach in the literature is to exploit that certain tax changes could differentially affect tax rates of low- and high-wage earners (e.g. Eissa, 1995; Feldstein, 1995; Gruber and Saez, 2002). This approach has its limitations, however, since it is only valid if individuals located at different percentiles at the income distribution are identical except for changes in their tax rates. It has been shown that this assumption is unlikely to hold (e.g. Goolsbee, 2002; Liebman and Saez, 2006).⁵

Our paper complements this literature by relying on geographic- and time-variation in labor productivity instead of tax law changes for identification. The advantage of our approach is that we have a clearly identified control group with characteristics that are observationally equivalent to the treatment group. Using falsification tests and tests of over-identifying restrictions we argue that our estimates reflect causal effects.

A large strand of literature has documented the rise in female labor force participation that took place in advanced economies since the late 19th century (e.g., Killingsworth and Heckman, 1986; Costa, 2000). Recent research claims that changes in social attitudes towards working women have been essential for this development (e.g., Goldin, 2006; Fernández and Fogli, 2009; Fernández, 2013). For example, Goldin (1990; 2006) argues that labor force participation of married white women in the US was low until about 1940 because there was a social "stigma" attached to wives working in paid labor. After 1940, labor force participation of white women rose quickly since more attractive jobs became available due to the rise of the clerical sector and the social "stigma" was reduced. Empirically, this argument is based on cross-city estimates that find that the labor supply curve for white married women between 1890 and 1930 is inelastic (e.g., Rotella, 1980; Goldin, 1990). Changes in female labor force participation of white married women in the US at the beginning of the 20th century are therefore very likely not driven by labor demand changes.

Black women, in contrast, holding mainly jobs in the agricultural and (non) household service sector, had a much higher labor participation rate than white women throughout American history (Goldin, 1990; Boustan and Collins, 2013). Goldin (1977; 1990) associates the higher labor force participation rates of black women with social norms deeply rooted in slavery. The black community developed a less hostile attitude towards women working in paid labor as black women were forced to work on the plantation fields under slavery. Goldin (1990) argues that compared to white women, black women were less socially stigmatized in the labor force as an indirect consequence of slavery. The greater sensitivity of black female

⁵Similar identification concerns arise for studies that exploit that the expansion of the EITC affects single women with and without children differently (Eissa and Liebman, 1996; Meyer and Rosenbaum, 2001; Meyer, 2002).

labor force participation to unfavorable economic conditions during the Great Depression of the 1930s indicates also a more elastic labor supply curve of black women (Goldin, 1990; Sundstrom, 2001). Our estimates imply a large elasticity for black women but a small (and often statistically insignificant) elasticity for white women, and are thus in line with the view of the existing literature.

Our paper also contributes to the literature on the boll weevil’s role for Southern US economic development. Recent studies find that the boll weevil fundamentally affected local economic development within the American South (Lange et al., 2009; Baker, 2013).⁶ In contrast to earlier studies that mainly relied on state-level data, Lange et al. (2009) exploit county-level variation within the US South to assess the boll weevil’s impact on local economies. These authors find that the boll weevil caused a persistent decline in cotton production, yields and acreage, reduced land values and triggered internal migration. Baker (2013) shows, using county-level data for the state of Georgia during 1914-1929, that black school enrollment rates increased in response to the reduction in cotton production caused by the boll weevil. Our study differs from Lange et al. (2009) and Baker (2013) in three key dimensions: (i) we examine how the boll weevil affected the Southern labor market thereby looking at a different outcome variable (labor force participation); (ii) we use a larger sample (all infested counties of the Cotton Belt for the years 1880-1940; linked individual Census data for migration); and (iii) our instrument – the interaction between boll weevil incidence and the initial cotton share – accounts, in the spirit of an intensity-to-treat effect, for the heterogenous effect the boll weevil had on output per worker.

2 The Organization of Cotton Production and the Spread of the Boll Weevil

2.1 The Organization of Cotton Production

Cotton production was a labor-intensive process in the postbellum American South where land was abundant and labor supply the limiting factor (Ransom and Sutch, 2001, p.47). The Southern rural labor markets were thin and labor demand very seasonal (Whatley, 1987). On cotton plantations, significant amounts of labor were needed for plowing, planting and cultivating (spring to mid-summer); thinning and weeding (May into July); and harvesting (late summer to early winter).⁷ For example, across the Cotton South, a single

⁶The earlier cliometrics literature has contrasting views to what extent the boll weevil affected the Southern economy (Street, 1955; Higgs, 1976; Osband, 1985; Wright, 1986; Ransom and Sutch, 2001). We refer to Lange et al. (2009), who summarize the findings of these studies, for further details.

⁷Hong (2001, pp. 9-11), for example, describes the seasonal variation in labor demand for cotton cultivation of the Pre Aux Plantation in Natchitoches Parish, Louisiana, 1852-1854. On the Pre Aux Plantation labor demand had its peak during the harvest season in fall to early winter and was also high in May and June for plowing, scraping, and hoeing. Cotton picking, the most labor intensive task, began in mid-August

acre of cotton required more than 150 hours of labor in 1930 (Aiken, 1998, pp. 97-100). It was until the start of mechanized cotton harvesting during the mid 1940s that barely any capital was used in cotton production (Musoke, 1981; Cogan, 1982; Wright, 1986; Heinicke, 1994).

While slave labor cultivated most of the cotton on large plantations before the Civil War, the labor relations between landlords and laborers in the American South changed with the abolition of slavery in 1865 (Alston and Higgs, 1982; Shlomowitz, 1979; Ransom and Sutch, 2001). Fixed wages, share-rent and fixed-rent contracts became the principal contractual forms for cotton farmers in the South after the Civil War (Alston, 1990). Family based sharecropping arrangements were common by the late 1870s and frequently used between landlords and black farm operators (Reid, 1973; Shlomowitz, 1979; Alston, 1990). Sharecropping involved the whole family in cotton cultivation, especially during the planting and harvesting season when labor demand was high (Jones, 1985, p. 58-68, pp. 81-95). Aiken (1998, p. 100) mentions, for instance, that "... all members of a black tenant household, ... were part of the production system" suggesting that women and children played a significant role in cotton cultivation.

In particular, Goldin and Sokoloff (1984) pointed out that females and children had a comparative advantage in crops that required extensive cultivation, such as cotton and tobacco. For the American South, historical accounts suggest that women had a relative comparative advantage in cotton picking, the most labor-intensive task in cotton cultivation (Metzer, 1975; Shlomowitz, 1979; Jones, 1985).⁸ Despite this comparative advantage, it were mainly black women working on the Southern cotton fields after the Civil War. Jones (1985, p. 64) and Ransom and Sutch (2001, p. 325) illustrate that it were black rather than white women that participated in the labor force in the Cotton South in 1870 and 1880. Throughout the 19th century and until recently black female labor force participation exceeded their white counterpart in the US (Goldin, 1990; Boustan and Collins, 2013). In 1870 the participation rate of black women was about 4 times higher than for white women; in 1930 it was more than 2 times that for white women (Boustan and Collins, 2013). For married women the racial gap in participation rates in the late 19th and early 20th century was even more pronounced (Goldin, 1990).

One explanation for the historical racial gap in female labor force participation is that black families relied on the women's income since they were significantly poorer than white

and ended in mid-January. The seasonal variation in labor demand for cotton cultivation in the American South turned out to be very persistent as Jones (1985, p.87) mentioned, for example, that the techniques used for cotton picking and planting remained the same before and after the Civil War.

⁸For example, Metzer (1975, p.139) points out: "The male field hands position was predominant in raising other crops and in other, more strenuous, activities that coincided with picking" and concludes that "planters ... were guided by the comparative advantage of productive resources such as that of female over male slaves in cotton picking." Shlomowitz (1979, p.568) writes that "on the plantation of J. Jenkins Mikell on Edisto Island for 1867, "women [were] to be reckoned as 3/4 hands until harvest when they will be counted as full hands." Jones (1985, p.87) writes: "Cotton picking was still [in the postbellum South] such a labor-intensive task, few tenant-farm wives could escape its rigors."

families. Several studies have however shown that differences in observable individual and family characteristics, such as education, number of children or family income, cannot account for differences in participation rates of black and white women (for a summary of the studies see Goldin, 1977). A recent study by Boustan and Collins (2013), using individual US census data from 1880 to 2000, confirms this finding as observables do not account for a significant amount of the racial gap in women's labor force participation, at least until 1940. Goldin (1977; 1990) attributes this gap to persistent cultural differences in attitudes towards working women that have their roots in slavery. After the Civil War black women were more likely to participate in the labor force: (i) as a direct consequence of slavery because black households were poorer than white households; (ii) indirectly, as black women were less stigmatized than white women for pursuing paid labor due to social norms developed in the black community under slavery.

2.2 The Spread of the Boll Weevil

De cotton come up and started to growin', and, suh, befo' de middle of May I looks down one day and sees de boll weevil settin' up dere in de top of dem little cotton stalks waitin' for de squares to fo'm. So all dat gewano us hauled and put down in 1922 made nuttin' but a crop of boll weevils. And de very same thing happen agin de nex' year (American Life Histories, 1939).

Manifested in historical accounts, songs and family tales, the boll weevil (*Anthonomus grandis*), an approximately one-fourth long beetle with a very long snout, is considered as the most well known agricultural pest in the American South (Lange et al., 2009; Giesen, 2004, 2011). Arriving near Brownsville, Texas, from Mexico in 1892, the boll weevil started to impair Southern's main economic engine: cotton production (Hunter and Coad, 1923; Ransom and Sutch, 2001). Depending on prevailing wind and weather conditions the boll weevil could cover from 40 to 160 miles a year (Hunter and Coad, 1923) such that thirty years after its arrival the whole Cotton Belt was almost completely infested (see Figure 1).

The boll weevil's life revolves around the cotton plant which is its main source of food and host of reproduction. A female boll weevil deposits her eggs – 100 to 300 per generation – into the growing squares or bolls of the cotton plant during the growing season resulting in a rapid infestation of the surrounding cotton fields.⁹ While very hot, dry summer months impede the infestations of cotton fields and mortality increases during cold winters lead mild, wet summers and frost free winters to massive reproduction and heavy infestation (Hunter and Coad, 1923; Fenton and Dunnam, 1929; Lange et al., 2009). As Lange et al. (2009, p.689) have pointed out "farmers and local authorities could do little to prevent the

⁹Over a quarter-million of offspring during one growing season can be accounted to a single pair of boll weevils (Giesen, 2004, pp.20-22).

boll weevil from entering their territory, implying that the timing of arrival was largely exogenous."¹⁰

Historical accounts document that the boll weevil was a large negative shock to cotton production; the dominant cash crop in the postbellum South (Alston, 1990).¹¹ With its tremendous rate of reproduction, and since the boll weevil feeds almost exclusively on cotton, the arrival of the boll weevil led to large declines in cotton yields and cotton acreage in the American South (Ransom and Sutch, 2001).¹² During 1909-1935 the average reduction from full yield in the US South was 10.9 percent, ranging from 0.8 percent in Missouri to 17.8 percent in Louisiana (Hyslop, Table 1, 1938). The estimated loss from full yield per acre of cotton reached its peak with 31 percent in 1921 (USDA, Table 52, 1951). The United States Department of Agriculture (USDA) estimated the average annual loss due to boll weevil infestation for the four years preceding 1920 about 200-300 million US Dollars (Hunter and Coad, 1923). These estimates indicate that the boll weevil adversely affected cotton production and hence the demand for labor.

This paper focuses on the Cotton Belt counties of the American South that were infested by the boll weevil during the late 19th and early 20th century (Hunter and Coad, 1923). As the boll weevil adversely affected cotton production and with it its most labor intensive task, cotton picking, our objective in the following sections is to empirically investigate how female labor force participation in general but especially of black women responded to the arrival of the boll weevil in the US South.

3 Data and Estimation Strategy

3.1 Data

This section discusses the data used to assess the impact that the boll weevil had on output per worker and on labor force participation. We use US Census data during the period 1880-1940 to construct measures of output per worker and labor force participation. County-level output data are retrieved from the Inter-University Consortium for Political and Social

¹⁰We refer to Hunter and Coad (1923), Lange et al. (2009) and Giesen (2004, 2011) for further information about the boll weevil and its spread through the American South.

¹¹The Southern economy relied heavily on cotton (Ransom and Sutch, 2001, pp.188-193), especially after the Civil War when production increased from 6.6 million bales in 1880 to 11.6 million bales in 1910 compared to 3.8 million bales before the Civil War in 1860 (US Bureau of Census, 1975, pp. 517-18). Ransom and Sutch (2001, p. 318-319) show that 75 percent of Southern farms planted in 1880 some acreage in cotton, over 90% did so in the Cotton South indicating the high degree of specialization in cotton production of Southern farmers during the postbellum period.

¹²Ransom and Sutch (2001, Table 9.2, p.175) compare cotton acreage and yield before and after boll weevil infestation for the cotton states Louisiana, Mississippi, Alabama, Georgia and South Carolina during 1889-1924. Their estimates reveal a decline of cotton acreage by 27.4 percent and cotton yield by 31.3 percent in the four years after complete boll weevil infestation.

Research (ICPSR) 2896 file (Haines, 2010).¹³ Measures of the labor force come from the Integrated Public Use Microdata Series (IPUMS-USA) database (Ruggles et al., 2010) and are aggregated at the county level.

Output per worker is calculated as the sum of value added per worker in the manufacturing and agricultural sector. Value added in manufacturing is calculated as manufacturing output minus the cost of materials.¹⁴ For the agricultural sector value added is calculated as agricultural output minus the expenditure for fertilizer (available 1880-1940) and feed (available 1910-1940). We consider individuals as agricultural or manufacturing workers when they reported in the Census a gainful occupation in one of those sectors (see the data appendix for more details).

The labor force participation rate is defined as the number of working-age individuals in the civilian labor force (age 16 to 65), divided by the total working-age population. The labor force participation rates for males and females (white and black) are defined accordingly. The 1910 Census over-counted female workers (unpaid female farm laborers) in the agricultural sector, see Goldin (1986, pp. 574-75). We correct for this overstatement by excluding the number of unpaid female farm labors from the female labor force participation rate in 1910.¹⁵ We further omitted the year 1890 from the analysis since the completed census forms were lost in a fire and thus individual data are unavailable for this census year (see Blake, 1996).

County-level data on the arrival of the boll weevil are based on the USDA boll weevil map reported in Hunter and Coad (1923, p.3).¹⁶ This map provides detailed information when the boll weevil infested a county for the first time and when it completely passed through (see Figure 1). County-level data on cotton acreage are from Haines (2010). We match the year of the boll weevil's arrival in a county with the decennial county-level data on output per capita, the labor force participation rate and cotton production.

A detailed description of all variables used in the empirical analysis is available in the data appendix. Descriptive statistics of the main variables of interest are shown in Table 1. The sample spans a total of 903 counties which have been infested during the period 1880-1940. We refer to those as the "Cotton Belt" counties. The panel is decadal and unbalanced; as a robustness check we will present in the supplementary online appendix estimates based on a balanced panel covering 754 counties during 1880-1940.

¹³We thank Michael Haines for sharing his county-level database from the United States Censuses of Agriculture in 1930 and 1940.

¹⁴We had to impute the manufacturing data for the year 1910 because no production data were reported in the 1910 Census at the county level.

¹⁵Our main findings are not affected when excluding the year 1910, see the supplementary online appendix for further details.

¹⁶We thank Fabian Lange, Alan Olmstead and Paul Rhode for sharing their boll weevil data.

3.2 Estimation Strategy

In order to estimate the effect of a change in labor income on labor supply we use a two-stage least squares estimation framework. The second-stage equation is:

$$LFP_{ct} = \alpha_c + \beta_{st} + \gamma \ln(\text{Output } pw_{ct}) + \lambda \text{BollWeevil}_{ct} + \epsilon_{ct} \quad (1)$$

where α_c are county fixed effects; β_{st} are state-by-time fixed effects; LFP_{ct} is the labor force participation rate in county c and period t ; and $\ln(\text{Output } pw_{ct})$ is the natural logarithm of output per worker in county c and period t . BollWeevil_{ct} is an indicator variable that is unity in county c and period t if a county is infested by the boll weevil and zero otherwise. The county fixed effects capture time-invariant factors that affect both output per worker and the labor force participation rate; for example, variables related to counties' geographic characteristics, such as rugged terrain, access to a river, longitude and latitude. The state-by-time fixed effects capture time-varying factors at the state level; for example, state-wide economic policy changes, such as changes in the tax rate, compulsory schooling laws and Southern states' specific variations in labor market regulation such as vagrancy, child labor and anti-enticement laws. We compute standard errors that are Huber robust and clustered at the county level. This type of clustering allows the residuals to be arbitrarily serially correlated within counties.

We use data on output per worker rather than wages since many (black) farmers were self-employed, working as owners, sharecroppers or tenants in the Cotton Belt after the Civil War (Reid, 1973; Shlomowitz, 1984; Ransom and Sutch, 2001).¹⁷ We note that output per worker is a good proxy for the wage if: (i) there is perfect competition in the labor market; (ii) movements in labor occur at the extensive margin.¹⁸ If both of these conditions are fulfilled, then it holds that $\ln(\text{Output } pw_{ct}) = \ln(\theta) + \ln(w_{ct})$, where $\ln(\theta)$ is the elasticity response of output to a percentage change in labor. In equation (1) $\ln(\theta)$ is absorbed by α_c , hence if conditions (i) and (ii) are satisfied, estimating equation (1) with $\ln(\text{Output } pw_{ct})$ is equivalent to using $\ln(w_{ct})$. We refer to the technical appendix for further details on labor supply curve identification.

The excluded instrument in the two-stage least squares regression (TSLS) is the interaction between the incidence of the boll weevil and the initial (beginning of period) intensity of cotton production. The first stage equation is:

$$\ln(\text{Output } pw_{ct}) = a_c + b_{st} + \delta \text{BollWeevil}_{ct} + \eta \text{BollWeevil}_{ct} \times \text{Cotton}_{c,1880} + u_{ct} \quad (2)$$

where $\text{BollWeevil}_{ct} \times \text{Cotton}_{c,1880}$ is the interaction between the incidence of the boll weevil

¹⁷Note, that for the 1880-1940 period systematic county-level data on hours worked are not available.

¹⁸The Southern agricultural labor market at the early 20th century is regarded as competitive; see Alston and Kauffman (1997), for example.

and county c 's (demeaned) acreage share of cotton planted in 1880. We use the 1880 value, and not time-series variation in the acreage share of cotton planted, in order to ensure that the interaction term is exogenous to changes in output per worker during the 1880-1940 period. The direct effect of cotton production in 1880 on output per worker is captured by the county fixed effects, a_c ; hence there is no need to include $Cotton_{c,1880}$ in the model.

The reduced form equation is:

$$\ln(LFP_{ct}) = c_c + d_{st} + \pi BollWeevil_{ct} + \sigma BollWeevil_{ct} \times Cotton_{c,1880} + e_{ct} \quad (3)$$

Compared to a standard differences-in-differences approach our estimation strategy follows the literature that uses a continuous measure of the intensity of treatment (see e.g. Bleakley, 2007; Nunn and Qian, 2011; Hornbeck and Naidu, 2014). In the first stage, η , captures the differential effect of boll weevil incidence on output per worker that arises from cross-county variation in the importance of cotton production. Ex-ante, η is expected to be negative. That is, in counties where cotton production is relatively more important the impact of boll weevil incidence on output per worker is more detrimental. In the reduced form, σ , captures the differential effect of boll weevil incidence on labor force participation that arises from cross-county variation in the importance of cotton production. The second-stage coefficient is $\gamma^{TSL} = \frac{\sigma^{LS}}{\eta^{LS}}$. The exclusion restriction in the instrumental variables estimation is that differences in the impact of boll weevil incidence, that arise from cross-county variation in the (initial) importance of cotton production, only affect the labor force due to their effect on output per worker. We will discuss and examine this exclusion restriction in detail in Section 4.2.

It is important to note that the boll weevil indicator variable captures the incidence of the plague only. The spread of the boll weevil was determined by time-varying weather conditions, such as wind, temperature and precipitation (see e.g. Lange et al., 2009). It therefore seems plausible to treat the incidence of the boll weevil as an exogenous variable. On the other hand, the actual damage inflicted by the boll weevil is endogenous to counties' economic conditions. For example, one may expect that periods of high output per worker growth are associated with increased cotton production; when the boll weevil hit the damage inflicted is relatively higher in counties experiencing higher output per capita growth (for reasons other than the boll weevil). In order to avoid this endogeneity issue, we use the incidence of the boll weevil.

4 Results

4.1 Baseline IV Estimates

Table 2 presents the reduced form impact that the boll weevil had on the labor force participation rate. The control variables are county fixed effects and state-by-time fixed effects; both fixed effects are jointly significant at the 1 percent level. The main finding is that the boll weevil had a particularly negative effect on the labor force participation rate in counties with a higher initial cotton share. This can be seen in column (1) from the significant negative coefficient on the interaction between boll weevil incidence and the 1880 cotton share. In columns (2) and (3) we see that the effect on male labor force participation is insignificant while the effect on female labor force participation is negative and highly significant. This is as expected since, as we document below, it were women that had a comparative advantage in picking cotton. In columns (5) and (6) we examine the impact of the boll weevil on white and black female labor force participation. From anecdotal evidence, we know that in the Cotton Belt it were predominantly black females that worked on the cotton fields (Ransom and Sutch, 2001). It is therefore not surprising that the coefficient on the interaction between boll weevil incidence and the 1880 cotton share is negative and highly significant for black females but quantitatively small and statistically insignificant for white females.

Table 3 documents that counties with greater cotton production had a relatively larger share of female workers. In columns (1)-(3) we regress the share of female workers on the log of cotton acres planted; in columns (4)-(6) we change the explanatory variable for the share of cotton acres in the total acres of main field crops planted. Least squares regressions (see columns (1), (2), (4), and (5)) show that the share of female workers is significantly positively related to cotton production. In columns (3) and (6) we address causality by instrumenting cotton production with the geographic suitability for cotton.¹⁹ Cotton suitability has a highly significant positive first-stage effect on cotton planted and the cotton share; the first-stage F-statistic is well in excess of 17 (10) so that, according to Stock and Yogo (2005), we can reject the hypothesis that the size distortion is larger than 10 (15) percent at the 5 percent significance level. The instrumental variables regressions show that greater cotton production leads to more women employed. This is consistent with the view that women had a comparative advantage in cotton production: when potential output of cotton is (relatively) higher, due to greater cotton suitability, there is an increase in the (relative) demand for labor; labor will be hired at lowest cost; and it are women that can pick cotton at (relatively) lower costs.²⁰

¹⁹Data on cotton suitability come from FAO (2012). FAO (2012) calculates cotton suitability as the maximum potential yield of cotton based on climate, soil type and ideal growing conditions for cotton; for more information see e.g. Hornbeck and Naidu (2014, footnote 22, p. 975). The county-level data are retrieved from the replication files of Hornbeck and Naidu (2014).

²⁰Metzer (1975) and Goldin and Sokoloff (1984) highlight the comparative advantage of females picking cotton in the US South during the antebellum period.

Table 4 presents instrumental variables estimates of the impact that the boll weevil had on the labor force participation rate through its impact on output per worker. In column (1) the dependent variable is the labor force participation rate of all working-age people living in a county. The estimated coefficient (standard error) on output per worker is 0.21 (0.05). Quantitatively, this coefficient implies that on average a one percent decrease in output per worker decreased the labor force participation rate by 0.2 percentage points. This effect is significant at the 1 percent level. Columns (2) and (3) show that there is a significant difference in the response of male and female labor force participation. The second-stage coefficient on output per worker is 0.02 (0.02) for male labor force participation, and 0.41 (0.10) for female labor force participation. The significant difference in the response of male and female labor force participation is expected since the boll weevil had an impact on cotton production and women had in this sector a comparative advantage. Moreover, from anecdotal evidence we know that it were primarily black women that worked on cotton fields in the Cotton Belt (see e.g. Sharpless, 1999; Ransom and Sutch, 2001). Columns (4) and (5) show that, consistent with this anecdotal evidence, it is the labor force participation rate of black females that responds significantly to the output shock; the labor force response of white females is insignificant.

The first-stage effect of the interaction between the boll weevil and the 1880 cotton share is negative and highly significant. We show this in Panel B of Table 4. The linear term on boll weevil incidence is insignificant; hence we only use the interaction term as an excluded instrument in the two-stage least squares regressions. The F-statistic on the excluded instrument is well in excess of 17 (10). According to Stock and Yogo (2005) we can reject the hypothesis that the size distortion in the TSLS regression is larger than 10 (15) percent at the 5 percent significance level. We note that the coefficient on boll weevil incidence is insignificant in the reduced form, the first stage, and the second stage (see Tables 2 and 4, respectively). In Appendix Table 1, we document that the second-stage coefficients on output per worker are similar to the second-stage coefficients in Table 4 if we do not include boll weevil incidence in the econometric model (the excluded instrument in the TSLS regressions continues to be the interaction between boll weevil incidence and the 1880 cotton share).

Table 5 presents least squares estimates of the relationship between output per worker and the labor force participation rate. Similar to the instrumental variables estimates, the least squares estimates are positive and significant for the labor force participation rate of all workers. They also provide a significant positive coefficient on output per worker for female labor force participation. Quantitatively, the least squares estimates are smaller than the instrumental variables estimates. The direction of bias is as expected since, with decreasing returns to labor, an increase in labor force participation leads to lower output per worker.²¹

²¹Statistically we can reject that the LS coefficient on output per worker is equal to the TSLS coefficient at the 1 percent level, for total labor force participation as well as for female labor force participation.

We have carried out a number of robustness checks on the baseline TSLS estimates. Appendix Table 2 shows that results are qualitatively similar if instead of the labor force participation rate the dependent variable is the log of the labor force. The findings in Table 4 are also robust to excluding outliers (Appendix Table 3); using a balanced panel (Appendix Table 4); replacing the 1880 cotton share with cotton suitability (Appendix Table 5); using as explanatory variable either expenditures for farm labor per agricultural worker (Appendix Table 6) or cotton yield (Appendix Table 7) instead of output per worker; and excluding the year 1910 from the regression (Appendix Table 8).

4.2 Discussion of Instrument Validity

The exclusion restriction underlying the instrumental variables estimates is that the boll weevil only affects labor force participation through its effect on output per worker. This exclusion restriction seems plausible from an economic point of view: the boll weevil, being an agricultural pest, lowered productivity, which, in turn reduced the marginal product of labor in cotton production and hence the demand for labor in that sector. In the next tables we will examine whether there is any evidence that our instrument, the interaction between the boll weevil and the beginning of sample cotton share, is invalid.

The survival probability of the boll weevil is strongly affected by weather conditions. Experiments conducted at the University of Missouri (Sorenson, 1995) showed that the boll weevil starts to die when temperature falls below 23 degrees Fahrenheit. At 5 degrees Fahrenheit most weevils don't survive longer than an hour. Hence, low temperatures in an infested county during winter are detrimental for boll weevil survival and should therefore ameliorate the negative effect of boll weevil incidence on cotton production in the following season. Here, we exploit this channel as an additional source for identification. Using county-level climate data from Fishback et al. (2011), we construct a variable that captures the share of winter days (1st of November - 28th of February) where temperature did not fall below 10 degrees Fahrenheit in a given county. Assuming that weather conditions remained relatively stable over time from 1880 to 1940, this variable should be a good proxy of having days with relatively "mild" temperatures during the winter months in a given county.

Panel B of Table 6 reports the first-stage regression where we use the interaction between the winter temperature proxy and boll weevil incidence as additional instrument for output per worker. This interaction term has a highly significant effect on output per worker. With an additional instrument in hand the two-stage least squares regression is overidentified and we can compute overidentification tests. From Panel A of Table 6 we see that the second-stage coefficient on output per worker is positive and significant for labor force participation when both interaction terms are used as excluded instruments (i.e. the interaction between boll weevil incidence and the 1880 cotton share, and the interaction between boll weevil incidence and the temperature proxy). We find that a 1% increase in output per worker

increases female labor force participation by 0.2 percentage points. As in Table 4, we see that the effect comes primarily from black female labor force participation.

The p-values from the Hansen J test that the instruments are correlated with the second-stage error term are well above 0.1. Hence, there is no evidence that the instruments are invalid. In terms of instrument relevance we note that both instruments are strong: they are individually statistically significant at the 1 percent level. The joint F-statistic is in excess of 12 so that, according to Stock and Yogo (2005), we can reject that the IV size distortion is larger than 15 percent at the 5 percent significance level. It is therefore not the case that the Hansen J test is underpowered due to the presence of weak instruments.

Another way to examine whether our instrument has a direct effect on labor force participation beyond output per worker is to estimate the reduced form in a sample where the boll weevil has no significant first-stage effect. If the boll weevil affects labor force participation beyond output per worker, then, in the sample where the boll weevil has no significant effect on output per worker, it should have a significant effect on labor force participation. In this vein, we present in Panel A of Table 7 first stage and reduced form estimates for a sample split at the 20th percentile of the 1880 cotton share. In the sample of counties in the bottom 20th percentile of the 1880 cotton share, there is an insignificant effect on output per worker (columns (1), (3) and (5)) and an insignificant effect on labor force participation (columns (2), (4) and (6)). On the other hand, in the sample of counties that are in the 80th percentile of the 1880 cotton share, see Panel B of Table 7, the effect of the boll weevil interacted with the 1880 cotton share on output per worker and labor force participation is negative and highly significant. Quantitatively, the estimated effects are also larger (in absolute size) in Panel B than in Panel A.

In Figure 2 we plot the coefficients and their 95 percent confidence bands of the lead, impact, and lagged effects of the interaction between boll weevil incidence and the 1880 cotton share on labor force participation. We obtain these coefficients by augmenting equation (3) with three leads and lags of the boll weevil incidence and its interaction with the 1880 cotton share. We find that the lead effects are all insignificant. The impact (period t) effect of the interaction term remains negative and is quantitatively larger (in absolute size) than the lagged effects, which are also negative and significant.

Our argument for using the interaction between the 1880 share of cotton and the boll weevil as an instrument for output per worker is that the impact of the agricultural pest on output per worker should be more detrimental where the potential damage is larger. As the boll weevil fed almost exclusively on cotton, the pest only affected cotton production, and its detrimental effect should be particularly large where cotton production was particularly large before the arrival of the boll weevil. As a placebo test, we report in Table 8 first stage and reduced form estimates where we include in the model an interaction term between boll weevil incidence and the 1880 share of corn. This interaction term has neither a significant

effect on output per worker, see column (1); nor does it have a significant effect on the labor force participation rate, see column (2). On the other hand, the interaction between boll weevil incidence and the 1880 cotton share continues to have a highly significant negative effect on both output per worker and the labor force participation rate.

4.3 Further Results

4.3.1 Response of Female Labor Force by Marital Status and Race

Disaggregating the female labor force participation rate by marital status and race, we find that the participation rate of black married women is more responsive to changes in output per worker than that of white married women. This result can be seen by looking at columns (1) and (2) of Table 9, Panel A. The second-stage coefficient (standard error) on output per worker when the dependent variable is the labor force participation rate of married white women is $-.04$ (0.04); for married black women it is 0.72 (0.18). The p-value from a test that the coefficient on output per worker is the same for married black and white women is 0.00. Our finding of a large labor supply elasticity of black married women and a small insignificant elasticity for white married women is in line with Goldin's (1977; 1990) social "stigma" argument. We find a similar pattern for single black and white women. These results can be seen by looking at columns (3) and (4). The second-stage coefficient on output per worker is positive and highly statistically significant for single black women while it is insignificant for single white women.

4.3.2 Response of Female Labor Force by Age

In Panel B of Table 9 we report the female labor force participation rate by age. We find that the participation rate of younger women is more responsive than that of older women. In column (1) the dependent variable is the female labor force participation rate of ages 16-25; column (2) ages 26-35; column (3) ages 36-45; column (4) ages 46-55; and column (5) ages 55-65. For all age groups the coefficients on output per worker are positive and significant; and they are descending in magnitude as age increases. For example, for female labor force participation ages 16-25 the second-stage coefficient (standard error) on output per worker is 0.61 (0.13); for female labor force participation ages 55-65 the coefficient (standard error) is 0.19 (0.08). The p-value from a test that the coefficient on output per worker is the same for female labor force participation ages 16-25 and ages 55-65 is 0.01.

4.3.3 Effects on Employment

Table 10 documents that output per worker had a significant positive effect on employment and the employment rate. In line with our findings on labor force participation, the effect of output per worker on employment is significant for (black) females but not for males.

Quantitatively the estimated effects are sizable. For example, the coefficient in column (5) of Panel A (B) in Table 10 suggests that employment (the employment rate) of black females increased by nearly 3 percent (0.8 percentage points) for a 1 percent increase in output per worker.

4.3.4 Effects on Immigration and Emigration

Table 11 examines the impact that the boll weevil had on immigration and emigration. We use micro data on individuals' immigration and emigration from the IPUMS. The IPUMS released a set of linked representative samples for the years 1850-1930. The database contains individual records of the 1880 complete-count data base that are linked to the 1% samples of the 1850 to 1930 US censuses of the population (Ruggles et al., 2010). We pool the linked samples of 1880-1900, 1880-1910, 1880-1920 and 1880-1930 to maximize coverage. The data allow us to investigate whether individuals were more likely to move out or into boll weevil infested counties. The estimation equation is:

$$\Delta y_i = \alpha + \beta \Delta \text{BollWeevil}_c + \gamma \Delta (\text{BollWeevil}_c \times \text{Cotton}_c) + \Delta \epsilon_i \quad (4)$$

where Δy_i is an indicator variable that is unity if individual i migrated out of (emigration) or into (immigration) a boll weevil infested county c between 1880 and the time period observed in the linked sample (i.e. 1900, 1910, 1920 or 1930). Note, that Δ denotes the change between 1880 and the year for which data exist for individual i in the linked sample. The variable of interest, $\Delta (\text{BollWeevil}_{c,t-1880} \times \text{Cotton}_{c,1880})$, is the interaction between the incidence of the boll weevil, $\text{BollWeevil}_{c,t-1880}$, and county c 's acreage share of cotton planted in 1880, $\text{Cotton}_{c,1880}$. Because we estimate equation (4) in first differences county (and individual) fixed effect are netted out.²²

Table 11, Panel A shows that the boll weevil was more likely to increase the likelihood of emigration in counties with a relatively high cotton share. This can be seen from the positive coefficients that emerge in the linear probability model (see columns (1) and (2)) and the non-linear probability (probit) model (see columns (3) and (4)). The estimated marginal effects are significantly different from zero at the 1 percent level. Quantitatively, they imply that the incidence of the boll weevil increased the probability of emigration by around 3 percentage points for each 10 percentage points increase in the 1880 share of cotton.

Panel B of Table 11 shows that the incidence of the boll weevil was more likely to decrease the likelihood of immigration into counties with a relatively high cotton share. This can be seen from the negative coefficients that emerge in the linear probability model (see columns (1) and (2)) and the non-linear probability (probit) model (see columns (3) and (4)). The estimated marginal effects are significantly different from zero at the 5 percent level.

²²We also add to estimation equation (4) an indicator variable for each linked sample (1880-1900, 1880-1910, 1880-1920 and 1880-1930).

Quantitatively, they imply that the incidence of the boll weevil decreased the probability of immigration by around 1 percentage point for each 10 percentage points increase in the 1880 share of cotton.

4.3.5 Effects on Non-market Labor

Columns (1) and (2) of Table 12 show that the incidence of the boll weevil had a significantly larger effect on the share of women staying at home (i.e. housekeeping/home production) in counties with an initially higher cotton share. This suggests that, in counties where the incidence of the boll weevil had more severe economic impacts there was a larger share of (black) females (that lost their job in cotton production) staying at home. Indeed, two-stage least squares estimation shows that the impact through output per worker on the share of (black) housekeepers living in a county is negative: a one percent increase in output per worker reduced the share of housekeepers by around 0.37 percentage points. This effect is significantly different from zero at the 1 percent level.

5 Conclusion

Estimating the response of labor supply to changes in labor income is complicated by the endogeneity of the latter variable. In this paper we used plausibly exogenous variation in the incidence of an agricultural pest, the boll weevil, to generate variation in labor income for a panel of 903 US Southern counties during the period 1880-1940. Our first stage regression exploited that the negative impact of the boll weevil on output per worker was more severe in counties with a higher initial cotton share (an intensity to treat effect). Using the interaction between boll weevil incidence and the initial cotton share as an excluded instrument, we find a significant positive effect of output per worker on labor force participation. The effect is particularly large and significant for female labor force participation, consistent with evidence that females had a comparative advantage in cotton cultivation. We also documented that in response to the agricultural pest there was a significant decrease in immigration, a significant increase in emigration, and a significant increase in non-market labor.

Technical Appendix

Note on Labor Supply Curve Identification

Labor demand: Suppose the labor market is competitive; there is an infinitely large number of farms where workers work and receive wage, w , and farmers maximize profits: $Y - wL$. Assuming a neoclassical production function $Y = aL^\alpha$, where a is labor productivity with $0 < \alpha < 1$, and L is labor; the price, p , has been normalized to one. Profit maximization implies that labor demand is given by:

$$\alpha a L^{\alpha-1} = w \tag{5}$$

Taking logs of equation (5), yields:

$$\ln(L) = \left(\frac{1}{1-\alpha} \right) (\ln(a) + \ln(\alpha) - \ln(w)) \tag{6}$$

Labor supply: There is a measure one of households. Households are faced with the decision problem of supplying labor at the extensive margin. For the following analysis we assume that the number of household members is large enough to guarantee insurance over consumption of household members. The households derive utility from consumption, c , and leisure, f , (i.e. those household members that are labor market non-participants). The maximization problem is:

$$\max U(c, f) \text{ s.t. } w(1-f) = c$$

The optimality condition is: $U_f(c, f)/U_c(c, f) = w$. As is well known, depending on the particular functional form of utility, this optimality condition could imply either a positive or negative response of labor supply with respect to changes in the wage, w , depending on whether the substitution effect dominates the income effect. For the following econometric analysis (see Section 3.2) we write

$$\ln(L) = \gamma \ln(w) + u \tag{7}$$

where u is an error term, capturing, for example, shocks to household preferences. The parameter of interest, γ , can be either positive (i.e. upward sloping labor supply curve) or negative (i.e. downward sloping labor supply curve).

Equivalence of using wage and output per worker in estimation of equation (7):

From equation (5) we have $\alpha a L^{\alpha-1} = w$. Using the production function $Y = aL^\alpha$, we can divide both sides by L ; this yields $y \equiv \frac{Y}{L} = aL^{\alpha-1}$. Hence, $w = \alpha y$ and

$$\ln(L) = \gamma \ln(\alpha) + \gamma \ln(y) + u \quad (8)$$

Least squares (LS) estimate of equation (8):

The least squares estimate of γ in equation (8) is:

$$\gamma^{LS} = \left(\frac{\text{cov}(\ln(L), \ln(y))}{\text{var}(\ln(y))} \right) = \gamma + \left(\frac{\text{cov}(\ln(y), u)}{\text{var}(\ln(y))} \right)$$

The bias in the LS estimation is $\text{cov}(\ln(y), u)/\text{var}(\ln(y))$. To evaluate this expression, substitute equation (6) into equation (7). This yields: $\ln(w) = \left(\frac{1}{1+(1-\alpha)\gamma} \right) [\ln(a) + \ln(\alpha) - (1-\alpha)u]$; hence, the wage (or output per worker, which is $\ln(y) = \left(\frac{1}{1+(1-\alpha)\gamma} \right) [\ln(a) + \ln(\alpha) - (1-\alpha)u] - \ln(\alpha)$) is a function of two shocks – a labor productivity shock, a ; and a labor supply specific shock, u .

Assuming that the covariance between productivity shock, a , and the labor supply specific (preference) shock, u , is zero, the LS estimator is

$$\gamma^{LS} = \gamma - \left(\frac{(1-\alpha)}{1+(1-\alpha)\gamma} \right) \frac{\text{var}(u)}{\text{var}(\ln(y))}$$

Hence, the least squares estimator is downward biased.

Two-stage least squares (TSLS) estimation of equation (8)

Our instrumental variable, z , the boll weevil, is an agricultural pest that negatively affects productivity, a ; i.e. $a = f(z, \text{other shocks})$. The TSLS estimator is:

$$\gamma^{TSLS} = \text{cov}(z, L)/\text{cov}(z, y) = \gamma + \frac{\text{cov}(z, u)}{\text{cov}(z, y)} = \gamma,$$

where we use in the last line the same assumption as for the LS estimator, i.e. $\text{cov}(a, u) = 0$.

Note, that a reduced form approach is not sufficient to identify whether labor supply is upward sloping. This is because under a neoclassical production function, dL/dz will always be positive. It is only once the response of output per worker to the z shock is taken into account that the labor supply response to changes in the wage is identified. This follows immediately from noting that the TSLS estimator is the ratio of the reduced form effect over the first stage effect.

Data Appendix

VARIABLE	YEARS	DESCRIPTION
<i>Labor Force Participation</i>	1880 - 1940	We use the microdata from IPUMS (Ruggles et al. 2010) to construct the labor force participation rate. This variable is defined as the number of persons in the workforce divided by the number of individuals in the working age (age 16-65) in a county. The US Census considered individuals in the labor force if they reported gainful employment for the censuses 1850-1930. From 1940 onwards the Census used a different concept of labor force participation. For consistency across censuses we consider every individual between age 16-65 that reported a gainful occupation in the workforce, i.e. all individuals with occupation codes 0-970 (see IPUMS variable OCC1950 for more details). Note, that the year 1890 is missing in our analysis since the completed census forms were lost in a fire and thus individual data are unavailable for this census year (see Blake, 1996). Our results are robust when excluding the year 1940 (available upon request). We refer to the description and comparability of the IPUMS variable "LABFORCE" and "OCC1950" for further details.
<i>Female Labor Force Participation</i>	1880 - 1940	We use the microdata from IPUMS (Ruggles et al. 2010) to obtain a measure of female labor force participation. The 1910 Census over-counted female workers (unpaid female farm labourers) in the agricultural sector, see Goldin (1986, pp. 574-575). For 1910, we correct for this bias by subtracting the number of unpaid female farm laborers (occupation code 830 of IPUMS variable OCC1950) from both the numerator and denominator: (females in workforce - females who state occupation code 830)/(females of working age - females who state occupation 830). Otherwise, the construction is analog to the total labor force participation (see description above). Our results are robust when excluding the year 1910 (see Appendix Table 8).
<i>Output per worker</i>	1880 - 1940	Output per worker is calculated as the sum of value added per worker in the manufacturing and agricultural sector at the county level. Value added in manufacturing is calculated as manufacturing output minus the cost of materials. We had to impute the manufacturing data for the year 1910 because no production data were reported in the 1910 Census at the county level. Value added in agriculture is calculated as agricultural output minus the expenditure for fertilizer (available 1880-1940) and feed (available 1910-1940). County-level data are retrieved from the ICPSR file 2896 (Haines, 2010) and for the United States Censuses of Agriculture in 1930 and 1940 from Michael Haines. We use the IPUMS (Ruggles et al. 2010) microdata to construct the number of agricultural and manufacturing worker. We consider individuals as agricultural or manufacturing workers when they reported in the Census a gainful occupation in one of those sectors (see IPUMS variable OCC1950 for more details).

VARIABLE	YEARS	DESCRIPTION
<i>Employment</i>	1910, 1930	We use the microdata from IPUMS (Ruggles et al. 2010) to construct the number of employed individuals and the employment rate. The IPUMS variable EMPSTAT == 1 contains the number of employed persons aged 16 or older. For year 1910 institutional inmates are dropped (IPUMS variable relate=13). See the description and comparability of the IPUMS variable "EMPSTAT" for further details.
<i>Share Female Worker out of Adult Laborers per Household in 1880</i>	1930 - 1940	We use the full individual count sample of the 1880 Census from the IPUMS (Ruggles et al. 2010) to calculate the following share for each household: (number of women in labor force and age 16 or older)/(all persons in labor force and age 16 or older). We then calculate the weighted mean of this share by county. We use the household weight provided by the Census (IPUMS variable HHWT).
<i>Share of Housekeepers</i>	1880 - 1930	We use the microdata from IPUMS (Ruggles et al. 2010) to obtain a measure of the share of female housekeepers. This variable is constructed as the number of females reporting housekeeping (IPUMS variable OCC1950 == 980) divided by the number of females in the working age (age 16-65) in a county. Information on non-occupational responses are only available until 1930.
<i>Boll Weevil Incidence</i>	1892 - 1940	Boll Weevil incidence is a dummy variable that takes the value 1 if county c is infested at time t and zero else. We received the county-level data of the boll weevil's spread throughout the American South from Paul Rhode. More details about this dataset can be found in Lange, Olmstead and Rhode (2009).
<i>Cotton Share</i>	1880	The cotton share in 1880 is constructed as county c's acreage share of cotton planted out of the total acreage of all main field crops (barley, corn, oats, rye, wheat, cotton, sugarcane, hay, rice, tobacco, potato and sweet potato) in 1880. These crops account for almost all cultivated acreage in the Cotton Belt (see e.g. Ransom and Sutch, 2001, p.256). The county level data on the main field crops acreage are retrieved from the ICPSR file 2896 (Haines, 2010). Our results are robust to using county c's share of cotton planted out of (improved) farmland (available upon request).
<i>Cotton Suitability</i>	1880	Data on cotton suitability come from the FAO who calculates cotton suitability as the maximum potential yield of cotton based on climate, soil type and ideal growing conditions for cotton; for more information see e.g. Hornbeck and Naidu (2014, footnote 22, p. 975). The county-level data are retrieved from the replication files of Hornbeck and Naidu (2014)
<i>Average Winter Temperature above 10 Fahrenheit</i>	1930 - 1940	Historical climate data on the county level for 1930 to 1940 are retrieved from Fishback et al. (2011). We compute the days the temperature in Winter (1st of November to 28th of February) fell below 10 degrees Fahrenheit. We then use that number to calculate the likelihood that the temperature on a given day did not fall below 10 degrees Fahrenheit as $(30+31+31+28\text{-days below } 10 \text{ degrees F})/(30+31+31+28)$

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Tables and Figures

Figure 1

USDA Map of the Spread of the Boll Weevil, 1892-1922

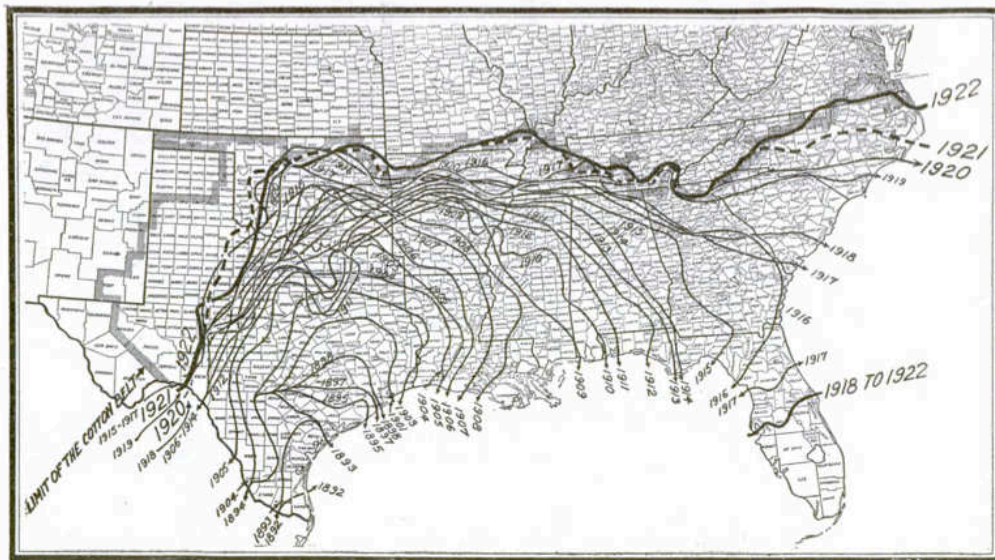
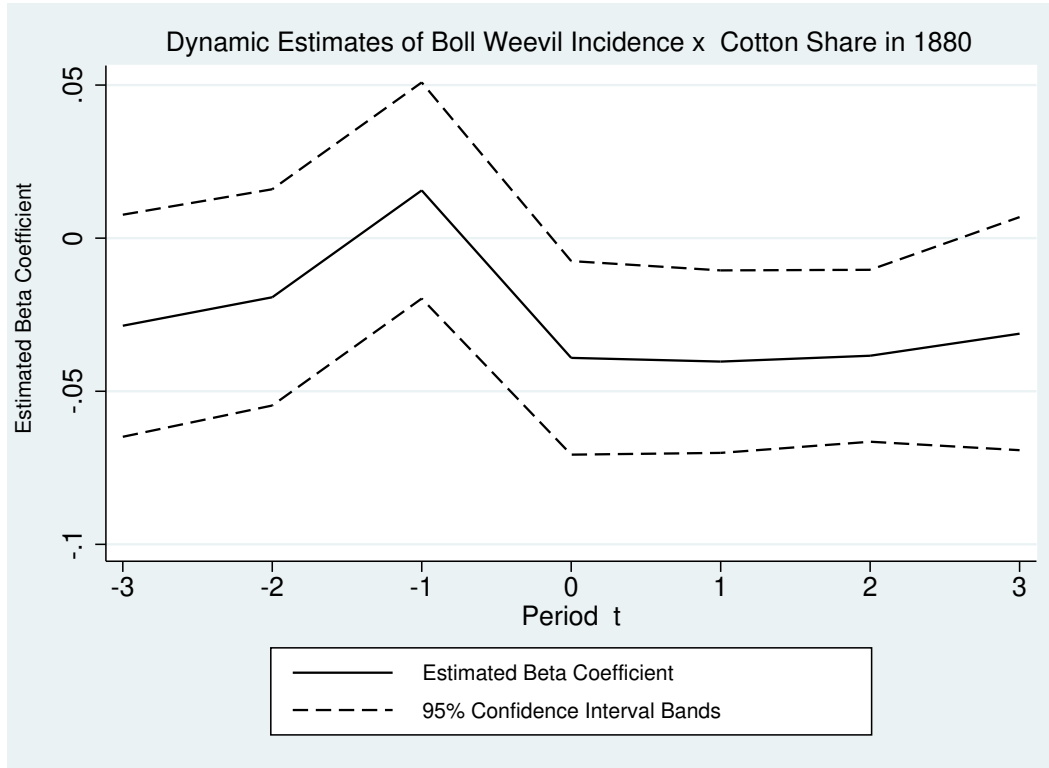


FIG. 1.—Map showing spread of the Mexican cotton boll weevil in the United States from 1892 to 1922, inclusive.

NOTE: The outer limit of the cotton belt advances or recedes slightly from year to year, and as shown on the map is not entirely accurate for 1922, as shown by the fact that in a few places the boll-weevil line is a little in advance of the indicated limit of cotton culture.

Source: Hunter and Coad (1923).

Figure 2
Dynamic Specification: Lead and Lagged Effects



We plot the coefficients and their 95 percent confidence bands of the lead, impact, and lagged effects of the interaction between boll weevil incidence and the 1880 cotton share on labor force participation. We obtain these coefficients by augmenting equation (3) with three leads and lags of the boll weevil incidence and its interaction with the 1880 cotton share. See section 4.2 for further details.

TABLE 1
DESCRIPTIVE STATISTICS

VARIABLES	(1) N	(2) MEAN	(3) SD	(4) MIN	(5) MAX
Labor Force Participation Rate (Total)	5,146	0.581	0.0751	0.291	0.991
Labor Force Participation Rate (Male)	5,145	0.918	0.0540	0.345	1
Labor Force Participation Rate (Female)	5,146	0.222	0.132	0	0.990
Labor Force Participation Rate (Female, White)	5,145	0.150	0.0966	0	1
Labor Force Participation Rate (Female, Black)	4,667	0.398	0.218	0	1
Output per worker (in logs)	5,146	4.752	0.739	0.382	7.686
Boll Weevil Incidence	5,146	0.577	0.494	0	1
Cotton Share (1880)	5,146	0.358	0.188	0	0.790

TABLE 2
Labor Force Participation Response to the Boll Weevil

<i>Dependent Variable: Labor Force Participation Rate</i>					
	(1)	(2)	(3)	(4)	(5)
Labor Force Participation	All	Male	Female	Female, White	Female, Black
<i>Boll Weevil</i> _{ct} × <i>Cotton</i> _{c,1880}	-0.0806*** (0.0108)	-0.00649 (0.00791)	-0.160*** (0.0174)	-0.00586 (0.0157)	-0.291*** (0.0370)
<i>Boll Weevil</i> _{ct}	0.00295 (0.00492)	0.00121 (0.00450)	0.00215 (0.00653)	0.00101 (0.00823)	0.00750 (0.0234)
Observations	5,144	5,144	5,144	5,144	4,638
R-squared	0.018	0.000	0.029	0.000	0.019
Number of Counties	903	903	903	903	860
County FE	YES	YES	YES	YES	YES
State-by-Time FE	YES	YES	YES	YES	YES

The dependent variable is the labor force participation rate. *Boll Weevil*_{ct} is an indicator variable that is unity in county *c* and period *t* if a county is infested by the boll weevil and zero otherwise. *Boll Weevil*_{ct} × *Cotton*_{c,1880} is the interaction between the incidence of the boll weevil and county *c*'s acreage share of cotton planted in 1880. See Section 3.2 and the data appendix for further details. Huber robust standard errors (shown in parentheses) are clustered at the county level: *** p<0.01, ** p<0.05, * p<0.1.

TABLE 3
Comparative Advantage of Women in Picking Cotton

<i>Dependent Variable: Share Female Worker out of Adult Workforce per Household in 1880</i>						
Method	(1)	(2)	(3)	(4)	(5)	(6)
	LS	LS	TOLS	LS	LS	TOLS
$\ln(\text{Cotton Acreage}_{c,1880})$	0.0154*** (0.00213)	0.0136*** (0.00220)	0.0303** (0.0148)			
$\text{Cotton Share}_{c,1880}$				0.808*** (0.0517)	0.764*** (0.0533)	0.905*** (0.261)
<i>First Stage Equation</i>						
$\text{Cotton Suitability}_c$			1.324*** (0.256)			0.0465*** (0.0088)
Observations	602	602	602	602	602	602
R-squared	0.648	0.665	0.598	0.738	0.745	0.733
State FE	YES	YES	YES	YES	YES	YES
Geo Controls	YES	YES	YES	YES	YES	YES
Kleibergen-Paap F-Stat			24.16			25.02

The dependent variable is the share of female worker out of the adult workforce at the county level in 1880. In columns (1), (2), (4) and (5) the method of estimation is least squares (LS). In columns (3) and (6) the method of estimation is two stage least squares (TOLS). In columns (1)-(3), the right hand side variable of interest, $\ln(\text{Cotton Acreage}_{c,1880})$, is total cotton acreage measured in logarithmic unites and the cotton share, $\text{Cotton Share}_{c,1880}$, in columns (4)-(6). The instrumental variable is cotton suitability, also see Section 4.1 for further details. We further add a set of geographic control variables: linear and squared terms of monthly temperature and precipitation, measures of soil quality and linear and squared terms of mean and standard deviation of elevation (estimates not reported). See the data appendix for further details. Huber robust standard errors (shown in parentheses) are clustered at the county level: *** p<0.01, ** p<0.05, * p<0.1.

TABLE 4
Labor Force Participation Response to Output per Worker

<i>Dependent Variable Second Stage: Labor Force Participation Rate</i>					
	(1)	(2)	(3)	(4)	(5)
Labor Force Participation	All	Male	Female	Female, White	Female, Black
$\ln(\text{Output per worker}_{ct})$	0.203*** (0.0479)	0.0164 (0.0199)	0.405*** (0.0941)	0.0148 (0.0394)	0.750*** (0.189)
Boll Weevil_{ct}	-0.00413 (0.00860)	0.000643 (0.00464)	-0.0119 (0.0147)	0.000490 (0.00861)	-0.0297 (0.0341)
<i>Dependent Variable First Stage: $\ln(\text{Output per worker})$</i>					
	(1)	(2)	(3)	(4)	(5)
$\text{Boll Weevil}_{ct} \times \text{Cotton}_{c,1880}$	-0.396*** (0.0907)	-0.396*** (0.0907)	-0.396*** (0.0907)	-0.396*** (0.0907)	-0.388*** (0.0961)
Boll Weevil_{ct}	0.0348 (0.0323)	0.0348 (0.0323)	0.0348 (0.0323)	0.0348 (0.0323)	0.0496 (0.0333)
Observations	5,144	5,144	5,144	5,144	4,638
Number of Counties	903	903	903	903	860
County FE	YES	YES	YES	YES	YES
State-by-Time FE	YES	YES	YES	YES	YES
Hausman Test Statistics (p-value)	0.000	0.432	0.000	0.927	0.000
Kleibergen-Paap F-Stat	18.80	18.80	18.80	18.80	16.06

The dependent variable is the labor force participation rate. The method of estimation is two-stage least squares. The instrumental variable is the interaction between the incidence of the boll weevil and county c 's acreage share of cotton planted in 1880, $\text{Boll Weevil}_{ct} \times \text{Cotton}_{c,1880}$. Boll Weevil_{ct} is an indicator variable that is unity in county c and period t if a county is infested by the boll weevil and zero otherwise. See Section 3.2, the data and technical appendix for further details. Huber robust standard errors (shown in parentheses) are clustered at the county level: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

TABLE 5
Labor Force Participation Response to Output per Worker

<i>Dependent Variable: Labor Force Participation Rate</i>					
	(1)	(2)	(3)	(4)	(5)
Labor Force Participation	All	Male	Female	Female, White	Female, Black
$\ln(\text{Output per worker}_{ct})$	0.00774*** (0.00283)	0.000428 (0.00214)	0.0201*** (0.00418)	0.00918*** (0.00353)	0.0242** (0.0113)
Observations	5,144	5,144	5,144	5,144	4,638
R-squared	0.003	0.000	0.009	0.002	0.002
Number of Counties	903	903	903	903	860
County FE	YES	YES	YES	YES	YES
State-by-Time FE	YES	YES	YES	YES	YES

The dependent variable is the labor force participation rate. The method of estimation is least squares. $\ln(\text{Output per worker}_{ct})$ is output per worker at the county level measured in logarithmic units. See Section 4.1 and the data appendix for further details. Huber robust standard errors (shown in parentheses) are clustered at the county level: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

TABLE 6
Boll Weevil's Sensitivity to Frost as Additional Instrument

<i>Dependent Variable Second Stage: Labor Force Participation Rate</i>					
	(1)	(2)	(3)	(4)	(5)
Labor Force Participation	All	Male	Female	Female, White	Female, Black
$\ln(\text{Output per worker}_{ct})$	0.186*** (0.0391)	0.0144 (0.0188)	0.382*** (0.0761)	0.0404 (0.0351)	0.746*** (0.171)
<i>Dependent Variable First Stage: $\ln(\text{Output per worker})$</i>					
	(1)	(2)	(3)	(4)	(5)
$\text{Boll Weevil}_{ct} \times \text{Cotton}_{c,1880}$	-0.359*** (0.0965)	-0.359*** (0.0965)	-0.359*** (0.0965)	-0.359*** (0.0965)	-0.360*** (0.101)
$\text{Boll Weevil}_{ct} \times \text{Winter Temp}_c$	-3.369** (1.645)	-3.369** (1.645)	-3.369** (1.645)	-3.369** (1.645)	-3.659** (1.844)
Observations	5,105	5,105	5,105	5,105	4,601
Number of Counties	896	896	896	896	853
County FE	YES	YES	YES	YES	YES
State-by-Time FE	YES	YES	YES	YES	YES
Boll Weevil Incidence	YES	YES	YES	YES	YES
Kleibergen-Paap F-Stat	13.97	13.97	13.97	13.97	12.07
Hansen p-val	0.226	0.910	0.342	0.141	0.934

The dependent variable is the labor force participation rate. The method of estimation is two-stage least squares. The instrumental variable is the interaction between the incidence of the boll weevil and county c 's acreage share of cotton planted in 1880, $\text{Boll Weevil}_{ct} \times \text{Cotton}_{c,1880}$ and the interaction between the incidence of the boll weevil and county c 's average winter temperature above 10 degree Fahrenheit, $\text{Boll Weevil}_{ct} \times \text{Winter Temp}_c$. Boll Weevil_{ct} is an indicator variable that is unity in county c and period t if a county is infested by the boll weevil and zero otherwise (estimate not reported). See Section 3.2 and the data appendix for further details. Huber robust standard errors (shown in parentheses) are clustered at the county level: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

TABLE 7
Sample Split by County's Cotton Share in 1880

<i>Dependent Variable:</i>	Labor Force Participation Rate			Output per Worker		
	(1)	(2)	(3)	(4)	(5)	(6)
<i>Panel A: Below 20th Percentile</i>						
<i>Boll Weevil</i> _{ct} × <i>Cotton</i> _{c,1880}	-0.0231 (0.0545)	-0.100 (0.0817)	-0.156 (0.222)	-0.171 (0.635)	-0.171 (0.635)	0.302 (0.610)
Observations	1,033	1,033	926	1,033	1,033	926
Number of Counties	183	183	175	183	183	175
<i>Panel B: Above 20th Percentile</i>						
<i>Boll Weevil</i> _{ct} × <i>Cotton</i> _{c,1880}	-0.0972*** (0.0152)	-0.190*** (0.0256)	-0.389*** (0.0564)	-0.826*** (0.119)	-0.826*** (0.119)	-0.769*** (0.131)
Observations	4,113	4,113	3,712	4,113	4,113	3,712
Number of Counties	720	720	685	720	720	685
County FE	YES	YES	YES	YES	YES	YES
State-by-Time FE	YES	YES	YES	YES	YES	YES
Boll Weevil Incidence	YES	YES	YES	YES	YES	YES

The dependent variable is the labor force participation rate in columns (1), female labor force participation rate in column (2) and black female labor force participation rate in column (3). In columns (4)-(6) the dependent variable is output per worker in logarithmic units. The method of estimation is least squares. *Boll Weevil*_{ct} is an indicator variable that is unity in county *c* and period *t* if a county is infested by the boll weevil and zero otherwise (estimate not reported). *Boll Weevil*_{ct} × *Cotton*_{c,1880} is the interaction between the incidence of the boll weevil and county *c*'s acreage share of cotton planted in 1880. See Section 4.2 and the data appendix for further details. Huber robust standard errors (shown in parentheses) are clustered at the county level: *** p<0.01, ** p<0.05, * p<0.1.

TABLE 8
The Share of Corn times the Boll Weevil as Falsification Test

<i>Dependent Variable:</i>	(1) Labor Force Participation Rate	(2) Output per Worker
<i>Boll Weevil</i> _{ct} × <i>Cotton</i> _{c,1880}	-0.0754*** (0.0124)	-0.453*** (0.125)
<i>Boll Weevil</i> _{ct} × <i>Corn</i> _{c,1880}	0.0152 (0.0184)	-0.184 (0.210)
Observations	5,146	5,146
Number of Counties	903	903
County FE	YES	YES
State-by-Time FE	YES	YES
Boll Weevil Incidence	YES	YES

The dependent variable is the labor force participation rate in column (1) and output per worker measured in logarithmic units in column (2) for 1880–1940. The estimating equation is (3) in column (1) and (2) for column (2). The method of estimation is least squares. *Boll Weevil*_{ct} is an indicator variable that is unity in county *c* and period *t* if a county is infested by the boll weevil and zero otherwise (estimate not reported). *Boll Weevil*_{ct} × *Cotton*_{c,1880} is the interaction between the incidence of the boll weevil and county *c*'s acreage share of corn planted in 1880. *Boll Weevil*_{ct} × *Corn*_{c,1880} is the interaction between the incidence of the boll weevil and county *c*'s acreage share of corn planted in 1880. See Section 4.2 and the data appendix for further details. Huber robust standard errors (shown in parentheses) are clustered at the county level: *** p<0.01, ** p<0.05, * p<0.1.

TABLE 9
Female Labor Force Participation Response to Output per Worker

<i>Dependent Variable: Female Labor Force Participation Rate (FLFP) by Marital Status and Race</i>				
	(1)	(2)	(3)	(4)
<i>Panel A: FLFP</i>	Married, White	Married, Black	Single, White	Single, Black
$\ln(\text{Output per worker}_{ct})$	-0.0411 (0.0373)	0.717*** (0.181)	0.128 (0.0856)	0.807*** (0.207)
Observations	4,040	4,040	4,040	4,040
Number of Counties	793	793	793	793
Kleibergen-Paap F-Stat	16.31	16.31	16.31	16.31

<i>Dependent Variable: Female Labor Force Participation Rate (FLFP) by Cohorts</i>					
	(1)	(2)	(3)	(4)	(5)
<i>Panel B: FLFP</i>	Age 16-25	Age 26-35	Age 36-45	Age 46-55	Age 56-65
$\ln(\text{Output per worker}_{ct})$	0.607*** (0.131)	0.386*** (0.0936)	0.313*** (0.0837)	0.244*** (0.0820)	0.188** (0.0837)
Observations	4,886	4,886	4,886	4,886	4,886
Number of Counties	896	896	896	896	896
Kleibergen-Paap F-Stat	21.70	21.70	21.70	21.70	21.70
County FE	YES	YES	YES	YES	YES
State-by-Time FE	YES	YES	YES	YES	YES
Boll Weevil Incidence	YES	YES	YES	YES	YES

The dependent variable is the labor force participation rate by marital status and race (Panel A) and by cohorts (Panel B). The method of estimation is two-stage least squares. The instrumental variable is the interaction between the incidence of the boll weevil and county c 's acreage share of cotton planted in 1880, $Boll\ Weevil_{ct} \times Cotton_{c,1880}$. $Boll\ Weevil_{ct}$ is an indicator variable that is unity in county c and period t if a county is infested by the boll weevil and zero otherwise (estimate not reported). See the data appendix for further details. Huber robust standard errors (shown in parentheses) are clustered at the county level: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

TABLE 10
Employment Response to Output per Worker

<i>Dependent Variable, Panel A: ln(Employment)</i>					
	(1)	(2)	(3)	(4)	(5)
Labor Force Participation	All	Male	Female	Female, White	Female, Black
$\ln(\text{Output per worker}_{ct})$	0.860** (0.336)	0.378 (0.255)	3.046*** (0.992)	-1.523 (1.327)	2.876** (1.264)
Observations	2,665	2,665	2,665	2,665	2,665
Number of Counties	902	902	902	902	902
Kleibergen-Paap F-Stat	14.48	14.48	14.48	14.48	14.48
<i>Dependent Variable, Panel B: Employment Rate</i>					
	(1)	(2)	(3)	(4)	(5)
Labor Force Participation	All	Male	Female	Female, White	Female, Black
$\ln(\text{Output per worker}_{ct})$	0.322*** (0.0966)	0.00376 (0.0500)	0.673*** (0.187)	-0.145 (0.0996)	0.825** (0.324)
Observations	2,665	2,664	2,665	2,664	2,353
Number of Counties	902	902	902	902	814
Kleibergen-Paap F-Stat	14.48	14.48	14.48	14.96	10.59
County FE	YES	YES	YES	YES	YES
State-by-Time FE	YES	YES	YES	YES	YES
Boll Weevil Incidence	YES	YES	YES	YES	YES

The dependent variable is employment measured in logarithmic units (Panel A) and the employment rate (Panel B). The method of estimation is two-stage least squares. The instrumental variable is the interaction between the incidence of the boll weevil and county c 's acreage share of cotton planted in 1880, $Boll\ Weevil_{ct} \times Cotton_{c,1880}$. $Boll\ Weevil_{ct}$ is an indicator variable that is unity in county c and period t if a county is infested by the boll weevil and zero otherwise (estimate not reported). See the data appendix for further details. Huber robust standard errors (shown in parentheses) are clustered at the county level: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

TABLE 11
Effects on Immigration and Emigration

<i>Dependent Variable: Probability Moving Out of Infested County</i>				
	(1)	(2)	(3)	(4)
Panel A	Total (LS)	Females (LS)	Total (Probit)	Females (Probit)
$\Delta(\text{Boll Weevil}_{ct} \times \text{Cotton}_{c,1880})$	0.303*** (0.0371)	0.270*** (0.0763)	0.298*** (0.0367)	0.261*** (0.0746)
Observations	15,261	4,349	15,261	4,349
$\Delta(\text{Boll Weevil Incidence})$	YES	YES	YES	YES
<i>Dependent Variable: Probability Moving Into Infested County</i>				
	(1)	(2)	(3)	(4)
Panel B	Total (LS)	Females (LS)	Total (Probit)	Females (Probit)
$\Delta(\text{Boll Weevil}_{ct} \times \text{Cotton}_{c,1880})$	-0.0694** (0.0342)	-0.148** (0.0717)	-0.0671** (0.0333)	-0.135** (0.0666)
Observations	116,048	38,694	116,048	38,694
$\Delta(\text{Boll Weevil Incidence})$	YES	YES	YES	YES

In Panel A (B) the dependent variable is an indicator variable that is unity if individual i migrated out (emigration) or into (immigration) a boll weevil infested county between 1880 and the time period observed in the linked sample. The method of estimation is least squares in columns (1)-(2) and probit in columns (3)-(4). See Section 4.3.3 and the data appendix for further details. Huber robust standard errors (shown in parentheses) are clustered at the county level: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

TABLE 12
Effects on Housekeeping

<i>Dependent Variable: Share of Housekeepers</i>		
	(1)	(2)
Share of Housekeepers	Female	Female, Black
$\ln(\text{Output per worker}_{ct})$	-0.374*** (0.113)	-0.376*** (0.109)
Observations	4,252	3,823
Number of Counties	903	844
County FE	YES	YES
State-by-Time FE	YES	YES
Boll Weevil Incidence	YES	YES
Kleibergen-Paap F-Stat	13.23	14.45

The dependent variable is the share of housekeeper. The method of estimation is two-stage least squares. The instrumental variable is the interaction between the incidence of the boll weevil and county c 's acreage share of cotton planted in 1880, $Boll\ Weevil_{ct} \times Cotton_{c,1880}$. $Boll\ Weevil_{ct}$ is an indicator variable that is unity in county c and period t if a county is infested by the boll weevil and zero otherwise (estimate not reported). See the data appendix for further details. Huber robust standard errors (shown in parentheses) are clustered at the county level: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.