Structural Change and the Fertility Transition

Ager, Philipp and Herz, Benedikt

University of Southern Denmark and CEPR, European Commission

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Philipp Ager Benedikt Herz†

Abstract

This paper provides new insights on the relationship between structural change and the fertility transition. We exploit the spread of an agricultural pest in the American South in the 1890s as plausibly exogenous variation in agricultural production to establish a causal link between earnings opportunities in agriculture and fertility. Households staying in agriculture reduced fertility because children are a normal good, while households switching to manufacturing reduced fertility because of the higher opportunity costs of raising children. The lower earnings opportunities in agriculture also decreased the value of child labor which increased schooling, consistent with a quantity-quality model of fertility.

Keywords: Fertility Transition, Structural Change, Industrialization, Agricultural Income.

JEL codes: J13; N31; O14

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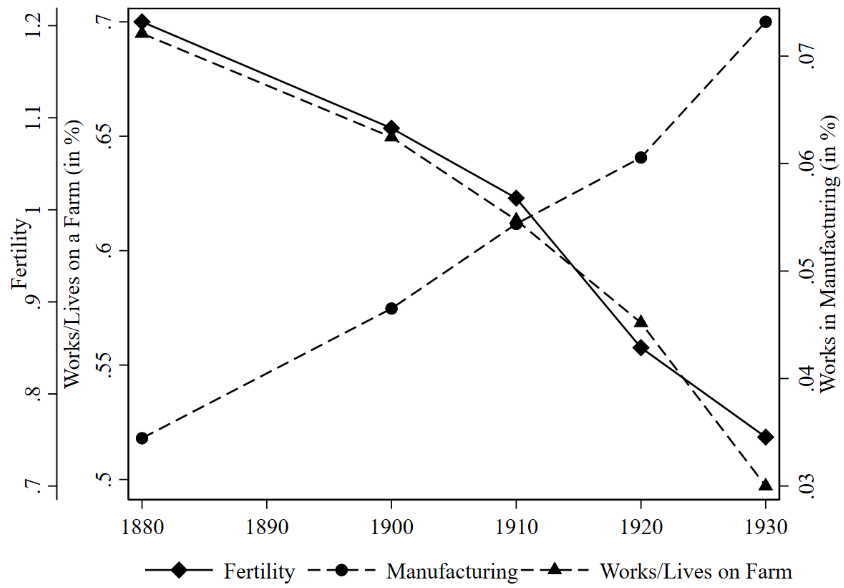
† Corresponding authors: Philipp Ager, University of Southern Denmark and CEPR; phag@sam.sdu.dk and Benedikt Herz, European Commission, 1049 Brussels, Belgium; benedikt.herz@gmail.com.

1 Introduction

The fertility transition that countries in North America and Europe experienced during the 19th and 20th centuries is regarded as one of the most important determinants of rapid and sustainable long-run growth (Guinnane, 2011). Falling fertility rates allowed the transition from a Malthusian regime, where income per capita was roughly constant, to a regime with lower population growth and higher living standards. During the same period, these countries experienced the structural transformation, a sustained shift from agriculture to manufacturing. For example, the number of children per white woman in the United States fell from around seven to two between 1800 and 2000, and real GDP per capita increased at the same time from 1,296 dollars to 28,702 dollars. Similarly, between 1810 and 1960, the share of the U.S. labor force working on a farm decreased from 80.9% to 8.1% while the share of manufacturing employment increased from 2.8% to 23.2% (Lebergott, 1966; Haines and Steckel, 2000; Bolt and van Zanden 2014). While unified growth theory suggests that the structural transformation contributed to the onset of the fertility decline (e.g., Galor, 2005), empirical evidence of a causal link is lacking so far.

In this paper, we show that the structural transformation was indeed causal for the fertility transition to take place. Our analysis focuses on the fertility transition in the American South that took place during the late 19th and early 20th centuries, a period that was also characterized by a sustained shift from employment in agriculture to manufacturing (see Figure 1). The empirical strategy exploits the arrival of an agricultural pest, the boll weevil, which adversely affected the cotton producing counties of the American South after the early 1890s as a quasi-experiment (Lange, Olmstead, and Rhode, 2009). Since the spread of the boll weevil was determined by geographic conditions—mainly prevailing wind and weather conditions—it provides a plausibly exogenous source of variation in agricultural production. Our estimation strategy uses two sources of county-level variation: the timing of the boll weevil's arrival and its relatively stronger impact on local economies that were more dependent on cotton cultivation. We combine this county-level variation with complete count U.S. Census microdata to estimate the causal link between structural change and fertility.

Figure 1: Structural Change and the Fertility Transition in the American South, 1880 to 1930



NOTE.—This figure shows the evolution of the average number of children under age 5 per 20 to 39-year-old married woman, as well as the fraction of 10 to 65-year-olds employed in manufacturing or living/working on a farm, from 1880 to 1930, for the Cotton Belt of the American South based on full count Census data.

We find evidence that the lower earnings opportunities in the agricultural sector decreased fertility in the American South during the 1880-1930 period via two channels: households staying in agriculture (*stayers*) reduced fertility due to lower income—consistent with children being a normal good (Becker, 1960)[1]—and households that left agriculture (*switchers*) reduced their fertility because of the higher implicit and direct costs of raising children in the manufacturing sector. The two channels imply that there is an unambiguously negative association between lower earnings opportunities in agriculture and fertility.[2]

In order to provide support for the first channel, we estimate the effect of a decline in agricultural income on fertility for stayers by using the interaction between the boll weevil incident and counties' (initial) dependence on cotton production as an instrumental variable. Our instrumental

[1]A recent literature shows that when income/wealth shocks are properly identified, children are indeed a normal good (e.g., Lindo, 2010; Black et al., 2013; Lovenheim and Mumford, 2013).

[2]This also suggests, in line with the theoretical framework by Mookherjee, Prina, and Ray (2012), that the wage-fertility relation can be positive within broad occupational categories but negative across occupational categories.

variable estimates reveal that lower agricultural income led to lower fertility among agricultural households, independent of race.[3] This result is compatible with the view that the opportunity cost of child rearing was relatively low for farm work in the American South at the beginning of the 20th century (Jones, 1985) and potentially in agrarian economies, more generally. In support of the second channel we show that lower agricultural earnings opportunities induced some households to switch to manufacturing. This shift towards manufacturing reinforced the fertility decline since manufacturing households had, on average, substantially fewer children than agricultural households, due to higher implicit and direct costs of raising children.[4] To disentangle and quantify the importance of each channel, we exploit the impact of an unprecedented increase in cigarette consumption during World War I on local tobacco cultivation in the American South as a second source of exogenous variation in agricultural production. Our instrumental variable estimates reveal that the effects of the structural change for the fertility transition in the American South are substantial: the shift away from agriculture explains about 29 percent of the overall marital fertility decline over the sample period.

The lower agricultural earnings opportunities also reduced the value of child labor in the American South, which resulted in higher direct costs of children and a decrease in the opportunity cost of schooling.[5] Consequently, we find a substantial decline in 10 to 15-year-olds working, and an increase in school attendance. We show that the rise in school attendance was driven by the decline in child labor and was not a result of a potential increase in the attractiveness of schooling and the returns to education per se. This finding is consistent with a standard quantity-quality (Q-Q) framework of fertility (e.g., Galor, 2005; 2011) which predicts that an increase in the direct costs of having children induces parents to invest more in the education ("quality") of their offspring. Our empirical findings therefore support the view that the Q-Q framework can rational-

[3]This finding is in line with research that documents a positive relationship between income and fertility for pre-industrial societies and predominantly agrarian economies (Clark, 2005; Clark and Hamilton, 2006).

[4]For example, during our sample period married 20 to 39-year-old women in the Cotton Belt in agricultural households reported having 1.08 children under age 5, while the number was 0.69 for non-agricultural households.

[5]The idea that child labor is an important determinant of fertility behavior since it increases the value of children's time and, at the same time, raises the opportunity cost of schooling was analyzed by Rosenzweig and Evenson (1977). In line with this argument, Hazan and Berdugo (2002) and Doepke (2004) show that child labor restrictions and education policies play an important role for the fertility decline and the transition to sustained economic growth.

ize the well-documented rise in school enrollment that went along with structural change and the fertility transition during the last two centuries.

Our paper relates to the unified growth theory literature which argues that the process of industrialization contributed to the onset of the fertility decline (Galor and Weil, 1999; 2000; Galor, 2005). While this theoretical literature is well developed, empirical evidence of a causal relationship is scarce due to complicated identification resulting from potential reverse causality and omitted variable bias. Our empirical model uses plausibly exogenous variation in the earnings opportunities in agriculture to address this identification problem. In line with the prediction of unified growth theory, we find evidence that there was a causal link between the structural transformation and the fertility transition in the American South in the late 19th and early 20th centuries.

The result that stayer households experienced a decrease in income and therefore lowered fertility (the first channel) is in line with recent empirical evidence showing that, when income/wealth shocks are properly identified, children are a normal good, as suggested by Becker (1960). For example, Lovenheim and Mumford (2013) exploit regional variation in the U.S. housing market to show that family wealth positively affects fertility. Bleakley and Ferrie (2016) find that winners of the Georgia Cherokee Land Lottery of 1832 had slightly more children than lottery losers. Lindo (2010) and Black et al. (2013) reach the same conclusion by exploiting exogenous shocks to household income. The positive relationship between household income and fertility within agricultural occupations is also consistent with the finding in some earlier literature based on cross-sectional U.S. data that higher income leads to more children within the same occupation (Freedman, 1963; Simon, 1969).

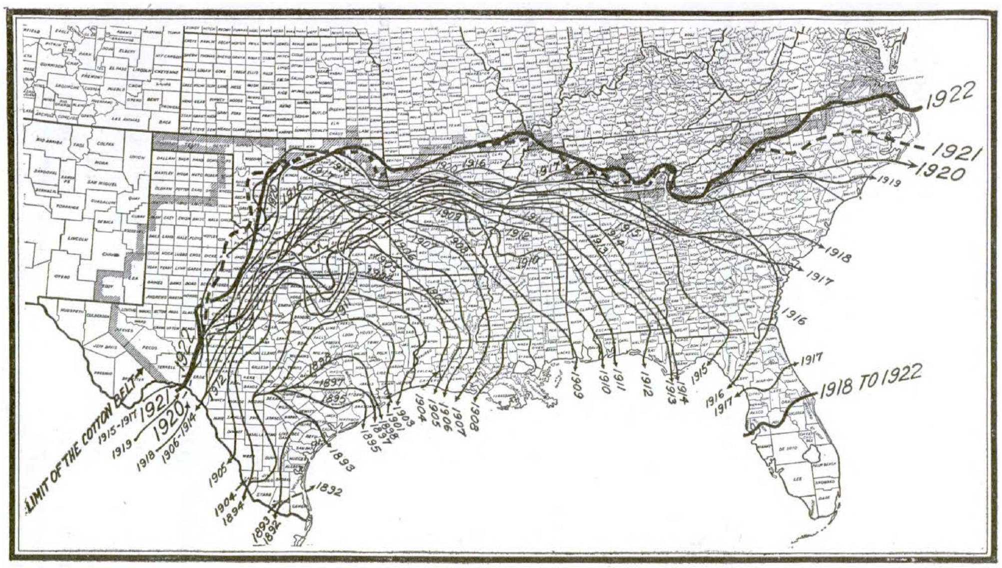
Our finding that switcher households decreased their fertility, because the implicit and direct cost of child rearing were higher in the manufacturing sector (the second channel), relates to Wanamaker (2012) who finds that industrialization was an important determinant for the fertility decline in South Carolina between 1880 and 1900. Unlike Wanamaker (2012), we find that the reduced fertility decline is not just a result of selective migration and that also human capital formation increased as a result of structural change in the American South.

We therefore also contribute to a literature that argues that human capital formation played an important role in the relation between structural change and the fertility transition (Galor, 2005, 2011). Becker (1960) and Becker and Lewis (1973) developed the idea that parents face a trade-off between the number of children and the investment in child quality. This quantity-quality (Q-Q) model is supported by the data, since there is ample evidence of a negative relation between family size and child quality (e.g., Hanushek, 1992; Becker, Cinnirella, and Woessmann, 2010; Tan, 2018). More recently, a number of studies test the Q-Q framework of fertility by using plausibly exogenous variation in the returns to education. For example, Bleakley and Lange (2009) argue that the sudden eradication of the hookworm in the American South during the 1910s led to an effective decrease in the price of child quality, particularly in areas with high pre-treatment infection rates. They document fertility behavior in line with the Q-Q model. Aaronson, Lange, and Mazumder (2014) exploit a substantial decrease in the cost of education for black children due to the roll-out of the Rosenwald schools in the American South during the early 20th century. They find that affected mothers reduced fertility along the intensive margin but, in line with Q-Q preferences, were less likely to remain childless. While these studies exploit variation in the returns to education to test the existence of a Q-Q trade-off, our paper provides direct evidence that the Q-Q model can rationalize the increase in school attendance during the structural transformation.

Finally, this study contributes to a copious literature on the fertility transition in the United States and the American South in particular. Economic historians suggest various competing hypotheses to explain the U.S. fertility decline during the 19th and early 20th centuries, ranging from changes in the cost of acquiring land (e.g., Easterlin, 1976), increases in the default risk of children to provide old-age care for parents (e.g., Sundstrom and David, 1988) to economic modernization (e.g., Greenwood and Seshadri, 2002).[6] The importance of economic modernization for the fertility transition in the U.S. has been emphasized by several studies, especially for the period after

[6]Note, that the southern region experienced only a modest decline in the child-woman ratio during the 19th century, while most of the fertility transition took place during the first decades of the 20th century (Steckel, 1992). Reasons for the delay in the southern fertility transition are manifold and are frequently associated with the specificity of the southern plantation economy at that time (e.g., Elman, London, McGuire, 2015). We refer the reader to Bailey and Hershbein (2015) for an overview of the literature on the U.S. fertility transition.

Figure 2: Spread of the Boll Weevil by Year in the American South



NOTE.—This map shows the spread of the boll weevil from 1892-1922 (Hunter and Coad, 1923).

the Civil War (Guest, 1981; Wahl, 1992, Tolnay, 1996). Consistent with the economic modernization hypothesis, recent empirical studies find industrialization (Wanamaker, 2012), better access to education (Aaronson et al. 2014), and health improvements (Bleakley and Lange, 2009) to be important determinants of the southern fertility decline. Our findings add to this literature and provide further evidence that structural change led to a fertility decline in counties of the American South that relied heavily on cotton production. The lower earnings potential in the southern agricultural sector contributed to the fertility transition by accelerating the process of industrialization and increasing the demand for human capital.

2 The Boll Weevil as a Quasi-Experiment

The boll weevil is a vermin that depends on the cotton plant — its main source of food and host of reproduction. It first appeared in the American South near Brownsville, Texas in 1892. By 1922 almost the entire Cotton Belt region was infested (see Figure 2). Depending on prevailing wind and weather conditions, the boll weevil could cover from 40 to 160 miles per year (Hunter and Coad, 1923).[7] Since the timing of the arrival of the weevil is determined by geography, it is plausibly exogenous to local economic conditions and can therefore be used to identify the causal effect of lower agricultural earnings opportunities on fertility.

The boll weevil's detrimental effect on the southern agricultural sector is well documented. Lange et al. (2009) combine county level data on agricultural production with the timing of the arrival of the boll weevil for the period 1889-1929 and show that it decreased local cotton production by about 50 percent in the first five years after contact, with no sign of recovery for at least a decade. The reduced revenues from cotton production had important impacts on local economies. Lange et al. (2009) document population movements and a shift of agricultural production from cotton to corn, the main alternative crop in the Cotton Belt. Ager, Brueckner, and Herz (2017) find that in highly cotton dependent counties the presence of the vermin led to farm closures, a change in tenancy arrangements, removal of land from agricultural production, and a substantial decline in farm wages and female labor force participation. Other recent work shows that the boll weevil increased school enrollment rates of blacks in Georgia (Baker, 2015) and delayed marriage, especially for young African-Americans, as the boll weevil infestation changed the prospects of tenant farming (Bloome, Feigenbaum, and Muller, 2017).

The findings based on disaggregated data resonate with the older economic history and social science literature that considers the boll weevil as a large negative productivity shock to the southern cotton production and a disruptive element of the whole Southern economy (Street, 1957; Crew, 1988; Ransom and Sutch, 2001; Merchant, 2012).[8] Between 1909-1935, the estimated average reduction from full yield in the American South was 10.9 percent, ranging from 0.8 percent in Missouri to 17.8 percent in Louisiana. In 1921, thirty years after the boll weevil entered the Cotton Belt, the estimated losses reached their peak of 31 percent (U.S. Department of Agriculture, 1951,

[7]Mild, wet summers and frost-free winters led to massive reproduction and heavy infestation, whereas very hot, dry summer months impeded the infestations of the Southern cotton fields and boll weevil mortality increased during cold winters (Hunter and Coad, 1923; Lange et al., 2009).

[8]For example Ransom and Sutch, (2001) compare cotton acreage and yield before and after boll weevil infestation for the cotton states Louisiana, Mississippi, Alabama, Georgia, and South Carolina from 1889 to 1924. Their estimates reveal a decline in cotton acreage of 27.4 percent and in cotton yield of 31.3 percent in the four years after complete boll weevil infestation.

Table 52). The estimated average annual loss due to the boll weevil infestation for the four years preceding 1920 was approximately 200-300 million U.S. dollars (Hunter and Coad, 1923).

The recent evidence based on disaggregated data revises findings of scholars that questioned whether the boll weevil played an important role for the development of the southern economy as a whole (Higgs, 1976; Osband, 1985; Wright, 1986; Giesen, 2011). Proponents of this view argued that a higher cotton price had completely offset the detrimental effects that the boll weevil had on local economies. For example, Wright (1986) argues that the higher cotton price kept the southern cotton economy going; it refrained farmers from diversifying agricultural production at a larger scale, and therefore did not lead to a shift of resources out of agriculture in the South.[9]

For our empirical approach, the literature based on aggregated data raises the concern that offsetting price effects might have mitigated the decline in agricultural earnings opportunities due to the boll weevil infestation. In this respect, it is important to note that our estimation strategy exclusively uses within-county variation and includes time fixed effects (see Section 4.1). This alleviates the concern that fertility might have responded to aggregate price effects. Our econometric model further includes state-by-time fixed effects which implies that our variation only comes from differentially affected counties *within* a given state and year. Our estimates therefore take into account any potential confounding effects that occur at the state level, even when they vary over time. For example, changes in state-specific laws, such as regulating child labor and school attendance, which potentially directly affected fertility outcomes, are captured by our econometric model.

For our empirical strategy, it is also not relevant to what extent the boll weevil led to an overall decline in agricultural earnings opportunities in the Cotton Belt, but only that it induced a *relative* decline in more cotton-dependent counties compared to less cotton-dependent counties.[10] Finally, it is also sufficient that the infestation created *some* exogenous variation in agricultural earnings

[9] Giesen (2011) argues that 30 years after the boll weevil's arrival in the Cotton Belt, the southern cotton economy remained relatively unchanged—the South produced even more cotton in 1921 than in 1892. Osband (1985) claims that the overall effect of the boll weevil on the southern economy was modest since he finds only minimal annual revenue losses for southern cotton producers.

[10] Even if agricultural production increased at the aggregate level it is not clear that this leads to an increase in farmers' net income because of potentially rising input costs, such as increased cost for fertilizer (see Lange et al., 2009, footnote 28). Our construction of agricultural income takes input costs into account (see the data appendix for further details).

opportunities. We do not argue that the boll weevil infestation necessarily was the main source of structural change in the American South.

3 Data

We use the recently released complete count U.S. Census microdata from the Integrated Public Use Microdata Series (IPUMS) to construct the relevant outcome measures for fertility, occupational choices, and school attendance (Ruggles et al., 2017). The data consist of a repeated cross-section of individuals that resided in the Cotton Belt of the American South during the period 1880–1930.[11] We use the following data sets for the empirical analysis: (a) to study fertility, we use a sample of about 13.5 million 16 to 49-year-old married women with spouse present;[12] (b) to study structural change and occupational choices, we draw on a sample of about 61 million individuals of working age (10 to 65); and (c) to analyze school attendance, we use a sample of about 7.5 million 10 to 15-year-old children who are listed together with their mothers in the Census. To overcome some of the drawbacks of a purely cross-sectional analysis, we further use data provided by IPUMS that link records from the 1880 complete-count database to the one percent samples of the 1900, 1910, and 1920 Censuses at various points in the empirical analysis.

Our study uses a novel measure of household income that combines various sources of agricultural income covering the decades 1880-1930. Farm income is based on county-level measures of farm revenues and expenditure from the United States Censuses of Agriculture (Haines, Fishback, and Rhode, 2015). Wages for farm laborers are retrieved from various official sources and vary by state over time. Unpaid family workers are assumed to receive a constant fraction of the county-specific farm income. We then assign agricultural income to individuals who report an agricultural occupation in a given year. This variable varies across agricultural occupations – farmers, farm laborers (wage workers), and unpaid family workers – by county or state and over

[11] The year 1890 is omitted from the analysis since the completed census forms were lost in a fire (Blake, 1996).

[12] The spouse is present for approximately 96 percent of the 16 to 49-year-old married women in the Cotton Belt of the American South.

time, and is denoted in constant prices.[13] For non-agricultural income of these households we use the occupation-based income score ("OCCSCORE") from IPUMS in constant prices.[14] The supplementary data appendix provides a detailed description of how the agriculture income variable is constructed.[15]

We then merge the microdata with county-level data on the arrival of the boll weevil and cotton production in 1899.[16] County-level data on cotton acreage are from the Census of Agriculture in 1889 (Haines et al., 2015). As many counties changed boundaries during our sample period, we form aggregate counties to time-consistent "multi-counties" as in Lange et al. (2009) and Ager, Bruckner, and Herz (2017). Descriptive statistics are reported in Online Appendix Table 1.

4 Reduced Form Evidence

In this section, we quantify the reduced form effects that the boll weevil infestation of the southern cotton fields had on fertility. Our econometric model follows a differences-in-differences strategy exploiting the fact that the boll weevil arrived in different counties at different times (variation over time) and that the boll weevil had a stronger impact in highly cotton-dependent counties (variation across counties).[17] Under the hypothesis that the boll weevil had a negative effect on fertility, we would expect to find the largest fertility declines in counties with a high initial intensity of cotton production after infestation.

[13] We used `https://www.measuringworth.com/uscompare/` to convert the variable into constant prices. We use 1900 as the reference year.

[14] The IPUMS occupation score has been used in the literature as an approximation for income over longer periods of time (e.g., Jones and Tertilt, 2008).

[15] The supplementary data appendix is available at `https://www.philippager.com/research`.

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

[17] Ager, Brueckner, and Herz (2017) show that highly cotton-dependent counties were the most affected places in the Cotton Belt.

4.1 Estimation Strategy

We use a sample of 16 to 49-year-old married women to estimate the following reduced form equation:

$$Fertility_{ict} = \alpha_c + \alpha_{st} + \beta Boll\ Weevil\ Intensity_{ct} + \Gamma X_{ict} + \varepsilon_{ict}, \tag{1}$$

where $Fertility_{ict}$ denotes mother i's number of own children under age 5.[18] Equation (1) further controls for county fixed effects, α_c, state-by-time fixed effects, α_{st}, and a set of individual control variables, X_{ict}, which includes age fixed effects, indicator variables for race, and whether the mother lives in a rural area. To account for potential time-varying effects of the latter variables, we also include race-by-rural-by-time fixed effects and all potential interactions among these three variables. The main variable of interest, $Boll\ Weevil\ Intensity_{ct}$, is the interaction between a dummy variable that equals one if county c was infested by the boll weevil at time t and county c's acreage share of cotton planted in 1889.[19] We use data from the pre-infestation year 1889 to ensure that the interaction term is exogenous to fertility changes during the boll weevil infestation period. Standard errors are Huber robust and clustered at the county level.

Since fertility is highly age dependent, we also use an extended specification that allows the effect of the boll weevil on fertility to vary by age

$$Fertility_{ict} = \alpha_c + \alpha_{st} + \sum_{g=1}^{G} \beta_g Age_g \times Boll\ Weevil\ Intensity_{ct} + \Gamma X_{ict} + \varepsilon_{ict}. \tag{2}$$

Our variable of interest, $Boll\ Weevil\ Intensity_{ct}$, is now interacted with a set of dummy variables that capture mother i's age cohort, g, in Census year t. We differentiate between women aged 16-19, 20-24, 25-29, 30-34, 35-39, 40-44, and 45-49. To capture cohort-specific differences in fertility that are independent of the boll weevil infestation, this specification also includes cohort fixed effects (interacted by county and by time). Under the hypothesis that the boll weevil has

[18]We follow Bleakley and Lange (2009) and rely on the variable "NCHLT5" from IPUMS as our main measure of fertility.

[19]The cotton share is constructed as in Ager, Brueckner, Herz (2017, footnote 14). There is no need to include the cotton share in 1889 in the empirical specification, since the direct effect of cotton production in 1889 on fertility is captured by the county fixed effects.

Table 1: The Impact of the Boll Weevil Infestation on Fertility

	(1)	(2)	(3)	(4)	(5)
	Dependent Variable				
	Number of Children under age 5				== 1 if Birth
Age 16-19 × *Boll Weevil Intensity*$_{ct}$	-0.014				
	(0.011)				
Age 20-24 × *Boll Weevil Intensity*$_{ct}$	-0.060***				
	(0.011)				
Age 25-29 × *Boll Weevil Intensity*$_{ct}$	-0.051***				
	(0.013)				
Age 30-34 × *Boll Weevil Intensity*$_{ct}$	-0.027**				
	(0.013)				
Age 35-39 × *Boll Weevil Intensity*$_{ct}$	-0.023**				
	(0.011)				
Age 40-44 × *Boll Weevil Intensity*$_{ct}$	0.006				
	(0.011)				
Age 45-49 × *Boll Weevil Intensity*$_{ct}$	-0.005				
	(0.009)				
Boll Weevil Intensity$_{ct}$		-0.041***	-0.038**	-0.046***	-0.012***
		(0.011)	(0.016)	(0.012)	(0.001)
Boll Weevil Intensity$_{ct}$ × Black			-0.007		
			(0.023)		
Boll Weevil Intensity$_{ct}$ × Above Median HH Income				0.004	
				(0.012)	
County FE	Yes	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes	Yes
State × Time FE	Yes	Yes	Yes	Yes	Yes
Birth Year FE	No	No	No	No	Yes
Mother FE	No	No	No	No	Yes
Observations	13,509,865	9,730,437	9,730,437	8,760,018	62,923,755
R-squared	0.160	0.093	0.093	0.090	0.098

NOTE.—This table shows the boll weevil's impact on fertility. The dependent variable is the number of own children in the household under age 5 in columns (1)-(4) and an indicator variable that is one if a mother gave birth in a given year t in column (5). *Boll Weevil Intensity*$_{ct}$ is the interaction between a dummy variable that equals one if county c was infested at time t and county c's acreage share of cotton planted in 1889. Columns (1)-(4) include county fixed effects, time fixed effects, and state × time fixed effects, and the following set of individual controls: dummies for race, rural, age fixed effects, and interactions between race, rural, and time. We interact *Boll Weevil Intensity*$_{ct}$ with a race dummy in column (3) and with a dummy indicating whether the household income is above the median in column (4). Both specifications include the mean effects for race and above median household income, respectively (not reported). Column (5) includes fixed effects for each mother (and hence county), birth year, and state × time, and controls for the mother's age at birth. Robust standard errors clustered at the county level in parentheses: *** p<0.01, ** p<0.05, * p<0.1.

a negative effect on fertility, we would expect $\beta < 0$ in equation (1). In equation (2), we would expect $\beta_g < 0$ with a larger coefficient in absolute size for mothers in their prime childbearing years.

4.2 Results

Column (1) of Table 1 reports results using estimation equation (2) for our sample of married women in the Cotton Belt of the American South. The estimates reveal that 20 to 39-year-old women were the most affected. The effect for women over age 40 is not statistically significant and practically zero. This finding is reassuring and serves as a consistency check since we would not expect systematic fertility adjustments of older women in reaction to the boll weevil's arrival.

Columns (2)-(4) report results using estimating equation (1), but restricting the sample to 20 to 39-year-old women. In line with our hypothesis, the coefficient on $Boll\ Weevil\ Intensity_{ct}$ is negative and highly statistically significant. Quantitatively, the estimate implies that in a county with median cotton dependency, the arrival of the boll weevil led to a reduction of the number of children less than 5 years old by 0.017 (the median cotton dependency in the sample is 0.424, such that $-0.041 \times 0.424 = -0.017$). This accounts for about 2 percent of the total fertility decline of married 20 to 39-year-olds in the Cotton Belt between 1880 and 1930.[20] Our results remain qualitatively unchanged when using a dummy whether the mother has any child under age 5 or the number of own children under age 10 as alternative measures of fertility (see columns (1) and (2) of Online Appendix Table 3).[21] We also obtain similar results when using alternative empirical specifications such as including a quadratic of $Boll\ Weevil\ Intensity_{ct}$ or using the years of duration of the infestation instead of a binary variable (available upon request). The estimates reported in columns (3) and (4) reveal that there are no significant differences for white and black women and between households below and above the median household income.[22] This shows that the effects

[20] As reported in the descriptive statistics, the mean of the variable $Boll\ Weevil\ Intensity_{ct}$ is 0.19. According to the estimated coefficient in column (2) of Table 1, the weevil's effect on fertility is therefore $0.19 \times (-0.041) = -0.008$. The average number of children under age 5 per married 20 to 39-year-old married women in our sample fell by about 0.45 between 1880 and 1930.

[21] Since estimating equations (1) and (2) include state-by-time fixed effects, our econometric model accounts for potential confounding factors at the state level, even when they vary over time. However, there is still a potential threat from confounding factors that vary over time at the county level. We address these concerns in specification (2) where we include county-by-time fixed effects and use older women (aged 40-44) as a control group. That is, identification comes from within-county variation across age cohorts only. While those older women are not the optimal control group for this specification, the estimates turn out to be similar to column (1) and hence suggest that it is not very likely that time-varying county-specific omitted variables are driving our findings (see column (3) of Online Appendix Table 3).

[22] We also show in Online Appendix Table 2 that estimates are similar when the sample is split by race.

of the boll weevil are independent of race and not driven by credit constrained households.

One drawback of using the decennial U.S. Census data is that we observe women's fertility at a rather low frequency. An alternative way of measuring the impact of the boll weevil on fertility is to construct a flow fertility measure. Since the U.S. Census reports the age of each child in a household, it is straightforward to calculate the respective birth year.[23] We use this information to construct each mother's fertility history. That is, we construct for every mother a time-varying indicator variable, which is one if a child was born in a given year, and zero otherwise. The sample is based on complete count Census microdata for the years 1900, 1910, and 1920 and restricted to observations where the mother's age when giving birth is between 15 and 44. Since we know exactly the year when the boll weevil entered into a county of the Cotton Belt, we can use this data set to explore the boll weevil's effect on the probability of a woman giving birth in a given year. The estimates using this alternative approach are reported in column (5) of Table 1.[24] Identification comes from within mother variation in the probability of giving birth in a given year due to differences in the timing of the boll weevil's arrival in counties with different cotton intensities. In line with our baseline results, we find that there is a lower probability of giving birth in counties with a high initial cotton intensity after the arrival of the boll weevil. The estimated coefficient is statistically significant at the 1-percent level.

4.3 Potential Threats to Identification

One potential threat to identification is that fertility trends in more and less cotton-dependent counties evolved differently before the boll weevil infestation. The existence of such "pre-trends" would undermine our differences-in-differences strategy, because it would invalidate the use of low cotton-dependent counties as a control group. To address this concern, we conduct an event study using the mother panel sample described above. The structure of the mother panel allows

[23]We restrict the sample to children younger than 15 at the time of the Census since older children are likely to have left the household.

[24]Note that county-specific effects are captured by the mother fixed effects (in case the mother stayed throughout her fertility history at her place of residence listed in the Census).

us to calculate the average number of births by 15-44-year-old women in a given county and year, $Fertility_{ct}$. Our estimating equation is

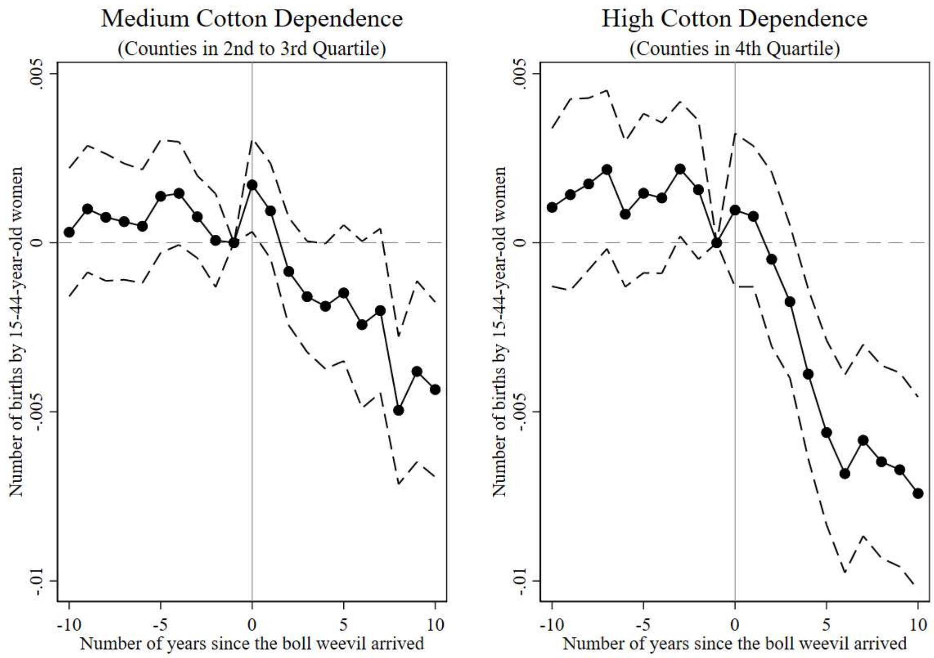
$$Fertility_{ct} = \alpha_c + \alpha_t + \sum_{j \in T} Boll\ Weevil_{ct}^{\tau+j} \times (\beta_j^{med} Cotton_{c,1889}^{med} + \beta_j^{high} Cotton_{c,1889}^{high}) + \varepsilon_{ct} \quad (3)$$

where $T = \{-10, \ldots, -2, 0, \ldots, 10\}$. We omit $j = -1$ (the base year) such that the post-treatment effects are relative to the year before the arrival of the boll weevil in a given county c. The parameter τ refers to the the year in which the boll weevil entered county c. $Boll\ Weevil_{ct}^{\tau+j}$ is an indicator equal to one when $t = \tau + j$ and zero otherwise. Also, to capture the fertility response 10 and more years prior (after) the boll weevil infestation, we define an indicator $Boll\ Weevil_{ct}^{\tau-10} = 1$ if $t \leq \tau - 10$ ($Boll\ Weevil_{ct}^{\tau+10} = 1$ if $t \geq \tau + 10$) and zero otherwise. The specification also includes fixed effects for county, birth year, and the interaction of birth year and state.

We differentiate between low, medium, and highly cotton dependent counties instead of using a continuous measure of cotton intensity to facilitate the interpretation of the event study. The indicator variables $Cotton_{c,1889}^{med}$ and $Cotton_{c,1889}^{high}$ equal one if the cotton share in county c in 1889 is "medium" (2nd to 3rd quartile) or "high" (4th quartile), respectively, while the 1st quartile is the omitted category. The estimated coefficients β_j^{med} and β_j^{high} trace out the effect of the boll weevil infestation on fertility, relative to the omitted category and base year (the year before the arrival of the boll weevil). These coefficients are visualized in Figure 3 and the corresponding estimates are reported in Online Appendix Table 4. We find that for all $j < 0$ $\widehat{\beta_j^{med}} \approx 0$ and $\widehat{\beta_j^{high}} \approx 0$, which clearly supports the identifying assumption of common pre-trends, while after impact the estimated coefficients become negative and statistically significant. The effect is also relatively stronger in high compared to medium cotton dependent counties, corroborating our baseline estimation strategy. From Figure 3, it is also apparent that the fertility decline due to the boll weevil infestation was persistent, which is in line with the finding of Lange et al. (2009) that the local effects of the boll weevil infestation were long lasting.

To further validate our identification strategy we conduct two additional placebo exercises. In

Figure 3: Event Study



NOTE.—This figure shows the dynamic effects of the boll weevil infestation on fertility. The x-axis measures the number of years since the boll weevil arrived in a county c. The solid line depicts the effect on fertility relative to the base year (the year before infestation). The left (right) panel shows the effect for medium (highly) cotton dependent counties. Low cotton dependent counties are the reference group. Dashed lines indicate 90% confidence intervals.

the first exercise, we report placebo regressions that test for effects of the boll weevil prior to actual infestation. To do so, we backdate the boll weevil infestation by 20 years. For example, in a county where the weevil entered in year 1910 we now assume it would have entered in year 1890. Estimates of regression equation (1) using this placebo specification are reported in column (4) of Online Appendix Table 3. Reassuringly, the interaction between the backdated boll weevil incidence and the 1889 cotton share is small and not statistically different from zero. This finding is also in line with our event study results which show that there are no pre-trends before infestation. In the second placebo exercise, we add the interaction between the boll weevil and the corn share planted in 1889 to estimating equation (1). Columns (5) and (6) of Online Appendix Table 3 show that our main results are unchanged, while the interaction effect between the boll weevil and the corn share is small and always statistically insignificant.

Lange et al. (2009) document that farmers, as a reaction to the boll weevil, shifted agricultural production from cotton to corn, the main alternative crop in the Cotton Belt. Crop-shifting might therefore have mitigated the weevil's negative effect on fertility. To analyze whether this was actually the case we include an interaction of $Boll\ Weevil\ Intensity_{ct}$ with a measure of a county's suitability for corn cultivation in our estimating equation.[25] Since crop-shifting should be especially attractive in counties where corn could easily be planted, we would expect this interaction to be positive if there was indeed such a mitigating effect. In columns (7) and (8) of Online Appendix Table 3 we show that this is not the case.

One potential concern is that our results might be driven by composition bias. The arrival of the boll weevil might have triggered selective migration of households. Households that migrated as a response to the boll weevil's arrival might on average have been wealthier and have more children. To address this issue, we look at samples of households from the 1900, 1910, and 1920 Censuses, which have been linked to the 1880 Census by the IPUMS (Ruggles et al., 2017). These linked samples allow us to evaluate the effect of migration on fertility. We only consider linked households where a wife of age 20 to 39 is present in the terminal period. Reassuringly, columns (1) and (2) of Online Appendix Table 5 show that households that migrated out of a county did not have higher fertility, but actually lower fertility. As an alternative test, in columns (3)-(4) of Online Appendix Table 5 we replicate the specifications of Table 1 columns (2) and (5), while restricting the sample to mothers who report to reside in their state of birth. Since the estimates are similar to the baseline estimates in Table 1 we can rule out that our findings are driven by inter-state migration. In conclusion, the presented evidence on migration corroborates our baseline results and makes it unlikely that composition bias is of great concern.

The boll weevil might also have increased child mortality due to poorer nutrition or even starvation, although recent empirical evidence from Clay, Schmick, and Troesken (forthcoming) suggests that this was not the case. To address this potential concern, we explore the effect of the boll weevil infestation on child mortality and stillbirths.[26] Online Appendix Table 6 columns (1)-(3) shows

[25] Data on corn suitability come from the Food and Agricultural Organization.

[26] Data are retrieved from the 1900 and 1910 Censuses (see IPUMS variable descriptions of "CHBORN" and

that there was no positive effect. In this context, one further potential concern is whether the arrival of the boll weevil impaired fecundity, for example, due to greater maternal stress. Since the Censuses in 1900 and 1910 list the number of children ever born, we can construct a dummy for being childless for women aged 20 to 39 who report to be married for at least two years to proxy for impaired fecundity.[27] The insignificant estimate in column (4) suggests that this was not the case. Overall, the results of Online Appendix Table 6 support the view that the decision of households to have less offspring was not a result of increased child mortality or impaired fecundity.

Even though we only consider married mothers in our analysis, it could be that in infested counties mothers have fewer children because they postpone marriage (Bloome et al., 2017). To address this concern, we include age at marriage fixed effects as additional controls in estimating equation (1).[28] Reassuringly, our results indicate that the fertility behavior of married women in our sample is not driven by delayed marriage in boll weevil infested counties (see column (9) of Online Appendix Table 3).

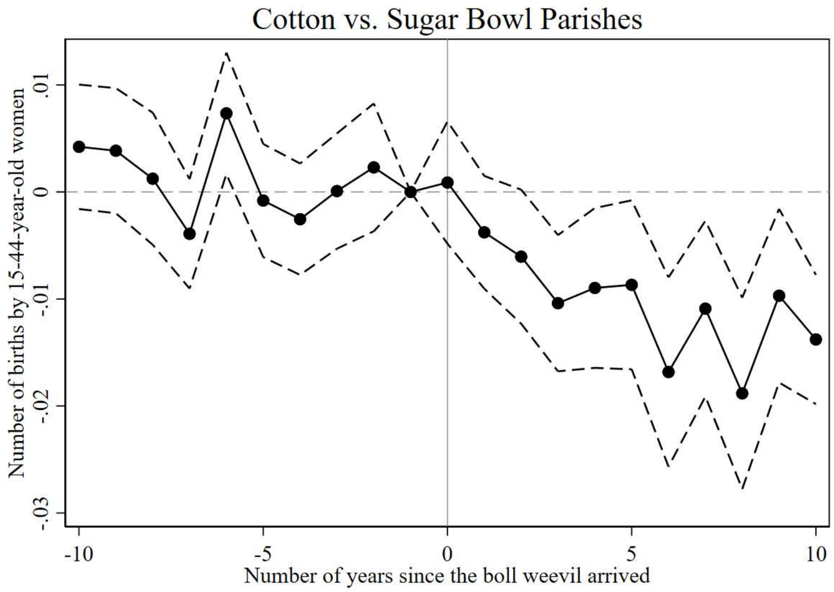
Finally, our results might also be driven by differential fertility dynamics in counties where plantation farming was considered to be important. Large-scale plantation favored family formation and provided strong incentives for child bearing since farm allotments were determined by family size (Elman et al., 2015). In column (10) of Online Appendix Table 3, we show that mothers' fertility behavior in plantation counties, as defined by Brannen (1924, p.69), did not respond differently compared to the rest of the sample after the boll weevil's arrival. Since these counties were also characterized by relatively high (land) inequality, this finding can also be regarded as suggestive evidence that land inequality is not a main driver of the impact that the boll weevil infestation had on fertility.

"CHSURV" for further details) and from Fishback, Haines, and Kantor (2007).

[27] In the American South at that time it was not common for married women to voluntarily delay the first marital birth; see, for example, Elman et al. (2015).

[28] The age at marriage is constructed using the IPUMS variables "DURMARR" (available for the Census years 1900 and 1910) and "AGEMARR" (available for the Census year 1930).

Figure 4: "Sugar Bowl" Case Study



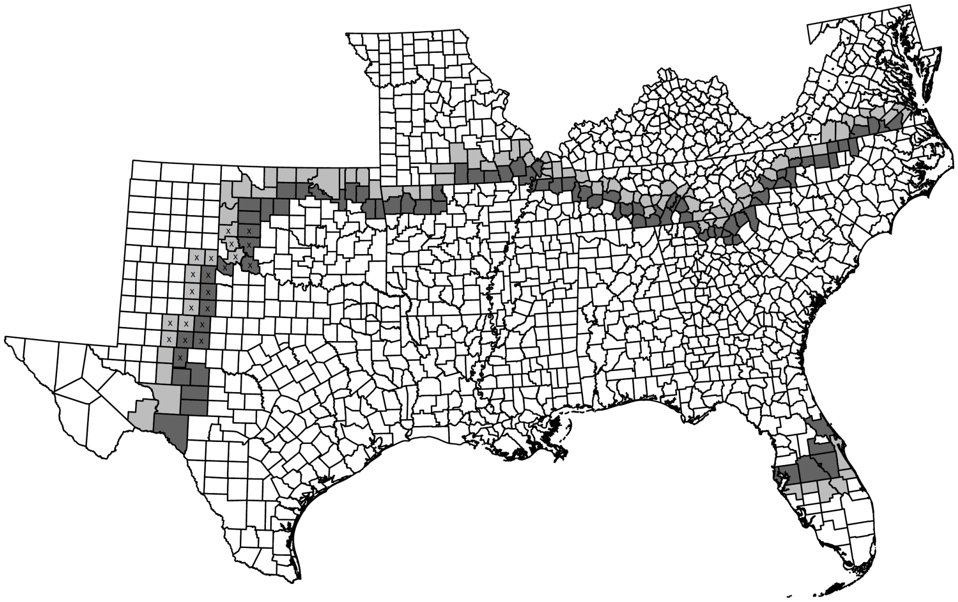
NOTE.— This figure shows the dynamic effects of the boll weevil infestation on fertility in Louisiana. The x-axis measures the number of years since the boll weevil arrived in a parish c. The solid line depicts the effect on fertility relative to the base year (the year before infestation). The panel shows the effect for highly cotton dependent Louisiana parishes. Parishes of the "Sugar Bowl" are the reference group. Dashed lines indicate 90% confidence intervals.

4.4 Case studies

This subsection provides evidence from two case studies that the boll weevil's negative effect on fertility is robust to using alternative sets of control groups. In particular, we consider control counties that were either specialized in producing other main cash crops within the cotton belt or are located on the frontier of the boll weevil infestation in the 1920s.

The first case study focuses on Louisiana. While Louisiana was part of the cotton-belt and many parishes were engaged in cotton cultivation, some parishes, well-known for specializing in sugar cultivation, formed the "Sugar Bowl" (see Rodrigue, 2001, footnote 2). These parishes serve as an ideal control group to study the impact of the weevil—they were highly agricultural, but cotton production played either a very minor or even no role, and the weevil infested all parishes in Louisiana at about the same time (the first parish was infested in 1903 and the last in 1909), which makes it less likely that our estimates are confounded by time-specific effects. Figure 4 shows an

Figure 5: The frontier of the boll weevil infestation in 1922



NOTE.—The figure shows the frontier of the boll weevil infestation in 1922, the year the vermin reached its maximal spread and almost the whole cotton belt was infested. The case study in Section 5.4 compares fertility in counties on the frontier that have not been infested (light gray) with adjacent counties that have been infested (dark gray). Counties with a high cotton dependency are marked with an "x."

event study based on equation (3) that compares the effect of the boll weevil on fertility in highly cotton-dependent parishes with "Sugar Bowl" parishes (the corresponding estimates are reported in Online Appendix Table 7). Reassuringly, the results are very much in line with our previous findings: At the time of impact, we see a significant and persistent reduction in fertility and no pre-trends before infestation.

In our second case study, we analyze counties on the frontier of the area infested by the boll weevil in the year 1922—when virtually the entire Cotton Belt was infested and the spread of the vermin reached its maximal extent (see Figure 2). While in our baseline analysis identification comes from varying degrees of counties' cotton-dependency, in this case study we compare counties that were infested with counties that were never infested by the weevil (see Figure 5).[29] Counties in our control group were not infested for two different reasons. One group had no or only

[29]We exclude Florida's boll weevil frontier from the analysis, as some border counties were only established a few years before the 1920 Census, such as Seminole or Okeechobee county, or even after the 1920 Census, such as Hardee, Highlands, or Indian River counties, making proper identification impossible.

Table 2: Case Study—Counties on the Frontier of the Boll Weevil Infestation

	(1)	(2)
	Dependent Variable	
	Number of Children under Age 5	
Boll Weevil Intensity$_{ct}$	-0.114***	-0.112**
	(0.041)	(0.051)
Boll Weevil Intensity$_{ct}$ $\times$ Low Cotton		-0.004
		(0.050)
County FE	Yes	Yes
Time FE	Yes	Yes
State $\times$ Time FE	Yes	Yes
Observations	1,142,806	1,142,806
R-squared	0.089	0.089

NOTE.—This table shows the boll weevil's impact on fertility for the subsample of counties on the frontier of the boll weevil infestation in 1922. We compare counties on the frontier that were infested with neighboring counties that were not infested by 1922; see Figure 5. The dependent variable is the number of own children in the household under age 5. The sample consists of married women age 20 to 39 for the decades 1910 to 1930. *Boll Weevil Intensity*$_{ct}$ is the interaction between a dummy variable that equals one if county c was infested at time t and county c's acreage share of cotton planted in 1889. Regressions include county fixed effects, time fixed effects, and state $\times$ time fixed effects, and the following set of individual controls: dummies for race, rural, age fixed effects, and interactions between race, rural, and time. Robust standard errors clustered at the county level in parentheses: *** p<0.01, ** p<0.05, * p<0.1.

very minor cotton cultivation while counties in the second group cultivated cotton but "adverse" weather conditions such as frost and dry climate prevented infestation. Important drawbacks of this case study, besides the smaller sample size, are that the infestation of the treated sample counties occurred relatively late (circa 1920); and some counties are sparsely populated while others did not cultivate any cotton. Table 2 reports the results of this case study based on regression equation (1). We find that infested counties experienced a significant decline in fertility relative to non-infested counties, albeit the estimate is somewhat larger compared to our baseline results. In column (2), we show that distinguishing between high and low cotton cultivating counties in the control group does not affect our estimates.

Table 3: The Boll Weevil's Effect on Agricultural Income and Industrialization

	(1)	(2)	(3)	(4)	(5)
			Dependent Variable		
	Agricultural Income	Works in Manufacturing	Works/Lives on Farm	% in Manufacturing	Leaves Farm 1880-1920
Boll Weevil Intensity$_{ct}$	-0.190***	0.009***	-0.041***	0.146***	0.057*
	(0.036)	(0.004)	(0.015)	(0.056)	(0.033)
County FE	Yes	Yes	Yes	Yes	No
State FE	Yes	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes	Yes
State × Time FE	Yes	Yes	Yes	No	No
Observations	5,831,000	61,089,255	61,089,255	3,572	6,140
R-squared	0.450	0.088	0.263	0.795	0.029

NOTE.— This table shows the impact of the boll weevil on agricultural income and industrialization. The dependent variables are the income of agricultural households; a dummy variable that indicates whether a person works in manufacturing; works/lives on a farm; the fraction of the county population working in manufacturing (in logarithmic units); and an indicator variable that is one if an individual left agriculture. The sample consists of married women of age 20 to 39 in agricultural households (column 1); individuals of working age (columns 2-3); and aggregated county level data in column (4) for the decades 1880 to 1930. The linked sample of male household heads is used in column (5). *Boll Weevil Intensity*$_{ct}$ is the interaction between a dummy variable that equals one if county c was infested at time t and county c's acreage share of cotton planted in 1889. In column (1), the set of individual controls includes dummies for race, rural, age fixed effects, and interactions between race, rural, and time. In columns (2)-(3), the set of individual controls includes dummies for gender, race, and age fixed effects, and interactions between race and time. The specifications in columns (1)-(3) further include fixed effects for county, and state × time. The county level regression in column (4) includes county and year fixed effects. The specification in column (5) includes a dummy for race, a quadratic in age, the cotton share in 1889, and fixed effects for time and state. Robust standard errors clustered at the county level in parentheses: *** p<0.01, ** p<0.05, * p<0.1.

5 Structural Change

Recent research has documented that the boll weevil had a persistent detrimental effect on cotton production (Lange et al., 2009; Ager, Brueckner, and Herz, 2017). In this section, we show that the infestation led to substantial income losses for agricultural households in cotton dependent counties (subsection 5.1). We also find that a significant number of households reacted to the reduced earnings prospects by leaving the agricultural sector for manufacturing jobs (subsection 5.2). We conclude that the boll weevil constitutes a useful source of plausibly exogenous variation that can be used to identify the economic consequences of structural change in the Cotton Belt.

5.1 The Boll Weevil's Effect on Agricultural Income

This subsection focuses on agricultural households based on the sample of married women (sample (a) described in Section 3).[30] We re-estimate equation (1) based on a sample of about 5.8 million households using agricultural household income as the dependent variable. Agricultural income is calculated as the sum of the wife's and husband's income which varies over time, across agricultural occupations, and across counties for farmers or states for farm laborers (see Section 3 and the data appendix for further details).

$$Income_{ict} = \alpha_c + \alpha_{st} + \beta Boll\ Weevil\ Intensity_{ct} + \Gamma X_{ict} + \varepsilon_{ict}. \tag{4}$$

Column (1) of Table 3 presents estimates for households with wives aged 20 to 39. We find a negative effect of the boll weevil on household income in more cotton-dependent counties, which is statistically significant at the 1-percent level. The estimates imply that households residing in a county with a median intensity of cotton production experienced a decline of agricultural income by about 8 percent upon arrival of the boll weevil. Part of this effect can be interpreted as households moving down the agricultural ladder, consistent with the findings of Ager, Brueckner, and Herz (2017). However, this result also reveals that agricultural households experienced a substantial loss in earnings within occupations. This is evident from estimating equation (4) using the IPUMS "OCCSCORE" variable as an alternative dependent variable. The estimated β is -0.03 with standard error 0.01, which is substantially smaller than the estimate presented in column (1). The likely reason for obtaining a smaller coefficient is that, compared to our agricultural income measure, the "OCCSCORE" variable only varies *across* but not *within* occupations. In line with the recent literature discussed in Section 2, our results reveal that agricultural households in the more cotton dependent counties suffered substantial and persistent income losses. We further test

[30]We consider a household to be agricultural if it resides on a farm (indicated in IPUMS by the variable "FARM") or if the husband reports one of the following occupations ("OCC1950" from IPUMS): farmers (owners and tenants) (100), farm managers (123), farm foremen (810), farm laborers, wage workers (820), farm laborers, unpaid family workers (830), farm service laborers, self-employed (840), and unclassified laborers (970) if the household's location is rural.

whether crop shifting mitigated the income losses for agricultural households by adding the interaction of the $Boll\ Weevil\ Intensity_{ct}$ with corn suitability (see Section 4.3). While the coefficient on the interaction term is positive, it is small and statistically insignificant (available upon request). This also implies that potential shifts to alternative crops in response to the boll weevil infestation as documented by Lange et al. (2009) and Ager, Brueckner, and Herz (2017) did not fully compensate for the income losses due to impaired cotton production.

5.2 The Boll Weevil's Effect on Industrialization

In this subsection, we document that the boll weevil triggered a shift from agriculture to manufacturing in the affected counties. We re-estimate equation (1) for individuals of working-age (10 to 65-year-olds) residing in the Cotton Belt of the American South during the 1880-1930 period. The dependent variable is a dummy that indicates whether an individual works in manufacturing or lives/works on a farm.[31] The estimating equation is

$$occ_{ict} = \alpha_c + \alpha_{st} + \beta Boll\ Weevil\ Intensity_{ct} + \Gamma X_{ict} + \varepsilon_{ict}. \tag{5}$$

Since this sample consists of both men and women, we also include a dummy for gender. Columns (2)-(3) of Table 3 summarize the results. Column (2) shows that individuals in boll weevil infested counties are more likely to be employed in manufacturing. For example, individuals living in a county with a high cotton intensity (i.e., all counties above the 75th percentile of the 1889 cotton share)[32] are about 0.5 percentage points more likely to be employed in manufacturing upon the boll weevil's arrival (approximately 5 percent of individuals are employed in manufacturing; see Online Appendix Table 1). Column (3) reports a significant decline of individuals living/working on a farm consistent with the findings of Ager, Brueckner, and Herz (2017). For example, in a county with a high intensity of cotton production, the farm population went down by about 2.2 percentage points.

[31]Based on the variable "OCC1950" from IPUMS, the categories are defined as follows: manufacturing is "OCC1950" 500-690 and lives/works on a farm is "OCC1950" 100, 123, 810-840, 970 (if rural) or lives on a farm ("FARM" = 2) if "OCC1950" >970.

[32]The 1889 cotton share at the 75th percentile is 54 percent.

This effect is quantitatively larger if we only consider individuals reporting a gainful occupation in agriculture (available upon request).[33] Column (4) complements the micro-level results with county-level data.[34] The relative increase in manufacturing activities in these counties is also in line with Ager, Brueckner, and Herz (2017), who find that there is a substantial relative decline in the number of farms and agricultural land usage in counties with a higher initial cotton intensity after the boll weevil's arrival. Overall, the evidence presented in this section suggests that the boll weevil triggered a shift out of agriculture in more cotton-dependent counties. The estimated effects of the boll weevil infestation on structural change may not seem very sizable (consistent with Wright, 1986), however, given that the average level of manufacturing employment reached at the time in the Cotton Belt was relatively low, they are quite substantial.

One potential concern is that the results documented above might be driven by a composition effect. That is, the shift from farming to manufacturing activities might be a consequence of selective migration. Using a set of linked representative samples from the IPUMS, we show in column (5) that in a county with a high cotton intensity, the boll weevil infestation increased the probability that households moved out of the agricultural sector by 3.1 percentage points. This confirms that our estimate reported in column (3) is not likely to be driven by selective migration.

6 Effect of Structural Change on Fertility

In this section, we exploit plausibly exogenous variation in agricultural production to estimate the causal effect of changes in the agricultural earnings potential on fertility in the American South. The following two subsections, 6.1 and 6.2, document two separate channels: (i) lower agricultural income reduces the fertility of stayer households, consistent with the notion that children are a normal good; and (ii) switcher households reduce their fertility, potentially because working in

[33]Individuals reporting a gainful occupation in agriculture corresponding to the following codes of "OCC1950:" 100, 123, 810-840, and 970 (if rural).

[34]For a county with an initial cotton share at the 75th percentile, the arrival of the boll weevil increased the share of the population working in the manufacturing sector by approximately 8 percent, which is consistent with the quantitative evidence reported in column (2).

Table 4: Structural Change and the Fertility Transition

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Dependent Variable								
	No. Children under Age 5	ln(Agricultural Income)	No. Children under Age 5	No. Children under Age 5	Δln(Income)	No. Children under Age 5	ln(Agricultural Income)	% in Manufacturing	No. Children under Age 5
ln(Agricultural Income)	0.156***					0.156***			
	(0.036)					(0.043)			
% in Manufacturing						-0.209***			
						(0.042)			
Boll Weevil Intensity$_{ct}$		-0.439***	-0.068***				-0.413***	0.127**	-0.091***
		(0.050)	(0.012)				(0.0380)	(0.0618)	(0.009)
Tobacco							-0.0218	-0.215***	0.042***
							(0.0280)	(0.0421)	(0.007)
Leaves Farm				-0.251***	0.242***				
				(0.040)	(0.068)				
County FE	Yes	Yes		No	No	Yes	Yes	Yes	
State FE	Yes	Yes		Yes	Yes	Yes	Yes	Yes	
Time FE	Yes	Yes		Yes	Yes	Yes	Yes	Yes	
Observations	3,568	3,568	3,568	2,346	1,149	5,693	5,693	5,693	5,693
R-squared		0.644	0.854	0.116	0.228		0.713	0.778	0.909
Kleibergen-Paap	75.66					12.52			
IV-Equation	2nd stage	1st stage	reduced form			2nd stage	1st stage	1st stage	reduced form
F-Statistic Instrument 1						41.23			
F-Statistic Instrument 2						26.58			

NOTE.— This table shows estimates of the causal impact of structural change on the fertility transition. Columns (1) and (6) show two-stage least squares estimates based on equations (6) and (8). Columns (2), (7)-(8) report the corresponding first-stage regressions and columns (3) and (9) report the reduced form regressions. The two-stage least squares specifications are conducted at the county level and include fixed effects for county and time. Columns (4)-(5) use a sample of linked households from IPUMS. The method of estimation is least squares. In column (4) we restrict the sample to men with a wife of age 20-49 in the terminal year; in column (5) we restrict the sample to men of age 20 or older in 1880 and not older than 65 in the terminal year. Further controls are a dummy for race, a quadratic in age, the cotton share in 1889, fixed effects for time and state. Robust standard errors clustered at the county level in parentheses: *** p<0.01, ** p<0.05, * p<0.1.

manufacturing is less compatible with childbearing, and because the direct costs of having children are higher (in particular, the value of child labor in agriculture might be higher). We then exploit a second source of exogenous variation in agricultural production—the dramatic increase of cigarette consumption during World War I on local tobacco cultivation—to disentangle the effects of the two channels on the fertility decline. In both subsections the analysis is conducted at the county-level since agricultural income is only observable for households staying in agriculture. Subsection 6.3 discusses the exclusion restriction of the instrumental variable strategy.

6.1 Effect of Agricultural Income on Fertility

In this subsection, we quantify the effect of agricultural income on fertility for households staying in agriculture. We would expect this relationship to be positive within agricultural occupations, since the income effect is likely to dominate the substitution effect when the opportunity costs of child rearing are low. To estimate the causal relationship between agricultural income and fertility for stayer households, our empirical analysis exploits exogenous variation due to the boll weevil infestation in a two-stage least squares approach. The estimating equation is

$$Fertility_{ct} = \alpha_c + \alpha_t + \delta Income_{ct} + \varepsilon_{ct}. \tag{6}$$

$Fertility_{ct}$ is the average number of children under age 5 of 20 to 39-year-old married women in agricultural households in county c in year t. $Income_{ct}$ is the average labor income from agricultural activities. The empirical specification controls for county fixed effects, α_c and time fixed effects, α_t. Standard errors are Huber robust and clustered at the county level.

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

$$Income_{ct} = \alpha_c + \alpha_t + \gamma Boll\ Weevil\ Intensity_{ct} + \varepsilon_{ct}, \tag{7}$$

where $Boll\ Weevil\ Intensity_{ct}$ is defined as in Section 4.1. Identification in the two-stage least squares estimation comes from the differential effect that the incidence of the boll weevil had on agricultural income and fertility due to differences in the importance of (initial) cotton production in the Cotton Belt counties of the American South.

Columns (1)-(3) of Table 4 present the two-stage least squares results for stayer households. The second-stage coefficient is reported in column (1) and implies that a decline in agricultural income of 10 percent decreases the number of children under age 5 by 0.015. Such an income reduction would explain about 3.5 percent of the overall decline in the number of children under age 5 between 1880 and 1930.[35] The estimated first-stage coefficient γ in column (2) is negative and statistically significant at the 1-percent level. In counties where cotton production is relatively more important, the boll weevil infestation had a larger, negative, effect on agricultural income. In terms of instrument quality, the two-stage least squares estimation strategy yields a reasonable first-stage fit, as the Kleibergen-Paap F-statistic exceeds the critical value of 10 (Stock and Yogo, 2005). For completeness, we show the reduced form estimate in column (3).

[35]The total decline in the number of children under age 5 in the Cotton Belt was 0.45 during the sample period.

6.2 Effect of Industrialization on Fertility

In this subsection, we show evidence that agricultural households that switched to manufacturing reduced their fertility. We then provide causal evidence that a shift to manufacturing due to lower agricultural earnings opportunities reduces fertility.

During our sample period, 20 to 39-year-old married women in agricultural and non-agricultural households reported to have 1.08 and 0.69 children below the age of 5, respectively. While suggestive, this is not conclusive evidence that switching to manufacturing will induce a household to reduce fertility, since households with a stronger preference for children might also be more likely to work in the agricultural sector, independent of the cost of child rearing. We address this issue by showing complementary evidence based on a sample of households from the 1900, 1910, and 1920 Censuses, which have been linked to the 1880 Census by IPUMS. This allows us to compare the fertility of switcher households to that of households remaining in the agricultural sector throughout the period.[36] We restrict our sample to households that were initially (in 1880) in the agricultural sector to alleviate concerns regarding the importance of selection bias. In column (4) of Table 4, the estimated coefficient on the dummy variable, *Leaves Farm*, indicates that switcher households have around 0.25 fewer children under age 5 than stayer households. This effect is statistically significant at the 1-percent level. In column (5), we show that switching to manufacturing also went along with a substantial increase in income. The results in this and the previous sections are therefore consistent with the theoretical framework by Mookherjee et al. (2012), which postulates a positive wage-fertility correlation within broad occupations or human capital categories, but a negative correlation between parental wages and fertility across occupations.

While compelling, the evidence discussed above does not show that industrialization had a causal effect on fertility. A challenge to identification is that the arrival of the boll weevil represents only one source of exogenous variation. We therefore cannot simultaneously use it as an instrument for structural change on the intensive margin (reduction of agricultural income for

[36] As shown in Section 5.1, the arrival of the boll weevil decreased agricultural income and therefore led to a fertility decline. We therefore exclude households that stayed in agriculture and lived in a county where the boll weevil was present in the terminal year (1900, 1910, or 1920).

stayer households) and on the extensive margin (industrialization; that is, households switching to the manufacturing sector).

In order to disentangle and quantify the importance of each channel we therefore exploit the unprecedented increase in cigarette consumption during World War I as a second source of exogenous variation in agricultural production.[37] The commander of the American Expeditionary Forces in World War I, General Pershing, regarded tobacco as essential for the morale of American soldiers in Europe and requested cigarettes be part of the daily ration of American troops in 1917 (Tate, 2000; Brandt, 2007). Following Pershing's request, the U.S. government spent approximately 80 million U.S. dollars (or equivalently 1,480 million U.S. dollars in 2015) on tobacco products between April 7, 1917 and May 1, 1919. "[Since the U.S.] government shipped about 5.5 billion manufactured cigarettes along with enough tobacco to roll another 11 billion oversees" (Tate, 2000, p.75) during that period, it is needless to say that such an unprecedented increase in demand stimulated tobacco cultivation in the American South and can be regarded as plausibly exogenous for local producers.

We construct the second instrument as the product of the tobacco farm price in a given year and the share of tobacco cultivated in a county in 1909 (the last Agricultural Census prior to WWI).[38] The instrument is in the spirit of a so-called "shift-share" instrumental variable approach as it predicts local tobacco production based on the interaction of aggregated demand shocks and a predetermined distribution of tobacco cultivation at the county level (e.g., Bartik, 1991). Since most of the tobacco cultivation took place outside the Cotton Belt counties, the sample for the following empirical analysis includes all counties of the state of Kentucky and the Cotton Belt states. This ensures that we include the most important tobacco producing counties of the American South in the empirical analysis.[39] It is important to note that this instrument does not need to capture the

[37]Tobacco was another major cash crop in the American South during the sample period; see, for example, Towne and Rasmussen (1960).

[38]The tobacco share is constructed analogously to the cotton share. We consider the tobacco farm prices of the state of Kentucky—the largest tobacco producing state at that time—as being representative of the tobacco producing states in the American South; the corresponding data sources are listed in the data appendix. The evolution of the tobacco farm price in Kentucky is shown in Online Appendix Figure 1.

[39]Kentucky, North Carolina, Tennessee, Virginia, and South Carolina were the five most important tobacco producing states accounting for more than 75 percent of the overall U.S. tobacco production in 1919.

main source of variation in agricultural earnings opportunities, for our identification strategy, it is sufficient that it provides some plausibly exogenous variation in agricultural production besides the boll weevil infestation.

We use the following two-stage least squares approach using two instruments:

$$Fertility_{ct} = \alpha_c + \alpha_t + \kappa Income_{ct} + \theta MfgShare_{ct} + \varepsilon_{ct}, \tag{8}$$

where $Fertility_{ct}$ denotes the average number of children under age 5 of 20 to 39-year-old women in county c at time t. The two endogenous variables are $Income_{ct}$, measured as the average logarithmic income of individuals working in agriculture, and $MfgShare_{ct}$, which is the fraction of the county population working in manufacturing measured in logarithmic units. Equation (8) further includes county fixed effects, α_c, and year fixed effects, α_t. We compute standard errors that are Huber robust and clustered at the county level.

The corresponding first-stage equations are:

$$Income_{ct} = \alpha_c + \alpha_t + \lambda Boll\ Weevil\ Intensity_{ct} + \mu Tobacco_{ct} + \nu_{ct} \tag{9a}$$

$$MfgShare_{ct} = \alpha_c + \alpha_t + \pi Boll\ Weevil\ Intensity_{ct} + \tau Tobacco_{ct} + \xi_{ct}. \tag{9b}$$

The excluded instruments are $Boll\ Weevil\ Intensity_{ct}$ and $Tobacco_{ct}$, defined as the interaction between the farm price of tobacco in year t and county c's acreage share of tobacco planted in 1909.[40] Identification comes from the differential effect that the incidence of the boll weevil and the tobacco instrument had on agricultural income, the manufacturing share, and fertility due to differences in the importance of local cotton and tobacco production in the American South.

Column (6) of Table 4 presents the county-level results on the effect that industrialization in the American South had on fertility based on estimating equation (8); the corresponding first-stage and reduced form estimates are reported in columns (7)-(9). Consistent with our previous find-

[40] The direct effects of the county share of cotton in 1889 and the tobacco share in 1909 are captured by the county fixed effects.

ings, the two-stage least squares estimates show that a decline in agricultural income and a rise in the manufacturing share significantly reduced fertility. The coefficients of interest are statistically significant at the 1-percent level and the Sanderson-Windmeijer first-stage F-statistic for both instruments indicates that the instrumental variable estimates are not substantially biased. A 10 percent increase in the manufacturing share reduces the number of children under age 5 of 20 to 39-year old mothers by about 0.02. This effect is quantitatively sizable: Based on our estimates, the increase in the manufacturing share over our sample period explains about 29 percent of the overall marital fertility decline between 1880 and 1930.

6.3 Exclusion Restriction and Sensitivity Analysis

One potential threat to identification is that our instruments might affect the fertility behavior of agricultural households through other channels than agricultural income or a shift in the manufacturing share. In Section 2, we discussed recent evidence that the boll weevil induced population movements, a shift of production to corn, changed southern agricultural labor arrangements, and labor market outcomes. It follows from this literature that these effects can be regarded as a direct consequence of changed earnings opportunities in the agricultural sector and therefore do not constitute a threat to the instrumental validity. However, it still might be the case that, regardless of any changes in agricultural earnings opportunities, initial differences in these attributes in affected counties might have contributed to differential changes in fertility over the sample period. We address this potential issue in Online Appendix Table 8. Columns (2) to (6) of Panel A show that the empirical estimates are robust to controlling for pre-infestation values of population, the black share, the corn share and total acres planted in crops, the tenant share, and the female labor force participation rate at the count level interacted with a full set of time fixed effects (column (1) reports the baseline for comparison). In Panel B we also include a measure of the 1880 fertility fully interacted with time fixed effects, which is a flexible and demanding way of controlling for any mean reverting fertility dynamics. While we find slight changes in the relative contribution of agriculture income and the manufacturing share to fertility, our results remain qualitatively unaffected.

Another potential issue is that the lower agricultural earnings opportunities might have directly incentivized parents to invest more in the education of their children and therefore reduced fertility independently of its effect through agricultural income or the manufacturing share. In Section 7, we provide evidence that this was not the case: Although we report a rise in schooling, we find no evidence of an increase in the returns to education due to the presence of the boll weevil per se. To the contrary, our evidence suggests that increased schooling is exclusively driven by diminishing returns to child labor and the associated increase in the direct cost of raising children (regardless of child quality), which decreased household income.[41] Moreover, if switcher households would decide to invest more in their children's education and therefore reduce fertility, this would ultimately be a consequence of the switching decision (triggered by the lower agricultural earnings opportunities) and, hence, not constitute a threat to our identification strategy.

7 Human Capital

In this section, we show that the lower earnings opportunities in agriculture led to a substantial decline in child labor, which stimulated human capital formation in the Cotton Belt. For the empirical analysis, we use a sample of 10 to 15-year-old children that can be linked to their mothers from the 1900 to 1930 full count U.S. Census microdata.[42] The specification in this section is identical to equation (1), except that the dependent variable is a dummy that equals one if a 10 to 15-year-old child reports a gainful occupation, regularly attends school,[43] or is considered to be "idle," that is, the child neither regularly attends school nor reports a gainful occupation. Our specification further accounts for potential differences in parental education levels by including dummies for

[41]Following the notation in Galor (2012, Section 4.1), this would correspond to an increase in τ^q (i.e., the fixed costs of child rearing regardless of child quality), while τ^e (i.e., the costs of investing in child quality) would remain unaffected.

[42]The 1880 IPUMS full count Census data do not include information on school attendance.

[43]As Bleakley and Lange (2009), regular school attendance is a dummy variable equal to one if a child is attending and not working. For 1900, we construct school attendance based on the IPUMS variable "SCHLMNTH." For 1910, we use the IPUMS variable "SCHOOL". We consider a child to be working if a gainful occupation is reported in the Census.

Table 5: The Impact of the Boll Weevil Infestation on Child Labor and Schooling

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Dependent Variable						
	==1 if child works	==1 if attends school	== 1 if idle	Schools	Teachers	Schools	Teachers
Boll Weevil Intensity$_{ct}$	-0.079***	0.046***	0.034***	0.212***	0.514***	-0.035	0.045
	(0.014)	(0.014)	(0.008)	(0.044)	(0.103)	(0.070)	(0.180)
Boll Weevil Intensity$_{ct}$ × Share Child Labor						0.481***	0.912***
						(0.140)	(0.331)
Black Share	No	No	No	Yes	Yes	Yes	Yes
County FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
State FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
State × Time FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	7,641,595	7,490,359	7,490,359	1,700	1,700	1,700	1,700
R-squared	0.234	0.221	0.047	0.785	0.774	0.790	0.776

NOTE.— This table shows the boll weevil's impact on child labor and schooling. The dependent variables in columns (1)-(3) are a dummy whether a child works, regularly attends school, or is idle. In columns (4)-(7) the dependent variable is the number of Rosenwald schools and teachers per 1,000 inhabitants. *Boll Weevil Intensity*$_{ct}$ is the interaction between a dummy variable that equals one if county c was infested at time t and county c's acreage share of cotton planted in 1889. *Boll Weevil Intensity*$_{ct}$ × Share Child Labor is the interaction of *Boll Weevil Intensity*$_{ct}$ with county c's child labor share in 1910. Columns (1)-(3) include the following set of individual controls: dummies for gender, race, rural, parents' literacy, age fixed effects, and interactions between race, rural and time. All specifications include fixed effects for county, and state × time. Columns (4)-(7) further control for the share of black people in county c at time t. Robust standard errors clustered at the county level in parentheses: *** p<0.01, ** p<0.05, * p<0.1.

father's and mother's literacy. Standard errors are Huber robust and clustered at the county level.

Table 5 summarizes the results. In columns (1) and (2) we find that in the more affected counties the boll weevil infestation resulted in a substantial decline in child labor, while, at the same time, regular school attendance of 10 to 15-year-old children increased significantly. Both effects are statistically significant at the 1-percent level. For a county with a high cotton intensity (ranked at the 75th percentile), the boll weevil infestation led to a decrease in the likelihood that a 10 to 15-year-old child reports a gainful occupation by more than 4 percentage points. Given that about 23 percent of children in the Cotton Belt worked during the period 1900-1930 (see Online Appendix Table 1), this effect is quantitatively important and also suggests that child labor at this time was relatively less valuable outside agriculture.[44] At the same time the likelihood that a child of the same age group regularly attended school increased by 2.5 percentage points.[45] Compared

[44]This is in line with the view that children had a comparative advantage in picking cotton (Goldin and Sokoloff, 1984).

[45]This finding is line with Baker (2015, p.1129), who argues that "since cotton generated more demand for child labor than did its substitutes, the shift away from cotton production following the arrival of the boll weevil provides an exogenous drop in the marginal product of child labor in agriculture. Because such a drop in child productivity reduces

to the effect on child labor, the schooling effect is more modest, as about two-third of children of this age group attended school regularly (see Online Appendix Table 1).

Column (3) of Table 5 shows that this smaller effect on schooling is due to the fact that a substantial fraction of parents left their children idle after the cotton fields were ravaged by the boll weevil. In a county with a high cotton intensity, this increase was almost 2 percentage points, which is a sizable effect, since only about 9 percent of 10 to 15-year-old children were listed as idle (see Online Appendix Table 1). These findings indicate that reduced agricultural earnings opportunities primarily reduced the value of child labor but did not increase the attractiveness of schooling and the returns to education per se.

We can also directly assess whether fertility declined due to changes in the returns to education by investigating fertility adjustments along the extensive and intensive margins following the theoretical framework of Aaronson et al. (2014). While increases in the returns to education would imply a decline on the intensive but not on the extensive margin, an increase in the direct cost of having children implies a decline of fertility along both margins. Column (2) of Online Appendix Table 3 shows that fertility also decreased along the extensive margin. If the boll weevil also affected fertility directly by changing the returns to education, our evidence suggests that this effect was quantitatively modest and negligible.

Finally, columns (4) to (7) of Table 5 provide additional county-level evidence that the increased direct costs of children stimulated the demand for schooling in the Cotton Belt. One prominent education program at the time was the Rosenwald Rural Schools Initiative (Aaronson and Mazumder, 2011; Carruthers and Wanamaker, 2013; Aaronson et al., 2014). The objective of this program was to narrow the racial education gap that existed in the American South at that time, especially in rural areas.[46] Between 1914 and 1931 the Rosenwald Program constructed about 5,000 new schools throughout the rural American South targeted to the black rural popula-

the opportunity cost of schooling, it is predicted to have a positive impact on school enrollment and attendance", and resonates with the documented positive long-run impact that the boll weevil had on educational attainment (Baker, Blanchette, and Eriksson, 2018).

[46]The racial gap in schooling in the American South at the beginning of the 20th century was substantial and is largely explained by differences in school characteristics and the lower economic status and education levels of black parents; see Margo (1990) and Collins and Margo (2006) for an overview.

tion.[47] The county-level regressions reported in columns (4) to (7) control for county fixed effects, state-by-time fixed effects, and the black population share. The estimates reveal that for infested counties, a 10 percentage point higher initial cotton share implies the construction of about two more schools and five more teachers per 1,000 inhabitants. These results show that the arrival of the boll weevil had a substantial impact on where schools were constructed. In columns (6) and (7), we add the interaction of $Boll\ Weevil\ Intensity_{ct}$ with the initial (1910) county child labor share. The estimates suggest that most Rosenwald schools were constructed in counties that experienced the highest decrease in the value of child labor. This is consistent with the notion that human capital formation in the Cotton Belt was triggered by the increased direct costs of children during our sample period.

Overall, the findings presented in this section are in line with the predictions of the standard Q-Q framework. The lower value of child labor increased the direct costs of children and induced parents to invest more in child quality. The Q-Q model can therefore rationalize the well-documented increase in school enrollment that went along with the structural change and the fertility decline that the American South experienced during the 1880-1930 period.

8 Conclusion

A prominent hypothesis in growth and economic development is that a sustained shift from agriculture to manufacturing contributed to the historical fertility decline in today's modern societies. Empirical evidence in support of this hypothesis remains scarce because identifying a causal relationship is challenging. The present paper fills this gap in the literature by using credibly exogenous variation in agricultural earnings opportunities to estimate the causal link between structural change and the fertility transition. We show that lower agricultural earnings opportunities triggered a structural change on the intensive margin (i.e., the reduction of agricultural income for stayer

[47] Since the roll-out of Rosenwald schools started during the 1910s, we include only Cotton Belt counties that were infested by the boll weevil after 1910. Consequently, the sample spans the period 1910-1930. Note that there are no county-level population data available for the year 1925. These are imputed using the mean of the total population from the 1920 and 1930 Censuses.

households) and on the extensive margin (i.e., households switching to manufacturing (industrialization)). In line with the notion that children are a normal good, we find that stayer households reduced fertility as they experienced income losses, while switcher households reduced fertility because manufacturing work is generally less compatible with raising children.

This finding also implies that there are more complex mechanisms behind the well-documented negative correlation between parental income and fertility (e.g., Jones and Tertilt, 2008). In line with the theoretical framework by Mookherjee et al. (2012), we find evidence of two potentially confounding effects: Mobility across sectors or broad occupational categories changes parents' incentives to invest in child quality and usually implies a negative fertility-income relation. Within the same occupational category, however, higher income could increase fertility depending on whether the income effect dominates the substitution effect (Doepke, 2004). Identifying the effect of a wealth/income shock for households staying within the same occupation and for households switching occupations separately is therefore crucial for researchers interested in establishing a causal relationship between fertility and parental income.

We further show that lower earnings opportunities in agriculture diminished the value of child labor which made schooling relatively more attractive. This finding is in line with the testable implications of a standard quantity-quality model of fertility (Galor, 2011), which can rationalize the well-documented increase in school enrollment that went along with structural change and the historical fertility transition in most of Europe and North America during the 19th and early 20th centuries.

One limitation of our empirical analysis is that individual Census data on wages are not available before 1940. While we collected additional historical data to improve existing measures that rely on occupational income, changes in agricultural income in this study result from wage differences across agricultural occupations or spatial and temporal variation in wages of farm laborers or farmer income. This data limitation implies that we cannot perfectly identify the income effect at the individual level. One further concern is the external validity of our findings. While our study is based on full count data covering responses of more than 10 million southern households, our findings might be specific to the particular history and characteristics of the American South. Further research on the relationship between the structural transformation and falling fertility rates in other historical settings would therefore be valuable.

Overall, our study supports the view that the structural transformation was an important determinant of the southern fertility transition during the late 19th and early 20th centuries. The lower earnings opportunities in agriculture contributed to a substantial fertility decline in southern households by accelerating the process of industrialization and stimulating the demand for human capital. Having the concerns discussed above in mind, this result seems not unique to historical settings. In particular, one could think of policies that reduce population pressure in developing countries by combining rigorous child labor laws with economic programs that stimulate the transition out of the agricultural sector.

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