Online Appendix – Schooling, Skill Demand and Differential Fertility in the Process of Structural Transformation

T. Terry Cheung

A Data

A.1 Birth Rate Construction

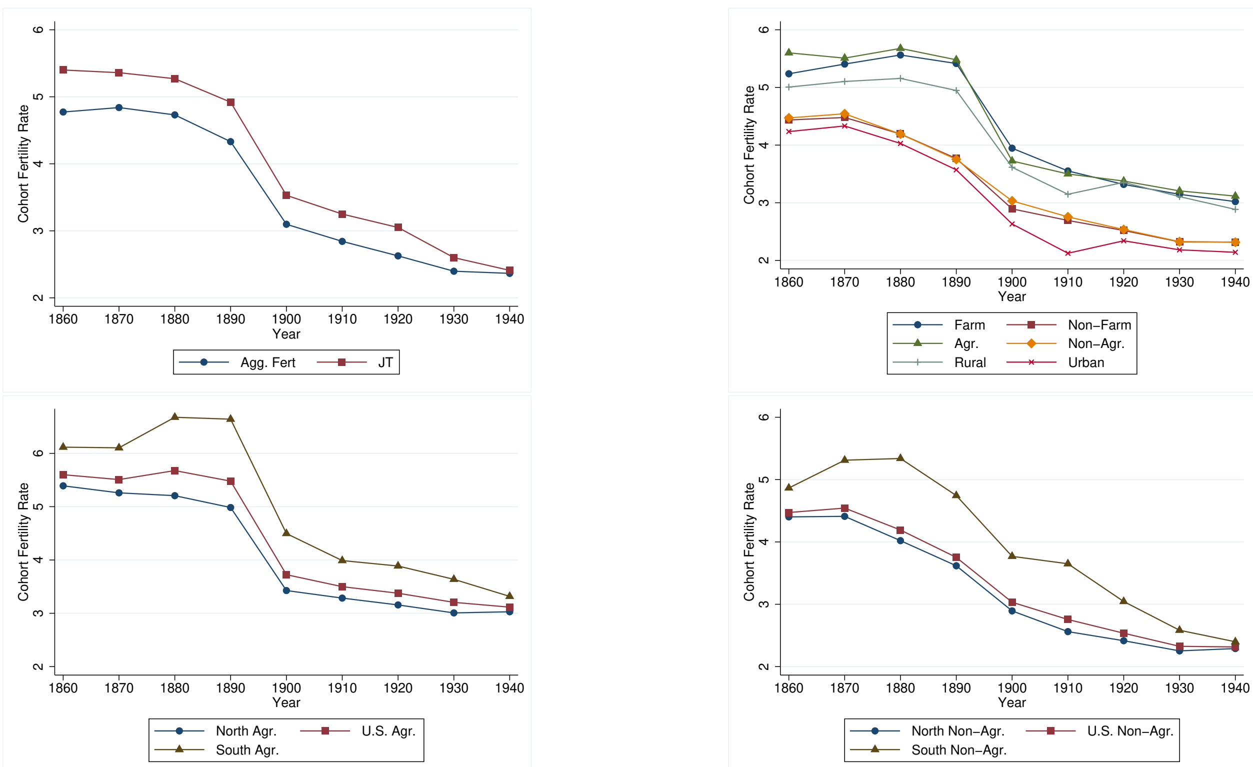

Figure A.1: Upper Left: Comparison with Jones and Tertilt (2006); Upper Right: Different Definitions; Lower Left: Agricultural Fertility; Lower Right: Nonagricultural Fertility. Source: IPUMS, various years.

The main data source is the 1% sample of the decennial census obtained from Ruggles et al. (2022). I measure fertility with the completed birth rate. From 1900 to 1990 (except for 1920 and 1930), females were asked how many children they had given birth to (Children Ever Born, or

CEB). Similar to most studies, I restrict the analysis to white, non-Hispanic women who were born in the U.S. and were not residents in a group quarter at the time of interview. We also follow Jones and Tertilt (2006, henceforth JT) and restrict our focus to those who were ever married before.

Cohorts appear in different census years. For example, the 1900 cohort appears in the 1950 census as 50-year-old and in the 1960 census as 60-year-old. To maximize the sample size, I use a weighted average of the cohort fertility rate for females who were 45-69 years old (to alleviate potential bias that is correlated with aging.) Twenty-seven years are shifted forward to the cohort fertility rate to make the measure comparable to the contemporaneous fertility rate (Goldin, 1990; Jones and Tertilt, 2006). My fertility rate closely resembles that in JT (see the upper left panel of Figure A.1). JT yield a slightly higher fertility rate in the earlier period due to (but not solely because of) the inclusion of the African American population who had higher fertility rates in the earlier years and subsequently converged to that of the white population (Goldin, 1990).

Although CEB is "*the best source for actual fertility decision made by women*" (Jones and Tertilt, 2006, p.14), the measure entails a drawback: the selection with respect to age. For example, if fertility is positively correlated with mortality,[1] then we would underestimate the true fertility rate. For a 15-year-old female, the chance she could finish her fecundity cycle (assumed to be at age 50) was just above 70% in the early twentieth century. As we do not know how fertility, mortality and other factors are correlated, however, it is difficult to correct for such bias.

A.2 Sectoral Classification

I adopt the sectoral classification used by Herrendorf, Rogerson and Valentinyi (2014, henceforth HRV). They used the ISIC definition from the UN, but there is no direct correspondence to the census. In particular, the service sector definitions are very different in these two classification methods.

To solve this problem, I classify sectors as either agricultural or nonagricultural. Hence, I follow HRV and put agriculture, forestry and fishing into the agricultural sector, and all other industries are put into the nonagricultural sector.

A.3 Data Robustness

Sectoral and Geographical Definitions One concern about using agriculture as a sectoral definition is that it is a market concept, and people only reported their sector when they were in the labor force. This might cause some selection bias if market force participation and fertility rates are correlated.

To alleviate this concern, I use two definitions: farm versus non-farm and rural versus urban. The results are reported in Figure A.1 (upper right panel). All definitions yield similar results, suggesting that the concern is not significant.

To also alleviate the concern that most of the southern states[2] were the battle field of the

[1] Poor families tend to have higher fertility, and tend to die earlier than those of wealthy families.

[2] I define Alabama, Arkansas, Florida, Georgia, Louisiana, Mississippi, North Carolina, South Carolina, Tennessee, Texas and Virginia as the southern states. The rest, except Alaska and Hawaii, are defined as northern states.

Civil War, I also report the fertility rates from the northern states, where little actual fighting was occurring, and compared them with the southern and national fertility rates. The northern states and the whole country had very similar agricultural and nonagricultural rates. The fact that southern states behaved differently does not undermine the theory in the main text since the southern states were poorer after the Civil War. When the income of individuals in the south increased after the Civil War, as long as the income did not exceed a certain threshold, they would increase the fertility rate but not education. This aligns with the fact that the education level in the southern states were lower (see, for example, Goldin and Katz, 2008, pp.156-7). After the income exceeded that threshold (due, for example, to increase in income or reduction of education cost), the fertility rate declined as the income increased. That explains the first increasing then decreasing fertility rate in the south.

Confounding Factors Another concern is that the high fertility rates observed in the agricultural sector are due to confounders. The concern is that agriculture is correlated with several variables that also affect fertility, thus making it difficult to identify its role in fertility. To explore this potential problem, I consider the following regression:

$$CEB_{it} = \alpha_0 + \alpha_1 Agri_{it} + \alpha_2 \mathbf{X}_{it} + \epsilon_{it}$$

where CEB_{it} is the number of children ever born to female i at time t, $Agri_{it}$ is an indicator that has the value of 1 when the female or her spouse were working in the agricultural sector and is 0 otherwise, and $\mathbf{X}_{it}$ is a vector of control variables likely to be confounding factors with fertility and agricultural status (e.g., literacy rate, income and urban status).

Table A.1 shows that literacy rate (only available 1900-10), income and urban status played important roles in explaining CEB, as they substantially reduce the effect of agricultural status on CEB.[3] Even when these are considered, the effect of agricultural status is still statistically and economically significant. A possible explanation is the high rural schooling costs.

A.4 Data Construction

Fertility and Mortality Rates: Fertility and mortality rates are constructed from several variables: children ever born (CHBORN), children surviving (CHSURV), gender (SEX), age (AGE), marital status (MARST), race (RACE), Hispanic origin (HISP), birthplace (BPL) and group quarters status (GQ). These derive from the IPUMS-USA dataset (Ruggles et al., 2022).

From 1900-90 (except 1920-30), the U.S. census included the number of children born (CHBORN). I restrict attention to ever married, native-born white, non-Hispanic women not residing in group quarters (henceforth, the "subgroup of females studied"). I further restrict the sample to those who were above 45 years old, and use different census years to maximize observations, but restrict my sample to those below 65 years old to minimize selection issues.

In 1900 and 1910 (but not other years), the census asked females how many children they had ever given birth to who were still living on the census day (CHSURV). This information, together

[3] As CEB was not available before 1900 and in 1920-30, the sample in Table A.1 is from 1900-10.

	Dependent Variable: Children Ever Born								
Agri. Family	1.091***	1.083***	0.877***	0.719***	0.691***	0.677***	0.681***	0.561***	0.438***
	(0.013)	(0.013)	(0.014)	(0.012)	(0.012)	(0.012)	(0.012)	(0.015)	(0.016)
Age				0.102***	0.100***	0.100***	0.100***	0.100***	0.100***
				(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Literacy					-0.383***	-0.309***	-0.383***	-0.375***	-0.301***
					(0.010)	(0.011)	(0.010)	(0.010)	(0.011)
Literacy: Spouse						-0.201***			-0.190***
						(0.011)			(0.011)
Occ. Score							-0.026***	-0.026***	-0.026***
							(0.002)	(0.002)	(0.002)
Occ. Score: Spouse								-0.008***	-0.007***
								(0.001)	(0.001)
Urban									-0.252***
									(0.015)
Year Control	N	Y	Y	Y	Y	Y	Y	Y	Y
State Control	N	N	Y	Y	Y	Y	Y	Y	Y
R-Squared	0.033	0.033	0.052	0.244	0.249	0.250	0.249	0.250	0.253
N	207,536	207,536	207,536	207,536	207,536	207,536	207,536	207,536	207,536

Table A.1: Determinants of the Number of Children Ever Born

with CHBORN in the "subgroup of females studied", determines the sector-specific mortality rates.

Sectoral Composition: Industry (IND1950) and spouse's location in the household (SPLOC) in IPUMS-USA, and U.S. sectoral employment in HRV, which are in turn from Carter et al. (2006) and Bureau of Economic Analysis (2022), are used to determine the sectoral composition.

Both IPUMS-USA and HRV defined "agricultural" as "agricultural, forestry and fishing", which are predominantly rural sectors. I define an agricultural family as one or both parents working in the agricultural sector. A finer separation of the economy into sectors does not change the qualitative result.

Productivity: Real GDP from (Maddison, 2008) and labor force from (U.S. Bureau of the Census, 1975, D167) are used to construct economy-wide productivity.

Schooling: School attendance (SCHOOL), employment status (EMPSTAT), industry (IND1950), age (AGE), state (STATEFIP), educational attainment (EDUC), father's and mother's locations in a household (POPLOC and MOMLOC) in the IPUMS-USA, U.S. Bureau of the Census (1975) and Snyder (1993) are used to determine the educational status.

School attendance is defined as the number of school-attending children aged 5-15 in a particular state, and each contributes to one's own sampling weight. I also map children to their parents using the POPLOC and MOMLOC. Using the parents' industries, children can be characterized as agricultural or nonagricultural decedents. Utilizing self-reported employment status and industry information, I can also infer whether a child was studying fulltime.

First Marriage: Age at first marriage (AGEMARR), gender (SEX), age (AGE), marital status (MARST), race (RACE), Hispanic origin (HISP), birthplace (BPL) and group quarters status (GQ) from IPUMS-USA are used to construct the age at first marriage for the "subgroup of females studied".

A.5 Alternative Explanations

This study argues that families will channel resources to the quality dimension of children when they become wealthier and education costs decline. This will then lead to a decline in fertility. However, numerous different theories have tried to explain the demographic transition. We discuss here why the observed pattern of fertility rates cannot be purely due to the decline in mortality rates, the increase in female labor participation, delayed marriages, contraception, culture and social security.

Mortality Rate: The U.S. mortality rate was lower in rural areas than in urban areas because of sparsely populated settlements (Klein, 2012). The calculation from the U.S. Census shows that the average mortality rates at the turn of the 20th century were approximately 22% in the agricultural sector and 25% in the nonagricultural sector. Therefore, if the mortality rate is positively correlated with fertility the agricultural sector should have a lower birthrate than the nonagricultural sector (the opposite is true).

In addition, Albanesi and Olivetti (2014) observe that maternal mortality rates in Western countries only started to decline after the late 1930s. Jones and Tertilt (2006) also note that both the number of children born and the number of surviving children born declined for females born during the 1860s to the 1880s. Finally, calculation using census data also show that the child mortality rate in the agricultural sector declined from 24% in 1880 to 19% in 1895, while in the nonagricultural sector, it decreased from 27% to 23%. This also indicates that mortality was not the main driver of the sectoral fertility difference.

Female Labor Force Participation: I use census data between 1870 and 1960 to investigate the labor market status of females between 15 and 60 years of age. I use the two definitions of labor status in IPUMS set out in Ruggles et al. (2022). The first is labor market status and the second is labor market occupation. The two measures are similar for rural and urban females. I also observe that the female labor participation rate only started to increase substantially after 1930, which is consistent with Goldin (1990).

Education, Marriage and Birth Patterns: In the early twentieth century, the age at first marriage and that at first birth were strongly correlated. The average age at first marriage remained very stable, at approximately 22.5 years for the 1870 to 1910 cohorts (Bailey, Guldi and Hershbein, 2013). For the "subgroup of females studied", IPUMS data (Ruggles et al., 2022) indicate that the age at first marriage of females born between the early 1860s and the late 1870s was approximately 23.5 years and was stable. Due to the absence of legal contraceptive methods, the reduction in fertility was mainly due to having fewer children farther apart in time and ending fecundity earlier. (Bailey and Hershbein, 2018).

Education is a strong determinant of age at marriage and early fertility (Breierova and Duflo, 2004). Although there was gender neutrality in education opportunities, the disparity was substantial after age 16 in the 1850s (Goldin and Katz, 2009). Even though this age increased from 16 to 17 in the 1880s, it was still considerably earlier than the average age at first marriage (23.5 years old). An increase in female education attainment was less likely to be the main determinant of declining fertility, at least via the channel of delayed marriage and delayed first birth, given that education attainment only started to increase rapidly at the turn of the twentieth century.

Contraception: The observations in Bailey (2006) and Bailey (2010), that contraceptive methods reduce fertility and delay the age of first birth in the U.S., combined with the earlier observation that the reduction in fertility was mainly due to having fewer children farther apart in time, indicate that families were reducing fertility. The timing of the availability of contraceptives, however, indicates that this is not a plausible explanation. According to Bailey (2006), the U.S. Congress outlawed the distribution of articles used for the prevention of conception in the nineteenth century. Such articles included diaphragms, condoms and birth control pills. Even by the 1920s, more than 45 states still had such laws. The situation only started to change in the 1960s.

Culture: Culture is an important factor in fertility. For example, Banerjee and Duflo (2011) argue that culture affects the expected number of births and that it directly determines fertility. Fernández and Fogli (2006) and Fernández and Fogli (2009) show that fertility in an immigrant's ancestral country has a significant impact on her own fertility. Hence, in this study, I exclude foreign-born women and only study the ever married native-born white non-Hispanic women not residing in group quarters. I observe a very rapid decrease in fertility around the turn of the century, which is even more surprising given that culture is transmitted slowly over time (Tabellini, 2010).

Social Security: It has also been well documented that parents perceive children as an important source of old-age support (see, for example, Banerjee et al., 2014). Therefore, the development of the social security system should have led to a reduction in fertility. However, as documented in Boldrin, De Nardi and Jones (2015), pensions started to become more significant after WWII. Therefore, the development of the social security system cannot be the main determinant for the reduction in fertility for the female cohorts in the nineteenth century.

B Causal Inference

The increase in education, resulting from the increased schooling opportunity, *caused* the decline in fertility and the surge in the nonagricultural sector. I show this using two strategies. The first is based on events' timing, and the second is based on school cost. The results consistently support the proposition.

First, I consider the timing of events. Aaronson, Lange and Mazumder (2014) argue that, when women face improved education opportunities for their children, they reduce family size. Figure 1 clearly shows that the decline in fertility occurred mainly for females born after the 1850s. Education attainment, as shown in Figure 3, increased at the turn of the century. The two are consistent, given the lags involved. A female born in the 1860s and 1870s would, on average, give birth in the 1880s-1890s. The children would then go to school, increasing school attendance approximately 1900 (Figure 3 in the main text). Hence, the fertility decline beginning for the 1850s cohort would be associated with observed increases in education beginning in the 1890s and into the twentieth century.

Porzio, Rossi and Santangelo (2020) argue that one of the channels that link human capital and structural transformation is the fact that agents who receive more education are less likely to be employed in agriculture (the cohort effect). I use census data from 1870 to 1940 to construct a cohort-by-age group for agricultural employment share. The results are shown in Table B.1. There are two features consistent with Porzio, Rossi and Santangelo (2020). First, younger cohorts were less likely to be employed in agriculture (the cohort effect). Second, within cohort, the older one becomes, the less likely one is to be in agriculture (the year effect).

Cohort Born in	1850s	1860s	1870s	1880s	1890s	1900s	1910s	1920s
20-30 years old	0.51	0.48	.	0.39	0.28	0.21	0.19	0.17
30-40 years old	0.51	.	0.35	0.29	0.24	0.17	0.13	.

Table B.1: Cohort-by-Age Agricultural Employment Share

Since the 1880s-1890s cohort was also responsible for the rapid increase in education attainment, comparing the cohort of the 1880s-1890s at 20-30 years of age to the previous cohort (e.g., that of the 1850s-1860s) shows that they were up to 45% less likely to be in agriculture. Since the 1890 census data are missing, we also explore the cohorts when their members were 30-40 years old (the third row in Table B.1). Note that the 1850s and 1870s cohorts, which were 20 years apart, were 30% less likely to be employed in agriculture. Comparing the 1870s and 1880s cohorts, we observe a decline exceeding 20% in a matter of 10 years. Moreover, education attainment started to plateau beginning in the 1920s. This matches the pattern observed for the agricultural employment share, which began a gradual drop for the 1910s cohort, which further corroborates such timing study.

Second, consider the decrease in school cost. I follow Aaronson and Mazumder (2011*a*) and use Julius Rosenwald's philanthropic initiative to build nearly 5000 schools– the Rosenwald Schools (1914-31)– as an instrumental variable because "*the construction of new schools made access easier for those who lived far from existing school building*" (Aaronson and Mazumder, 2011*a*, p.831). This led to a reduction in family size when education opportunities of children improved (Aaronson, Lange and Mazumder, 2014) and an increase in school attendance in rural areas (Aaronson and Mazumder, 2011*a*). Even though the establishment of the Rosenwald Schools did not occur when fertility dropped the most rapidly, and mostly benefited African American students (which is excluded from this study), the initiative provides a good example illustrating how an exogenous reduction in the schooling cost can lead to an increase in schooling and a reduction in fertility and agricultural employment.

Aaronson and Mazumder (2011*a*) and Aaronson, Lange and Mazumder (2014) combined show that the reduction in education cost leads to the quality-quantity tradeoff. In what follows, it suffices to show that such an increase in schooling led to an expansion in the nonagricultural sector. I use the presence of Rosenwald schools in a particular county as an instrumental variable for aggregate county school attendance, which are from Aaronson and Mazumder (2011*b*) and Carruthers and Wanamaker (2019). The empirical relationship of interest is

$$NAshare_{cs,t+1} = \theta_0 + \theta_1 Edu_{cst} + \theta_2 X_{cst} + \nu_{cst}$$

where $NAshare_{cs,t+1}$ is the growth of nonagricultural employment in county c and state s from period t to $t+1$, Edu_{cst} is school attendance in period t, and X_{cst} is a county-state level control. As census data are used, one period represents 10 years. The endogeneity problem exists and will lead to a biased estimator. Therefore, exogenous exposure to Rosenwald Schools $Rosenwald_{cst}$ in period t is used to predict school attendance:

$$Edu_{cst} = \beta_0 + \beta_1 Rosenwald_{cst} + \beta_2 X_{cst} + v_{cst}$$

The identification assumption is that Rosenwald sites are exogenous interventions affecting schooling outcomes, given the county-state control X_{cst}. Aaronson and Mazumder (2011*a*) argue that selection bias is minimal, and Carruthers and Wanamaker (2013) argue that, whatever selection bias exists, it can be corrected for by adding controls. X_{cst} thus includes the share of African American children in the population, education quality measures such as the number of schools and the percentage change of nonagricultural employment in the previous period. The results are shown in Table B.2.

	Independent Variable: School Attendance						
	OLS	2SLS (IV: Rosenwald Schools)					
		First Stage	Second Stage	First Stage	Second Stage	First Stage	Second Stage
A: Nonagricultural Growth (1930-40)	0.00	1.03***	0.11**	0.40**	0.43*	0.43**	0.48**
	(0.02)	(0.17)	(0.05)	(0.15)	(0.22)	(0.17)	(0.21)
N	553	553	553	401	401	372	372
B: Agricultural Elasticity (1940)	-0.16***	0.89***	-0.10	0.40***	-0.43***	0.30***	-0.25**
	(0.03)	(0.24)	(0.09)	(0.05)	(0.16)	(0.05)	(0.10)
N	503	503	503	362	362	342	342
State Control	N	Y	Y	Y	Y	Y	Y
County Characteristics	N	N	N	Y	Y	Y	Y
Time Trend	N	N	N	N	N	Y	Y

Table B.2: Regression Result

Two pieces of information are worth mentioning. First, confirming Aaronson and Mazumder (2011*a*), Rosenwald exposure, which lowered education costs, indeed increased school attendance, as consistently seen from the first-stage regression results. Second, such an increase in schooling translated into faster growth in nonagricultural employment, controlling for children's composition, education quality and the time trend (the change in nonagricultural employment in 1920-30). The persistence of economic and statistical significance in coefficients, after controlling for the trend indicates that reverse causation concern is ameliorated.

Using the Rosenwald school data, the average elasticity of agricultural employment share (for the young cohort below 25 years old) with respect to school attendance in the previous period can be as high as -0.43, depending on the control variables, smaller than the model's implied values.[4]

[4] The regression equation is:

$$\ln(AGEMP_{i,1940}) = \gamma_0 + \gamma_1 \ln(ATT_{i,1930}) + X_{i,1930} + \varepsilon_i$$

where $AGEMP_{i,1940}$ is the agricultural employment share, $ATT_{i,1930}$ is the attendance rate, and $X_{i,1930}$ includes the share of African American children in the population and education quality measures. The estimation uses the presence of Rosenwald Schools in 1930 as an IV and the reported value $\hat{\gamma}_1$ is the elasticity.

This can be reasonable because, in addition to the wage compression, there was racial discrimination in the Southern States that deterred some educated African American workers from entering the nonagricultural sector.

C Equilibrium and Computation

C.1 Equilibrium

I focus the analysis on a stationary competitive equilibrium. As occupational choice depends on the individual's human capital, the endogenous stationary distribution of human capital allows us to draw a conclusion about one's occupational choice with few assumptions about the initial exogenous joint distribution of education and productivity draw.[5]

DEFINITION 1 Denote an individual's state variables $\{s, z\}$ by x and the respective human capital by $h(x)$. A stationary competitive equilibrium is a set of prices $\{p, \hat{w}_a, \hat{w}_m, \gamma_a, \gamma_m\}$, a set of farmers' choices $\{c_a(x), c_m(x), n(x), s(x)\}$, a set of workers' choices $\{\tilde{c}_a(x), \tilde{c}_m(x), \tilde{n}(x), \tilde{s}(x)\}$, a human capital distribution G, a dummy variable for individual's occupational choice $D(x)$, factor demand set $\{L_a, L_m\}$ and a set of outputs $\{Y_a, Y_m\}$ such that the following holds.

1. Given prices, farmers and workers maximize their utility (2) subject to the budget constraint (3). Choices $\{c_a(x), c_m(x), n(x), s(x)\}$ and $\{\tilde{c}_a(x), \tilde{c}_m(x), \tilde{n}(x), \tilde{s}(x)\}$ solve the optimization problems for farmers and workers.

2. Given prices, the farm and firm demand $\{L_a, L_m\}$ to maximize their profit by setting wage rates according to equation (1).

3. Markets clear:

   (a) Agricultural good market:

$$Y_a = \int_x c_a(x)D(x)G(dx) + \int_x \tilde{c}_a(x)(1 - D(x))G(dx)$$

   (b) Nonagricultural good market:

$$\begin{aligned} Y_m = &\int_x \left[c_m(x) + \gamma_a n(x)s(x)\right] D(x)G(dx) \\ &+ \int_x \left[\tilde{c}_m(x) + \gamma_m \tilde{n}(x)\tilde{s}(x)\right] (1 - D(x))G(dx) \end{aligned}$$

   (c) Labor markets:

$$L_a = \int_x \rho(h(x))(1 - \tau n(x))D(x)G(dx)$$

[5] Another approach is to estimate a distribution of adult talent, as in Lagakos and Waugh (2013) and Cordoba, Liu and Ripoll (2016), but such data were lacking in the nineteenth century.

$$L_m = \int_x h(x)(1 - \tau \tilde{n}(x))(1 - D(x))G(dx)$$

4. The law of motion of $\tilde{G}$, $\Lambda(\tilde{G})$, defined as

$$\Lambda(\tilde{G}) = \frac{\int_x I_{x:s'=s(x)} \left[D(x)n(x) + (1 - D(x))\tilde{n}(x)\right] \tilde{G}(dx)}{\int_x \left[D(x)n(x) + (1 - D(x))\tilde{n}(x)\right] \tilde{G}(dx)} \tilde{G}_z(z)$$

implies that $\Lambda(G) = G$, where I is an indicator and s' is future education.

C.2 Computation

Assuming the parameter values, the initial guess of price p and distribution G, the model is solved in the following step:

1. Discretize the state space; the model is solved on the grid (g_s, g_z).
2. Given a price p, the wage rates $w_a(h)$ and $w_m(h)$ are obtained on (g_s, g_z).
3. For each state (g_s, g_z) of the parent, solve for $\{c_a^*, c_m^*, n^*, s^*, D^*\}$.
   (a) Given a distribution G, use $\{n^*, s^*, D^*\}$ to construct a new distribution according to Λ. For s^* not exactly on the grid g_s assign s^* proportionally to two adjacent grids.
   (b) Compare Λ with G; if the difference is significantly small, set $G^* = \Lambda$ and go to step 4). Otherwise, replace G with Λ and repeat step 3a).
4. Given G^*, compute the aggregate demand and supply of the agricultural good. Compare the difference between aggregate demand and supply. If the difference is significantly small, stop. Otherwise, adjust p accordingly and return to step 2.

D Preference

In this section, I discuss my choice of utility function. Recall that the functional assumption for utility follows Greenwood and Seshadri (2002):

$$u_{CRRA}(c_a, c_m) = \nu \frac{(c_a - \bar{c})^{1-\eta_c}}{1 - \eta_c} + (1 - \nu) \frac{c_m^{1-\eta_c}}{1 - \eta_c}$$

Although power utility is widely used in the literature on long-run growth (see, for example, Jones, 2001), a variation of CES utility (for within-period utility) is commonly used in the literature on structural transformation. However, given the budget constraint $c_a + pc_m + p\gamma_i ns \leq (1 - \tau n)w_i$ and a general utility function $v(n, q(s))$ defined on fertility n and education s, the choice of either consumption utility does not change the allocation. To see this, consider the first-order conditions for the household maximization problem with power utility (λ denotes the Lagrangian multiplier associated with the budget constraint):

$$\nu(c_a - \bar{c})^{-\eta_c} = \lambda \tag{D1}$$

$$(1-\nu)c_m^{-\eta_c} = \lambda p \tag{D2}$$

$$v_n(n, q(s)) = \lambda(\tau w + p\gamma s) \tag{D3}$$

$$v_s(n, q(s))q'(s) = \lambda p \gamma n \tag{D4}$$

Now, suppose that the consumption part of utility is CES:

$$u_{CES}(c_a, c_m) = \left[\nu(c_a - \bar{c})^{\frac{\sigma-1}{\sigma}} + (1-\nu)c_m^{\frac{\sigma-1}{\sigma}}\right]^{\frac{\sigma}{\sigma-1}}$$

Such a change does not affect equations D3 and D4 as long as consumption part u and demographic part v of the utility function are separable. Equations (D1) and (D2) become

$$u_{CES}^{\frac{1}{\sigma}}\nu(c_a - \bar{c})^{\frac{-1}{\sigma}} = \lambda \tag{D1'}$$

$$u_{CES}^{\frac{1}{\sigma}}(1-\nu)c_m^{\frac{-1}{\sigma}} = \lambda p \tag{D2'}$$

Note that in the power utility case, the elasticity of substitution between $(c_a - \bar{c})$ and c_m is given by $1/\eta_c$ (Jones, 2001), while that in the CES utility is given by σ. So for all $\eta_c > 0$, there exist $\sigma > 0$, such that $\sigma = \frac{1}{\eta_c}$ and making the ratio c_a/c_m, the budget constraint and equations D3 and D4 the same in both cases. Therefore, the allocation will be the same. The only assumption required for the result to hold is that v is separable from u, which is not uncommon in the literature.

E Model Fit

To test the reliability of the model, I assume that $\{A_t, \tau_t, \gamma_{a,t}, \gamma_{m,t}\}$ follow exogenous paths as discussed below and compare the paths of endogenous variables to the data. I assume that the economy grew at 13% per decade between 1870 and 1940 to identify A_t. I then use the census data to determine the portion of child labor and construct τ_t using the method set out in the main text Section III.A. Furthermore, I assume that $\{\gamma_{a,t}, \gamma_{m,t}\}$ declined linearly from 1880 to 1930.

All endogenous variables, except agricultural fertility, track the data quite well, and overall, the model performs well. While the model misses the timing of the decline in the agricultural fertility rate, the magnitude of the overall decrease nevertheless roughly tracks the data. Several reasons might explain this discrepancy. For example, institutional details on the agricultural sector or extra rural education subsidies are excluded from the model. One of the explanations that can be tested by limited data using the different sectoral productivity growth rates.

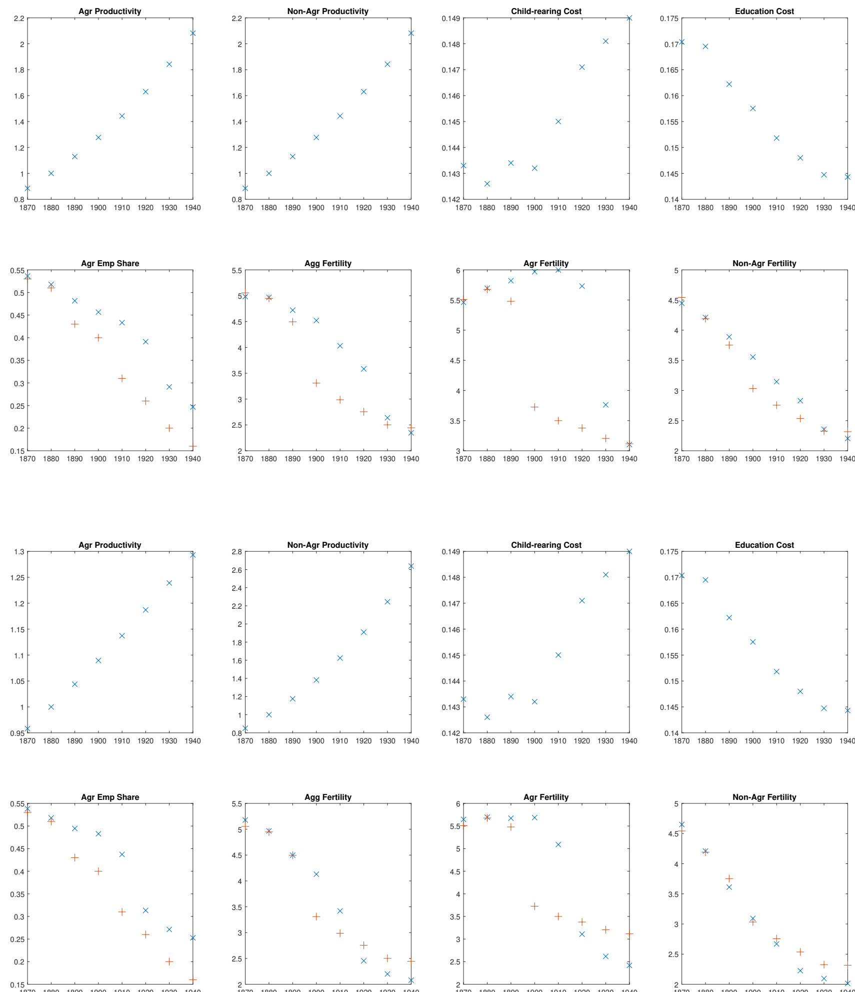

Figure E.1: Paths of Exogenous and Endogenous Variables. Blue x is the Model's Implied Value; Red + is the Data. Upper Panels: Economy-wide Productivity A. Lower Panels: Sectoral Productivity $\{A_a, A_m\}$.

To do this, I use the different sectoral productivity growth rates to trace out the paths for $\{A_{at}, A_{mt}\}$. I then use Jorgenson and Gollop (1992) to obtain the productivity growth rates in the agricultural and nonagricultural sectors from the 1880s to the 1930s. The decadal growth rate in the agricultural sector was 4.4% and that in the nonagricultural sector was 17.6%. I use the same values of τ_t and γ_t as in the economy-wide productivity analysis above. The results are shown in Figure E.1 (lower panels). Splitting A_t into $\{A_{at}, A_{mt}\}$ improves model performance because a faster-growing nonagricultural sector provides a cheaper education cost, which is in terms of nonagricultural goods.

Since Caselli and Coleman (2001, Appendix D) cast doubt on the numbers reported in Jorgenson and Gollop (1992) and acknowledges that it is difficult to devise an accurate measure of sectoral productivity in the premodern era, I also use a more conservative measure, economy-wide TFP, as in Lagakos and Waugh (2013), since economy-wide TFP is considered to have better accuracy.

Even though the economy-wide TFP is used in the main text, sectoral labor productivity can be very different because people with different human capital self-select into different sectors. For example, as in the calibration exercise, the relative wage in the agricultural sector is only one-fifth of that outside of agriculture (Caselli and Coleman, 2001), while the relative price difference is only 0.9, which is too small to justify the wage difference. Figure E.2 compares the relative price data from Alvarez-Cuadrado and Poschke (2011) with the model. The price data generated by the model do not exhibit any obvious trend prior to 1920, which resembles the data well. A deviation is detected in the year 1930, but the overall fit is good.

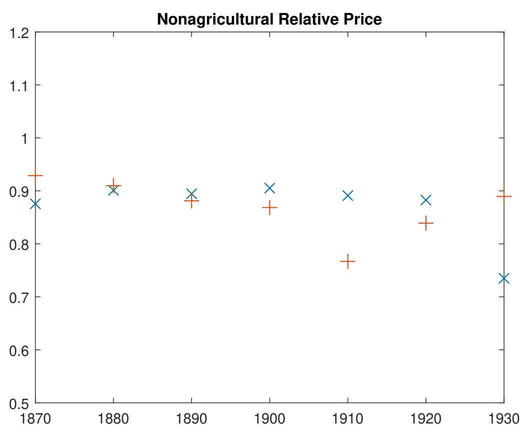

Figure E.2: Path of Relative Price. Blue x is the Model's Implied Value; Red + is the Data.

Although this paper focuses on the temporal aspect of the U.S. demographic and structural transformation data, the model can also be assessed by its cross-sectional behavior. In particular, I evaluate the model using the income elasticity of fertility documented by Jones and Tertilt (2006). I use (a simple decadal average of) the researchers' reported cohort elasticity and shift forward 30 years to make it comparable to my model's implied elasticity. For example, I compare their study's 1853 and 1858 cohorts average with my 1880 model value. The result is plotted in Figure 4 in the main text, showing that the model traces the U-shape pattern in the data quite well.

I also test the model by using the cross-state data. Since I could only find the cross-state teacher-pupil ratio in 1920, I compare the predicted change in fertility rates and agricultural employment share with the change in the data between 1880 and 1920. Specifically, I use the average wage in the manufacturing sector in each state d as a proxy for $A_{d,1920}$ (and normalize the mean to the national level TFP in 1920), use the state-specific teacher-pupil ratio to determine $\gamma_{d,1920}$, and use the state's child labor prevalence to determine $\tau_{d,1920}$. Then, I use these numbers in the model without recalibration to compute the predicted difference between 1880 and 1920. The results are shown in Figure E.3. The overall performance for the changes in agricultural employment share is quite good. However, the model underestimates the change in aggregate fertility, explaining approximately 70% of the drop. Nonetheless, the correlation between the model and the data are good, at 0.77.

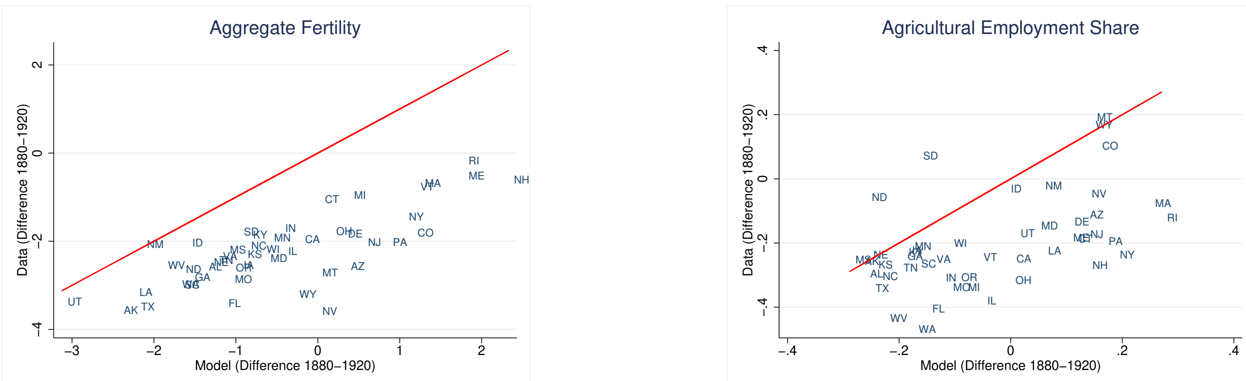

Figure E.3: Left Panel: Change in Aggregate Fertility (Correlation: 0.77). Right Panel: Change in Agricultural Employment Share (Correlation: 0.51). The red line is the 45° line.

F Further Robustness Check

I consider a robustness check involving the sensitivity of the results to smaller initial values of $\gamma_{a,1880}$. Instead of assuming that $\gamma_{a,1880}$ is 30% higher than $\gamma_{m,1880}$, I now assume that $\gamma_{a,1880}$ is only 20% or 10% higher. The decomposition results are shown in Table F.1. The relative contributions of γ are reduced but are still significant so the main message remains unchanged. First, education cost is still a key driver in reducing the agricultural fertility rate. Second, productivity still plays a role in both structural transformation and demographic decisions. Third, demographic factors, namely, γ and τ, still change the agricultural employment share (by more than one-fifth in both cases) via their effect on family decisions to increase human capital.

I also consider one last robustness check involving more detail on ν. Caselli and Coleman (2001) propose a method to pin down the value of ν. Following their method, I use the long-term value of $s = c_a/(c_a + pc_m)$ to measure ν. As the information on consumption is lacking, I use the output data to proxy for consumption. I use data from 1869-1940 and 1869-1969 on sectoral GDP (U.S. Bureau of the Census, 1975, F127-8) to estimate the process $s_{t+1} = a_0 + a_1 s_t$. All of the data cover the Progressive Era. Then, I use the long-run value $s^* = a_0/(1 - a_1)$ to determine ν.

	Agricultural Fertility	Nonagricultural Fertility	Agricultural Employment	Human Capital (1880=1)
Panel A: $\gamma_{a,1880} = 1.2 \times \gamma_{m,1880}$				
Education cost γ	40.3%	13.6%	23.2%	31.4%
Productivity A	43.9%	77.5%	69.0%	55.3%
Time Cost τ	15.8%	8.9%	7.8%	13.3%
Panel B: $\gamma_{a,1880} = 1.1 \times \gamma_{m,1880}$				
Education cost γ	23.2%	6.7%	12.4%	20.3%
Productivity A	56.5%	83.6%	78.7%	64.2%
Time Cost τ	20.3%	9.6%	8.9%	15.5%

Table F.1: Decomposition for Smaller Values of $\gamma_{a,1880}$

For the data from 1869-1940, $\hat{a}_0 = 0.0005$ ($p = 0.878$) and $\hat{a}_1 = 0.98$ ($p < 0.001$) and that from 1869-1969, $\hat{a}_0 = 0.002$ ($p = 0.629$) and $\hat{a}_1 = 0.97$ ($p < 0.001$). Both estimates have the constant terms statistically insignificant at the conventional level. The data from 1869-1940 give $\nu = 0.07$ (consistent with the calibrated value in the main text), while those from 1869-1969 give $\nu = 0.03$. Then I use the two values of ν and recalibrate the model; the results are shown in Table F.2. Both parameter values match the data moment well, but the model fitness of $\nu = 0.07$ is better.

Target Moments circa 1880	Data	$\nu = 0.07$	$\nu = 0.03$
Income Elasticity of Fertility	-0.37	-0.37	-0.40
Agricultural Fertility	5.68	5.68	5.68
Nonagricultural Fertility	4.19	4.19	4.19
Agricultural Employment Share	0.51	0.52	0.50
Agricultural Relative Wage	0.20	0.20	0.20
Agricultural Immobility	0.62	0.60	0.57
Nonagricultural Relative Price	0.90	0.90	0.90

Table F.2: Model Fitness of Different ν

Then, I carry out the same analysis in the main text to compare the model performance using the two values of ν, and the results are reported in Table F.3. Both of the parameter values of ν give very similar predictions. For example, in 1870, models with both values correctly predict a decline in the sectoral fertility difference. That is, they both capture the fact that only a small number of farmers educated their children. With farmer as a group, the income effect dominates the quantity-quality effect and leads to a decline in fertility. Nonagricultural workers reduced their education expenditure on average and gave birth to more children.

However, the model with parameter value $\nu = 0.07$ does a better job in predicting the agricultural fertility rate drop between 1880 and 1930. The reason is because ν also determines the relative expenditure on consumption and child-rearing. A smaller $\nu = 0.03$ means that more resources are allocated to child-rearing, which leads to higher fertility or higher education, depending on the relative strength of income and quantity-quality effects. The model predicts that the income effect is larger in this case. This leads to higher fertility and lower relative human capital when compared to the case with $\nu = 0.07$. It is also not surprising that the quantity-quality tradeoff channel is

	Data			$\nu = 0.07$			$\nu = 0.03$		
Variables	1880	1930	1870	1880	1930	1870	1880	1930	1870
Agricultural Fertility	5.68	3.21	5.51	5.68	3.64	5.34	5.68	4.55	5.32
Nonagricultural Fertility	4.19	2.33	4.54	4.19	2.33	4.56	4.19	2.33	4.48
Aggregate Fertility	4.95	2.51	5.05	4.96	2.71	5.00	4.93	2.90	4.96
Agricultural Employment Share	0.51	0.20	0.53	0.52	0.28	0.56	0.50	0.26	0.57
Relative Human Capital (1880=1)	.	.	.	1.00	4.21	0.88	1.00	3.38	0.89
% Δ ST by exo. Fertility					36%			27%	

Table F.3: Performance of Different ν

less important in this parameter value setting. The relative contributions from all the parameter changes are also similar, as shown in Table F.4. Finally, I also compare the paths of income elasticity of fertility, and both values of ν give a similar U-shape pattern in Figure F.1.

	Agricultural Fertility	Nonagricultural Fertility	Agricultural Employment	Human Capital (1880=1)
Model Change ($\nu = 0.07$)	-2.04	-1.86	-0.23	3.21
% accounted for by Δ in				
Education Cost γ	45.2%	15.6%	29.6%	34.7%
Productivity A	40.3%	75.6%	63.2%	52.6%
Time Cost τ	14.5%	8.7%	7.1%	12.7%
Model Change ($\nu = 0.03$)	-1.13	-1.86	-0.24	2.38
% accounted for by Δ in				
Education Cost γ	44.1%	18.6%	21.4%	31.2%
Productivity A	27.7%	68.5%	70.0%	51.8%
Time Cost τ	28.1%	13.0%	8.6%	17.0%

Table F.4: Relative Decomposition of Different ν

In the main text, I use $\nu = 0.07$ as my preferred parameter value since it better predicts the drop in agricultural fertility and aligns with the calibrated value should I calibrate ν. As shown above, the main conclusion of the paper is not sensitive to the parameter value of ν. However, readers should be cautious that the contribution of the quantity-quality tradeoff channel can be weaker with a smaller value of ν.

Due to the space limit, I carry one more robustness that was not done in the main text. Consider now the performance of the model in Table 2 in the main text, which depends critically on α. To explore potential sensitivity, I consider $\alpha = 0.75$ (versus $\alpha = 0.65$ in the benchmark case). The revised model performance in 1930 is qualitatively similar to that in Table 2. Both sectoral fertility rates declined, with a greater decline in agricultural fertility. Agricultural employment also decreases as human capital increases. This is reasonable because α is also the utility weight assigned to human capital: when α is high, we expect more schooling. This implies a lower agricultural employment share and lower fertility.

The revised model, however, does not provide a good quantitative match: the effect of the quantity-quality tradeoff is too strong for the higher α. I argue that $\alpha = 0.75$ might not be reasonable in the mid-twentieth century during an era of wage compression (Goldin and Margo, 1992). Recall that α also captures the effect of return to educational investment (Bils and Klenow,

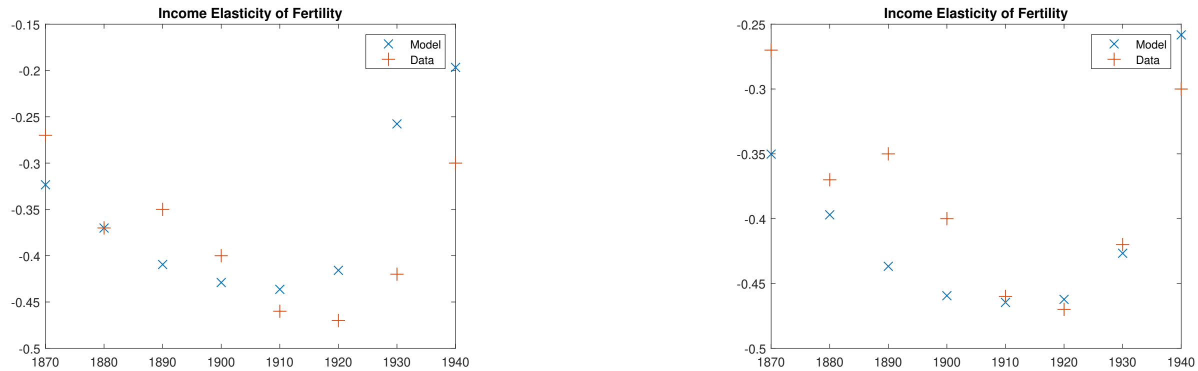

Figure F.1: Left: $\nu = 0.07$; Right: $\nu = 0.03$.

2000). Using equations (1) and (10) in the main text, we obtain $dlnw_m/ds = \alpha/(s + \underline{e})$; considering the information in Goldin and Katz (2009, Table 2.4 and 2.6), the estimated α circa 1940 should be between 0.6-0.7. Thus, $\alpha = 0.75$ is possibly too high. The current $\alpha = 0.65$ sits in the middle of this range, resulting in a reasonable predicted fertility rates. Note that the model does not allow for a time-varying α, nor does it endogenize α. I accept this as a model limitation.

Parameter(s) Changed	$\psi = 0.49$		$\gamma_{a,1930} = 0.13$ $\gamma_{m,1930} = 0.18$		$\alpha = 0.75$		$\nu = 0.03$		$\gamma_{a,1930} =$ $0.66 \times \gamma_{m,1930}$	
Model Years	1880 (I)	1930 (II)	1880 (III)	1930 (IV)	1880 (V)	1930 (VI)	1880 (VII)	1930 (VIII)	1880 (IX)	1930 (X)
Agricultural Fertility	5.67	3.75	5.68	3.21	5.68	2.35	5.68	4.55	5.68	2.73
Nonagricultural Fertility	4.19	2.33	4.19	2.32	4.19	1.54	4.19	2.33	4.19	2.22
Agricultural Employment	0.52	0.29	0.52	0.27	0.51	0.23	0.50	0.26	0.52	0.25
Human Capital (1880=1)	1.00	4.20	1.00	4.44	1.00	11.17	1.00	3.38	1.00	5.75
% Δ ST by exo. Fertility	.	34%	.	34%	.	32%	.	27%	.	28%

Table F.5: Robustness Checks. Columns (I) to (IV) and (VII) to (X) are reported in main text Table 5.

References

Aaronson, Daniel, and Bhashkar Mazumder. 2011*a*. "The Impact of Rosenwald Schools on Black Achievement." *Journal of Political Economy*, 119(5): 821–888.

Aaronson, Daniel, and Bhashkar Mazumder. 2011*b*. "Supplemental Material: The Impact of Rosenwald Schools on Black Achievement." *Journal of Political Economy*, 119(5): 821–888. https://www.journals.uchicago.edu/doi/suppl/10.1086/662962. Accessed November 3, 2022.

Aaronson, Daniel, Fabian Lange, and Bhashkar Mazumder. 2014. "Fertility Transitions Along the Extensive and Intensive Margins." *American Economic Review*, 104(11): 3701–24.

Albanesi, Stefania, and Claudia Olivetti. 2014. "Maternal Health and the Baby Boom." *Quantitative Economics*, 5(2): 225–269.

Alvarez-Cuadrado, Francisco, and Markus Poschke. 2011. "Structural Change out of Agriculture: Labor Push Versus Labor Pull." *American Economic Journal: Macroeconomics*, 3(3): 127–58.

Bailey, Martha J. 2006. "More Power to the Pill: The Impact of Contraceptive Freedom on Women's Life Cycle Labor Supply." *The quarterly journal of economics*, 121(1): 289–320.

Bailey, Martha J. 2010. """ Momma's Got the Pill": How Anthony Comstock and Griswold v. Connecticut Shaped US Childbearing." *American economic review*, 100(1): 98–129.

Bailey, Martha J, and B Hershbein. 2018. "US Fertility Rates and Childbearing, 1800-2010." *Oxford Handbook of American Economic History.*

Bailey, Martha J, Melanie E Guldi, and Brad J Hershbein. 2013. "Is There a Case for a" Second Demographic Transition"? Three Distinctive Features of the Post-1960 US Fertility Decline." NBER Working Paper 19599.

Banerjee, Abhijit, and Esther Duflo. 2011. *Poor Economics.* Public Affairs.

Banerjee, Abhijit, Xin Meng, Tommaso Porzio, and Nancy Qian. 2014. "Aggregate Fertility and Household Savings: A General Equilibrium Analysis Using Micro Data." NBER Working Paper 20050.

Bils, Mark, and Peter J Klenow. 2000. "Does Schooling Cause Growth?" *American Economic Review*, 90(5): 1160–1183.

Boldrin, Michele, Mariacristina De Nardi, and Larry E Jones. 2015. "Fertility and Social Security." *Journal of Demographic Economics*, 81(3): 261–299.

Breierova, Lucia, and Esther Duflo. 2004. "The Impact of Education on Fertility and Child Mortality: Do Fathers Really Matter Less than Mothers?" NBER Working Paper 10513.

Bureau of Economic Analysis. 2022. "National Data: National Income and Product Accounts." *https://www.bea.gov/data/employment/employment-by-industry. Accessed November 3, 2022.*

Carruthers, Celeste K, and Marianne H Wanamaker. 2013. "Closing the Gap? The Effect of Private Philanthropy on the Provision of African-American Schooling in the US South." *Journal of Public Economics*, 101: 53–67.

Carruthers, Celeste K, and Marianne H Wanamaker. 2019. "County-Level School Enrollment and Resources in Ten Segregated Southern States, 1910–1940." *Ann Arbor, MI: Inter-university Consortium for Political and Social Research [distributor]. https://doi.org/10.3886/E109625V1. Accessed November 3, 2022.*

Carter, Susan B, Scott Sigmund Gartner, Michael R. Haines, Alan L. Olmstead, Richard Sutch, and Gavin Wright. 2006. *Historical Statistics of the United States, Earliest Times to the Present (Millennial Edition).* Cambridge University Press, New York.

Caselli, Francesco, and Wilbur John Coleman, II. 2001. "The US Structural Transformation and Regional Convergence: A Reinterpretation." *Journal of Political Economy*, 109(3): 584–616.

Cordoba, Juan Carlos, Xiying Liu, and Marla Ripoll. 2016. "Fertility, Social Mobility and Long Run Inequality." *Journal of Monetary Economics*, 77: 103–124.

Fernández, Raquel, and Alessandra Fogli. 2006. "Fertility: The Role of Culture and Family Experience." *Journal of the European Economic Association*, 4(2-3): 552–561.

Fernández, Raquel, and Alessandra Fogli. 2009. "Culture: An Empirical Investigation of Beliefs, Work, and Fertility." *American Economic Journal: Macroeconomics*, 1(1): 146–77.

Goldin, Claudia, and Lawrence F Katz. 2008. "Mass Secondary Schooling and the State: the Role of State Compulsion in the High School Movement." In *Understanding Long-Run Economic Growth: Geography, Institutions, and the Knowledge Economy.* 275–310. University of Chicago Press.

Goldin, Claudia, and Robert A Margo. 1992. "The Great Compression: The Wage Structure in the United States at Mid-Century." *The Quarterly Journal of Economics*, 107(1): 1–34.

Goldin, Claudia Dale. 1990. *Understanding the Gender Gap: An Economic History of American Women.* Oxford University Press.

Goldin, Claudia Dale, and Lawrence F Katz. 2009. *The Race Between Education and Technology.* Harvard University Press.

Greenwood, Jeremy, and Ananth Seshadri. 2002. "The US Demographic Transition." *American Economic Review*, 92(2): 153–159.

Herrendorf, Berthold, Richard Rogerson, and Ákos Valentinyi. 2014. "Growth and Structural Transformation." *Handbook of Economic Growth*, , ed. Steven N. Durlauf Philippe Aghion.

Jones, Charles I. 2001. "Was an Industrial Revolution Inevitable? Economic Growth Over the Very Long Run." *Advances in macroeconomics*, 1(2).

Jones, Larry E, and Michèle Tertilt. 2006. "An Economic History of Fertility in the United States: 1826-1960." *NBER Working Paper 12796.*

Jorgenson, Dale W, and Frank M Gollop. 1992. "Productivity Growth in US Agriculture: A Postwar Perspective." *American Journal of Agricultural Economics*, 74(3): 745–750.

Klein, Herbert S. 2012. *A Population History of The United States.* Cambridge University Press.

Lagakos, David, and Michael E Waugh. 2013. "Selection, Agriculture, and Cross-Country Productivity Differences." *American Economic Review*, 103(2): 948–80.

Maddison, Angus. 2008. "Historical Statistics for the World Economy: 1-2006 AD."

Porzio, Tommaso, Federico Rossi, and Gabriella Santangelo. 2020. "The Human Side of Structural Transformation."

Ruggles, Steven, Sarah Flood, Ronald Goeken, Megan Schouweiler, and Matthew Sobek. 2022. "IPUMS USA: Version 12.0 [dataset]." *https://doi.org/10.18128/D010.V12.0. Accessed November 3, 2022.*

Snyder, Thomas D. 1993. *120 Years of American Education: A Statistical Portrait.* National Center for Education Statistics.

Tabellini, Guido. 2010. "Culture and Institutions: Economic Development in the Regions of Europe." *Journal of the European Economic Association*, 8(4): 677–716.

U.S. Bureau of the Census. 1975. "Historical Statistics of the United States, Colonial Times to 1970."