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Rainfall risk, fertility and development: Evidence from farm settlements during the American demographic transition

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Michael Grimm

Rainfall Risk, Fertility and Development: Evidence from Farm Settlements During the American Demographic Transition



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Michael Grimm¹

Rainfall Risk, Fertility and Development: Evidence from Farm Settlements During the American Demographic Transition

Abstract

I analyze whether variation in rainfall risk played a role for the speed of the demographic transition among American settlers. The underlying hypothesis is that children constituted a buffer stock of labor that could be mobilized in response to income shocks. Identification relies on fertility differences between farm and non-farm households within counties and over time. The results suggest that in areas with a high variance in rainfall the fertility differential between farm households and non-farm households was significantly higher than in areas with a low variance in rainfall. This channel is robust to other relevant forces such as income, education and children's survival as well as the spatial correlation in fertility levels. The analysis also shows that this effect was reduced and finally disappeared as irrigation systems and agricultural machinery emerged. Hence, access to risk-mitigating devices significantly contributed to the demographic transition in the US. These findings also have potentially important implications for Sub-Saharan Africa, especially for those areas where income risks are a major threat to households and where fertility is still high and only slowly declining or not declining at all.

JEL Classification: J13, N31, N32, O12, Q12

Keywords: Demographic transition; fertility; rainfall risk; insurance

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1. Introduction

The old age security motive predicts that fertility will be higher in a context in which formal old age insurance is absent compared to a situation in which such support is available (Neher, 1971; Willis, 1980; Caldwell, 1982; Ehrlich and Lui, 1991; Carter et al., 2002). Although the argument sounds compelling, the empirical evidence in support of this argument is mixed (see e.g. Hohm, 1975; Nugent, 1985; Jensen, 1990; Rendall and Bahchieva, 1998). Galor (2012) shows that at least for the demographic transition in Western countries the decline in the importance of old-age support is unlikely to be a major force. Surprisingly, only very few studies have examined whether fertility decisions are also made in view of insuring income shocks that occur much earlier in life and which are hard to predict such as an income shock due to crop disease, a shortage in rainfall, a case of serious illness or a job loss. This fertility motive was first discussed by Cain (Cain, 1981, 1983, 1986) and, more generally, by Pörtner (2001). The idea is that children can be used to smooth consumption over time by providing additional labor in the event of a shock. Children can also free up the time of older household members by taking on household chores such as cooking, cleaning or taking care of their younger siblings. De Vany and Sanchez (1979), Cain (1990) and Dasgupta (1995) provide descriptive evidence in support of this motive for the context of developing countries. More robust evidence comes from Pörtner (2011) who uses the geographical variation in hurricane risk across municipalities in Guatemala to examine the effect of risk-exposure on fertility. If indeed fertility is in part a response to high risk, it may explain why in some regions, and in particular in poor rural semi-arid or arid areas of Sub-Saharan Africa, the demographic transition has often not even started or, if it has started, progresses only slowly or has stalled (Bongaarts and Casterline, 2013).

In this paper, I focus on the demographic transition in the United States. I empirically analyze to what extent the exposure to rainfall risk shaped fertility patterns among American settlers in the second half of the nineteenth and first half of the twentieth century and whether the emergence of risk-mitigating devices such as irrigation systems agricultural machinery and financial services boosted the demographic transition by reducing the need to have many children. Although the mechanism is unlikely to be the only force in the demographic transition, it could be an important element to understand

differences in the pace of the fertility decline in farm and non-farm households and across different climate zones.

This study adds to the vast body of literature that has analyzed the determinants of the demographic transition in the US.¹ It is related to two other recent papers that looked at households' behavior and risk during the nineteenth century in America. Ager and Ciccone (2014) show that religious membership strongly varied with risk exposure, suggesting that Americans at that time also tried to cope with risks through informal insurance schemes that were set up within religious communities. Basso et al. (2014) show that fertility decisions by Americans (using data from eight Northeastern states) varied according to the degree of financial development, i.e. in those areas where the financial system was already more advanced, fertility rates were much lower. The authors interpret their findings as evidence in support of the old age insurance motive. This study also adds to the literature that has explored households' strategies to cope with anticipated risks ex-ante in a poor agrarian context (see e.g. Morduch, 1995; Kochar, 1999; Dercon, 2004; Kazianga and Udry, 2006).

Examining the role of the insurance motive for the American demographic transition is particularly interesting as at the time most rural households generated their income from agriculture, particularly households in the Central region of the country, and hence had to cope with the many risks and uncertainties which significantly shaped their lives. The most well-known crises people had to go through were the widespread death of cattle in 1886, the influenza pandemic in 1918, the agricultural recession in 1920 and the immense drought in the 1930s, also known as the dust bowl (Thomson and Whelpton, 1933). Fertility was generally higher in new settlement regions than in old settlement regions even when only considering rural areas. Easterlin (2000) argued that this can be explained by land abundance and high returns in agricultural production in newer settlement regions which in turn allowed for the generous bequeathing to many children. In contrast, in older areas, land started to become scarce and farmers became

¹ See e.g. Yasuba (1962), Forster and Tucker (1972), Easterlin (1976, 2000), Vinovskis (1976), Guest (1981), Bourne Wahl (1992), Steckel (1992), Haines (2000), Greenwood and Seshadri (2002), Hacker (2003), Haines and Hacker (2006), Johnson and Rathge (2006), Jones and Tertilt (2006), Curtis White (2008), Bleakley and Lange (2009), Wanamaker (2012), Aaronson et al. (2014), Hansen (2014), Hansen et al. (2014), Lahey (2014) and Ager et al. (2015) among many others.

increasingly concerned about providing for their children and hence reduced fertility. Similar arguments were made by Yasuba (1962) and Forster and Tucker (1972). Sundstrom and David (1988) and Bourne Wahl (1992), among others, however argued that fertility rather declined in these areas as a result of improved labor market opportunities outside agriculture which reduced children's incentives to stay on the farm. The value of children as old-age security assets consequently diminished.

The remainder of the paper is organized as follows. Section 2 provides context and theoretical considerations. Section 3 presents the data. Section 4 outlines the empirical identification strategy. Section 5 presents the results and various robustness checks. Section 6 concludes.

2. Context and some theoretical considerations

This study focuses on the period between the civil war and the great depression. Whereas the Northeast, the Mid-Atlantic, the Southeast and the West were already quite densely settled, the South, North and Midwest were still subject to substantial population movements (Gallaway et al., 1974). The fertility transition was relatively advanced in New England, but in the rest of the country, particularly in the South, the total fertility rate was well above four children per woman (Jones and Tertilt, 2006). In the second part of the nineteenth century, the country was, with the exception of the Northeast, still very rural, with more than half of the population working in agriculture, typically on small family-owned farms relying only on horse and manpower (Perelman, 1973; Dimitri et al., 2005; Dempster and Isaacs, 2014). This started to change rapidly at the beginning of the twentieth century as innovations such as the tractor, new varieties and cultural practices, fertilization and other sophisticated inputs emerged which increased productivity substantially and allowed for larger farms (Cochrane, 1979; Olmstead and Rhode, 2001, 2002; Dimitri et al., 2005). According to Olmstead and Rhode (2001), the horsepower provided by tractors rose from roughly 2.5 million hp in 1920 to 11 million hp in 1930 and was one of the great labor-saving innovations in the twentieth century. Since 1900, new technologies and the development of rural infrastructure brought farming households closer to markets for labor and capital, as well as goods and services. This positive dynamic was abruptly stopped with the start of the great depression during which prices for food and cash crops collapsed.

In the second half of the nineteenth century it was normal for children to help on farms. Children also increasingly worked in industry where such opportunities existed. Many children combined work with schooling (Walters and O'Connell, 1988). Compared to households in the Northeast region, child work was somewhat more common in the Midwest and substantially more common in the Southern states (Horan and Hargis, 1991). School enrolment in the Southern states was substantially lower. Laws regulating child labor existed in some states, but were typically only strictly enforced after the great depression to avoid children taking the jobs of adults (US Department of Labor, 1968).

The key idea of this paper is that in the event of shocks, children could free up time of other household members by taking on household chores, including taking care of younger siblings, so that these other household members could increase their labor market participation (Walters and O'Connell, 1988). Children could with increasing age also help on the family farm or work on other farms or in industry (Horan and Hargis, 1991). This implies that children could help to smooth income if needed, probably more efficiently than other informal and religious sharing networks. In other words, in the given context, children constituted a cheap, trusted and flexible buffer stock of labor. There is also plenty of evidence from developing countries today that children's labor supply is a common ex-post coping strategy (see e.g., Edmonds, 2006; Duryea et al., 2007; Landman and Frölich 2015). Children obviously also generated costs, but as long as they could reduce the variance in income, they made families better off. Children could of course die, but this made children no riskier than many other forms of insurance and parents anticipating that risk could increase their fertility further in response.

Hence, the first research hypothesis is that farm households in areas with a high exposure to rainfall risk and hence a higher variance in income had more children than farm households in areas with a low exposure to rainfall risk and hence a lower variance in income. The second research hypothesis is that the emergence of risk mitigating devices and labor-saving machinery reduced this effect as it reduced the variance in income and the return to child labor. The assumption is that these hypotheses hold even after accounting for a possible risk-related income level effect on fertility. It is important to note that what is postulated here is a link between the perceived exposure

to risk and fertility and not between experienced income shocks and a possible fertility response.

3. Data

I use four different data sources: population census data, agricultural census data, data from the survey on banks and bank deposits and geographic information, especially rainfall data. I present each source in turn.

Historical population census data is available from the Integrated Public Use Microdata Series (IPUMS). I use the data from the years 1870, 1880, 1900, 1910, 1920 and 1930. IPUMS provides 1% samples in each year. Additionally, for 1880 IPUMS provides a 10% sample and for 1900 and 1930 a 5% sample each. Hence for 1880, 1900 and 1930 I use the larger samples.² The 1890 census records were destroyed by fire and flooding and are not available for analysis. From the census data I draw individual-level information about women's fertility, their age, their education, their spouse's education, their migration background and their location. The number of children ever born is unfortunately only available for 1900 and 1910 and then again for 1940 onwards. For earlier years there is just the total number of children living in the household or the number below the age of five living in the household. I follow Basso et al. (2014) and compute for each 15 to 39-year-old woman the number of children below the age of five living in the household. Using child-woman ratios as a measure of fertility is quite common in the historical literature (see e.g. also, Becker et al., 2013).³ Other authors have constructed retrospectively fertility data by using the number of children ever born reported in the 1940 census. Yet, in my case this is not a preferable option as women may have changed the county between the birth of their children and 1940. In addition, selective mortality could bias the results.

Given that during the observation window the economic and social context was very different for white and black families, I use for the analysis only information about white women. I also limit my sample to ever married women and focus on marital fertility. Moreover, since I consider the exposure to rainfall risk not very relevant for

² IPUMS recently also released preliminary versions of full count data for the years 1880, 1920 and 1930.

³ The conditions under which this is a valid approximation are discussed in the online appendix.

urban households, I also limit my data set to rural areas.⁴ I also exclude the states of Alaska and Hawaii and the population living in military camps. Since, county borders changed over time - some counties disappeared, and others were added by dividing existing counties - I work with county-groups that have a constant border over time.

The Census of Agriculture provides data for the same years as the population census. I use the average value of farmland and buildings, the average farmland area per farm and the average value of implements and machinery per farm. For the years 1900 and 1910 there is also information about the existence of irrigation systems.

I remove from the data set those observations where information on key variables is missing.⁵ Table 1 shows the composition of the total sample used for analysis, in total 945,038 observations. It can be seen that the number of covered counties and county-groups increases over time as, at the beginning of the observation window, many counties were not yet settled.

[Table 1 and Figure 1 about here]

Figure 1 shows a set of maps tracking the fertility decline in rural areas across counties over time. White areas indicate areas where no census was conducted. Table 2 describes the sample over time by showing the mean of various women's, household's and county characteristics in each census year. The used fertility measure declines by about 23% over the entire observation window. Literacy increases over time. At the end of the observation window, female literacy exceeds literacy levels of household heads, largely due to a cohort effect. The share of farming households at first increases and then, at the beginning of the twentieth century, declines. The size of farms, the value of farmland and farm buildings and the value of machinery and implements also continuously rise. The increase in the value of machinery and implements is particularly pronounced after 1900, documenting the increasing mechanization of agriculture. The decline of the value of farmland, machinery and buildings in 1930 mirrors the start of the great

⁴ The term 'rural' generally denotes places with less than 2,500 inhabitants. There is a slight variation over time with respect to the coding within the New England states.

⁵ The only information that is not available for all women is the information that comes from the Census of Agriculture. The fact that a few counties were not covered removes 35 counties from the sample.

recession. For the years 1920 and 1930, data from the Survey of banks and bank deposits allows to explore the impact of financial market development on fertility.

Finally, rainfall data comes from the PRISM data set. For the US it provides monthly rainfall data for the period 1895 to 1980 for 4 x 4 km grid points.⁶ Using the minimal Euclidian distance, I attributed each rainfall station to a specific county-group and computed for each county-group and each month the average rainfall. From this I computed the average rainfall during the growing season (assumed to last from March to November) for each year. Based on these means, I computed the variance in rainfall for each county-group. For both average rainfall and the variance in rainfall I use log rainfall to capture relative rather than absolute deviations from the mean. As an alternative measure of rainfall risk, I also computed the probability that a drought will occur, i.e. the probability that in a specific year rainfall will be less than 75% of the long-term average rainfall (growing season) in that county-group.

[Figure 2 about here]

Figure 2 shows a set of maps documenting the distribution of rainfall, rainfall variation and droughts across the US (counties). Rainfall levels are particularly high in the Northeast, along the Atlantic coast and in the Southeast more generally. The area to the left of the 100° West meridian is very dry, yet rainfall is relatively high in Colorado, the Rockies and in the Northern part of the Pacific coast. Rain-fed agriculture was, without irrigation, barely possible in the West; livestock farming was the dominant activity. In the latter half of the nineteenth century the US experienced major droughts in 1856-1865, 1870-1877 and in 1890 and 1896 (Herweijer et al., 2004). In the first half of the twentieth century the dust bowl, i.e. a period of severe dust storms that caused

⁶ The dataset uses whatever station networks and data sources are available for the relevant period. The rainfall time series were modelled using climatologically-aided interpolation (CAI), i.e. the Parameter-elevation Regressions on Independent Slopes Model (PRISM), which used the long-term average pattern as a first guess of the spatial pattern of climatic conditions for a given month or day. CAI is robust to wide variations in station data density, which is necessary when modeling long-term series. Data is based on monthly modelling. Removing those counties from the sample for which rainfall data is not available reduces the sample size by 79 counties.

enormous damage to farm land, farm yields and cattle, stands out. It started in the early 1930s, i.e. outside my observation window, and lasted several years (Worster, 1979).

4. Empirical specification

To identify the effect of rainfall risk on fertility I use the pooled sample of all census data covering the period from 1870 to 1930. I regress fertility on the county-group-specific rainfall variance controlling for rainfall levels, individual, household and county characteristics in each census year and accounting for state-specific time effects in fertility. The indices i , c , s and t stand for the individual, the county-group, the state and time respectively. Since rainfall variability should, at least directly, only matter for farm households, I interact rainfall and rainfall variability with being in a farm household, which allows me to control for county-group-fixed effects. Hence identification relies on the differential effect of rainfall variability on fertility between farm and non-farm households.⁷ Non-farm households in rural areas include for example carpenters, construction workers, millers, mine workers, carriers, mechanics, teachers and traders among others. Moreover, because the effect of rainfall variability may also change over time, for instance because agriculture becomes less dependent on rain, I also interact rainfall and rainfall variability with time. Hence, the full model reads:

$$\begin{aligned} fert_{icst} = & \beta_1(rain_{cs} \times farm_{icst}) + \beta_2(rain_{cs} \times farm_{icst} \times T_t) \\ & + \beta_3(rainvar_{cs} \times farm_{icst}) + \beta_4(rainvar_{cs} \times farm_{icst} \times T_t) \\ & + \beta_5(rainvar_{cs} \times T_t) + \beta_6(rainvar_{cs} \times T_t) \\ & + \rho W fert_{cst} + X'_{icst} \beta_7 + C'_{cst} \beta_8 + \vartheta_{cs} + \beta_9(\gamma_s \times T'_t) + \varepsilon_{icst} \quad (1) \end{aligned}$$

where $rain$ stands for the average yearly rainfall level (in log) in the growing season, $rainvar$ for the average yearly rainfall (in log) variance in the growing season, the matrix X for a set of individual and household controls including age, education, education of the household head, being born in a different county or abroad and whether the household is a farming household. The matrix C stands for time-varying county-level controls such as the average value of farmland and buildings, machinery and

⁷ Note that for 1870 and 1880 IPUMS coded a household as “farm household” if it contained at least one person with the occupation “farmer”. In later years the coding was based on the enumerator’s explicit identification of a farm (cultivated land, production and use of agricultural labor).

implements and the average size of farmland per farm, T stands for year effects (census years) and γ_s for state effects. The parameter ϑ_c stands for county-group-fixed effects. To account for spatial correlation of fertility, I also estimate specifications, where the spatially lagged fertility, $Wfert$, is included among the controls. To do so, I first estimate a spatial weight matrix using the geographical information of latitude and longitude (Kondo, 2017). This matrix is then used to compute a county-specific spatially lagged variable that accounts for spatial dependencies across counties.

Since rainfall variability shows also some variation over time, I also use a specification, where rainfall variability is not calculated over the entire observation window covered by the PRISM data, but over ten-year intervals around the census year, i.e. for the census of 1900 for the period 1895 to 1905 and for the census of 1910 for the period 1905 to 1915 and so on. This measure is supposed to reflect the rainfall conditions around a specific census year. Obviously, the virtue of this specification is that it creates within-county-group variation in rainfall-variability over time which can be used in addition for identification:

$$fert_{icst} = \beta_1(rain_{cst} \times farm_{icst}) + \beta_2(rainvar_{cst} \times farm_{icst}) + \rho Wfert_{cst} + X'_{icst}\beta_7 + C'_{cst}\beta_8 + \vartheta_{cs} + \beta_9(\gamma_s \times T'_t) + \varepsilon_{icst} \quad (2)$$

Since the PRISM data only starts in 1895, this specification does not use the census data of 1870 and 1880.

To test for the effect of risk-mitigating technologies (I), I re-estimate Equation (1) as follows:

$$\begin{aligned} fert_{icst} = & \beta_1(rain_{cs} \times farm_{icst}) + \beta_2(rain_{cs} \times farm_{icst} \times I_{cst}) \\ & + \beta_3(rainvar_{cs} \times farm_{icst}) + \beta_4(rainvar_{cs} \times farm_{icst} \times I_{cst}) \\ & + \beta_5(rain_{cs} \times I_{cst}) + \beta_6(rainvar_{cs} \times I_{cst}) + \beta_7(farm_{icst} \times I_{cst}) + \beta_8 I_{cst} \\ & + \beta_9(rainvar_{cs} \times T_t) + \beta_{10}(rainvar_{cs} \times T_t) \\ & + \rho Wfert_{cst} + X'_{icst}\beta_{11} + C'_{cst}\beta_{12} + \vartheta_{cs} + \beta_{13}(\gamma_s \times T'_t) + \varepsilon_{icst} \quad (3) \end{aligned}$$

If the emergence of risk-mitigating technologies indeed reduces the need of farm households for more children to cope with rainfall shocks, I should find $\beta_4 < 0$.

5. Results

5.1 Main results

A precondition for seeing an effect of rainfall variability on fertility that can be traced back to households' need for insurance, is that rainfall is a determinant of agricultural production. Although it has been shown many times in the literature, I nevertheless verified that this link also holds true in my data. For this purpose, I regressed the county average value of production per farm in year t on rainfall during the growing season in year t controlling for average farm size, the average value of land per acre, the average value of machinery and implements per farm, state-specific period effects and county-group fixed-effects. I find an elasticity of 0.37, i.e. one percent more rainfall during the growing season increases the value of output by 0.37%. The results are shown in Table A.1 in the Appendix. In what follows I therefore take for granted that agricultural production and hence agricultural income varies with rainfall. Table A.1 (cols. (4)-(6)) also shows that county-group-specific rainfall variability in itself, i.e. the extent to which rainfall typically varies from one year to another is in turn not a determinant of the value of production in year t once rainfall in year t is controlled for. Rainfall variability is measured here as the variance in rainfall over the period covering the five years prior and five years following the census year. Hence, if below I find an effect of rainfall variability on fertility controlling for the rainfall level, it is unlikely that this effect is driven by a simple income effect.

I now turn to the estimation of Equation (1). To show the sensitivity of the results with respect to different sets of controls and estimation methods I show several specifications. The results are shown in Table 2. Col. (1) does not yet account for county-group fixed-effects and state-time effects, it just includes general time effects. Col. (2) controls for county-group fixed-effects. Col. (3) estimates year-specific effects of rainfall variability on fertility. Col. (4) allows in addition for state-specific time effects. Col. (5) accounts for a spatial dependence of fertility levels across countries. Col. (6) uses instead of rainfall variation the risk of drought measurement. Col. (7) includes also urban areas in the analysis and col. (8) removes women from the sample who were born in another state than their current state of residence or abroad.

[Table 2 about here]

The results in col. (1) show that the general effect of rainfall variability on fertility is negative, but the interaction effect with being in a farm household is positive and over-compensates the general negative effect. Hence, rainfall variability is associated with an increase in fertility in farm households but not in non-farm households. In the following specifications identification relies on that difference between farm and non-farm households within county-groups and hence all county-group-specific characteristics that do not vary over time and do not impact farm and non-farm households differently are controlled for through the introduction of county-group fixed effects.

In farm households the effect of rainfall variability on fertility is across all specifications significant positive. Col. (2) suggests if rainfall variability is increased from a level that corresponds to the mean in the tenth percentile to the mean in the ninetieth percentile the number of children below the age of five in farm household increases on average by 0.09 or 9.2% of the mean relative to non-farm households. This is about half of the difference in fertility between literate and illiterate women. Such a shift in rainfall variability corresponds, for example, to a move from Chippewa, Michigan to Culberson, Texas.

Cols. (3) and (4) reveal an interesting time pattern: The effect of rainfall variability on fertility observed for farm households is reduced as time progresses. Whereas the estimated effect is 0.830 in 1870 it decreases by about 60% to 0.338 in 1930 (col. (4)). This means that if rainfall variability is increased, again, from a level that corresponds to the mean in the tenth percentile to the mean in the ninetieth percentile the number of children below the age of five in farm households relative to non-farm households increases in 1870 on average by 12% and in 1930 by only 5%, hence the fertility differential that is due to rainfall risk has almost disappeared by the end of the observation window. The time pattern is illustrated in more detail in Figure 3. The effect is relatively constant between 1870 and 1900 and then starts to decline.

During the period 1870 to 1930 the US experienced substantial social and economic change. In very arid areas, irrigation systems were built, formal safety nets and financial services became available and farms became more and more capital intensive. It also coincides with a massive expansion in the use of electricity. All this might have reduced the role of children in coping with rainfall risks. Whether this hypothesis is coherent

with the empirical evidence will be explored in more detail below. This time pattern is also robust to the inclusion of a spatial lag, i.e. if the spatial dependence of fertility levels across counties is taken into account (col. (5)). The results do also not change qualitatively if instead of rainfall risk the risk of drought is used (col. (6)). Including urban households into the sample does also not significantly change the results used (col. (7)). Finally, if migrants are removed from the sample the rainfall variability effect even increases (col. (8)). This makes it unlikely that my estimates are driven by selective migration. This potential bias will be further discussed below. The results are also qualitatively similar if a count data model is used, but given the sample size and complex interactions and fixed effects these models need an excessive time to converge. Before turning to further robustness checks, I will briefly comment on the effects associated with some of the control variables. The results show that the level of rainfall had only a small effect on fertility. As expected, literate women have lower fertility than illiterate women. The fertility rate of women who were born in a different state is not significantly different. Yet, women who were born abroad have on average an additional 0.25 children below the age of five in their household. Interestingly in col. (8) the farm effect turns negative suggesting also that migrant farms had significantly more children than non-migrant farms. Fertility also decreases as the value of land and buildings per acre and farm size increases. The value of implements and machinery per farm alone has an insignificant or only small negative effect. Other specifications where I controlled in addition for the distance to the next river interacted with time and longitude and latitude interacted with time have also not led to different results (not shown in Table).⁸

To conclude, the results above suggest that farm households increased their fertility with increasing rainfall variability. Yet this effect started to decrease at the beginning of the 20th century. Before I explore the underlying time pattern in more detail, I conduct several robustness checks to provide further support to my main findings.

⁸ Distance from the centroid of a county-group to the next river was calculated using a shapefile from the US Geological Survey. It contains all rivers and lakes in North-America. Only rivers that are longer than 100 miles or alternatively 500 miles were considered. Yet, the data refers to rivers today, the exact course of a river might have been slightly different at the end and 19th century.

5.2 Robustness checks

Shorter term rainfall variability

The estimations above are based on county-group-specific rainfall variability calculated for the period 1895 to 1980. I now re-estimate this model using county-group-decade-specific rainfall variability as specified in Equation (2). The advantage of this specification is that it allows not only to use within-county-group variation between farm and non-farm households but to use also within-county-group variation in rainfall variability over time. For each census year and each county-group I calculate the rainfall variability for the period starting five years prior to the census year and ending five years after the census year. Again, the intention is to capture the rainfall conditions in the period ‘around’ the census year. Alternatively, one could also use for example rainfall variability over the ten years preceding the census to ensure to capture only weather conditions that prevailed before a birth was reported. This has also been done, but did not change the results reported below. Since rainfall data is only available for 1895 onwards, the estimation of Equation (2) does only use the census data of the years 1900-1930. Table 3 shows the results: Col. (1) without rainfall-farm interactions, col. (2) with rainfall-farm interactions, col. (3) includes in addition state-specific time effects and col. (4) uses county-group fixed effects for farm and non-farm households separately.

[Table 3 about here]

I find that the overall effect of rainfall variability on fertility is clearly positive (see col. (1)). As rainfall variability increases, rural households tend to have more children. Col. (2) shows that this effect is driven by farm households, as the linear effect is insignificant. The order of magnitude of the effect is very similar to the one identified using the specification with the time-constant rainfall variability. If state-specific time effects are included, the effect of rainfall variability shrinks somewhat but is still sizeable and statistically significant. The effect is also robust to the inclusion of farm and non-farm-specific fixed-effects (col. (4)). Hence, overall these results support the findings above. Fertility in farm households increase with rainfall variability.

Timing effects

Next, I divided the sample into a subsample with all women younger than 25 years and a subsample with all women 25 years and older allowing to check whether the rainfall risk effect is only driven by younger women. This could be the case if in fact rainfall variability did not induce parents to have more children but only to have them earlier. The results are shown in Table S.1 in the online appendix. I estimated two alternative specifications for both age groups. The estimates show that splitting the sample by women's age does not change the previous results. For both subsamples, higher rainfall variability is associated with higher fertility. The effect has a similar size for both age groups at the end of the 19th century. Yet, a sizeable decline of the rainfall variability effect as time progresses can only be observed for the older age group. For the younger group the rainfall-time-farm interactions are also negative for more recent years but not statistically significant. Overall, these results make it unlikely that the rainfall risk effect on fertility is only driven by women in farm households who have their children earlier.

Rainfall risk-induced child mortality

The results above would be biased if the increased fertility in counties with higher rainfall variability was partly a response to increased infant and child mortality induced by the rainfall variability. If droughts led to shortages of food and diseases that caused children to die more frequently, parents in counties with high rainfall variability may have increased their fertility to compensate (Olsen, 1980).

Unfortunately, mortality data for that period of time is scarce. Death registration procedures were universally in place only after 1933. Until 1910 deaths were only registered in the more industrialized and urbanized states of the Northeast. After 1910, death registries were slowly introduced in the rest of the country (Pope, 2000). Based on the little data that existed, Haines (2008) estimates that the infant mortality rate for white people declined from 176 per 1000 live births in 1870, to 111 in 1900 and 60 in 1930 (Haines, 2008; see also Cutler and Meara, 2001). The general decline in mortality in the late nineteenth century was largely the result of improvements in public health and sanitation (see, e.g., Cutler and Miller, 2005; Cutler et al., 2006; Haines, 2008). Better diets, clothing and shelter also played a role. Later heating and clean cooking made accessible through electrification further lowered infant mortality (Lewis, 2014).

Medical interventions to curb specific infectious and parasitic diseases, including tuberculosis, pneumonia, bronchitis and gastro-intestinal infections, as well as lethal diseases such as cholera, smallpox, diphtheria, and typhoid fever led to significant mortality reductions only well into the twentieth century (Haines, 2008; Fishback et al., 2007). Malaria was a major cause of death until its eradication in 1950. Risks were high in the Southern and Southeastern regions and in the area along the Mississippi and Missouri Valleys and up through the Old Northwestern regions (Hong, 2007).

With the data at hand, it is not possible to control for infant and child mortality systematically. However, there is little indication that mortality was highly correlated with rainfall variability. Mosquito breeding may increase with rainfall but the effect of rainfall variability on breeding is rather ambiguous. Droughts would certainly reduce breeding and hence reduce rather than increase mortality. Famines were very uncommon in the US at that time, given the abundant land resources. Even during the dust bowl of the 1930s, mortality did not reach levels that are typically associated with famines (see, e.g., Worster, 1979; Hansen and Libecap, 2004). This makes it unlikely that rainfall variability led to higher fertility through increased mortality.

Nevertheless, to further rule out that such a bias drives the results, I use the census data of 1900 and 1910, where women were not only asked about the number of children in their household but were also asked to report the number of children ever born and the number of children that survived. I use these two variables to estimate child mortality rates for each year in each county. I calculate the rate separately for farm and non-farm households. With this data I test whether child mortality was correlated with fertility, whether the mortality effect off-sets part of the rainfall variability effect and whether rainfall variability in turn can explain child mortality. Table 4 shows the results.

[Table 4 about here]

Col. (1) in Table 4 re-estimates Equation (1) using the data of 1900 and 1910 only and instead of using the number of children below five in the household it uses the number of children ever born as dependent variable. The differential effect of rainfall variability on fertility between farm and non-farm households is qualitatively similar to the effects shown in Table 2. Col. (2) shows that indeed, as expected, higher child mortality is

associated with higher fertility, i.e. parents seem to compensate. An increase in the mortality rate by 10 percentage points would be associated with an increase in fertility by 0.078 children per mother. If as in col. (3) mortality and rainfall variability are introduced jointly, both the effect of mortality and the effect of rainfall variability are more or less unchanged. These results make it unlikely that the effect of rainfall variability is transmitted through rainfall risk-induced child mortality.

Rainfall risk and returns to education

Another potential concern is that differences in rainfall risk lead to differences in returns to education and, in consequence, also to returns to quantity (i.e. the number of children). In this case the higher fertility was not the result of risk mitigation but the response to low returns to quality and hence high returns to quantity. This argument is not very different from the one tested in this paper as the underlying hypothesis is that rainfall-risk increases the return to quantity. Yet, to exclude that the effect only goes through education, I re-estimate Equation (1) controlling for the children's year and county-specific school enrolment rate, i.e. I test whether there is still a positive association between rainfall variability and fertility, once the effect of parental educational investments on fertility is controlled.

The census data reports for each child in the household whether this child is enrolled in school or not. In the second half of the 19th century school enrollment rates for 5 to 19-year olds fluctuated around 50% to 60% and started to rise from 1900 onwards quite rapidly. Since, older children are likely to have left the household already, I focus in what follows on the age group 6 to 11. For every census year I calculate for each woman the share of her children in that age group that is enrolled in school and average these rates at the county level. Using the year-specific county-level enrollment rate instead of the household level enrollment rates should mitigate endogeneity problems to some extent.

[Table 5 about here]

Table 5 shows the results. The comparison of cols. (1), (2) and (3) shows that the effect of rainfall risk on farm households' fertility is not significantly changed if school

enrolment is among the controls. School enrolment itself is negatively correlated with fertility as the quality-quantity trade-off model predicts, however the effect is small and statistically insignificant. Rainfall variability in turn is not correlated with enrolment rates (col. (4)). Based on these findings it is unlikely that the effect of rainfall variability on fertility dominantly passes through reduced educational investments.

5.3 The effect of risk-mitigating technologies and institutions

The results above suggest that the effect of rainfall risk on fertility is reduced as time progresses. In this section I test whether this phasing out can be explained by the adoption of risk-mitigating technologies and the emergence of risk-mitigating institutions. I focus on the adoption of irrigation systems, the use of physical capital more generally and the spread of formal banks. For all three it can be argued that they reduce the need of parents to have many children to cope with rainfall risks. Unfortunately, data for the availability of irrigation systems and formal banks is only available for selected years. Maps showing the spatial distribution of irrigation systems, agricultural machinery and banks over time can be found in the Online Appendix (Figures S.2 - S.4).

Figure S.2 shows that irrigation was used particularly in the arid West, but also spread to the western and southern parts of the Central region as time progressed. The use of machinery increased rapidly at the beginning of the twentieth century, especially in the Great Plains (Fig. S.3). This can be explained by several innovations that became available for large scale adoption, such as tractors and reapers (Olmstead and Rhode, 2001). It is also due to the ongoing electrification which started in 1880, and the increasing availability of credit, both of which made it possible for households to use more machinery. Banks were especially concentrated in New England and the northeastern Central states. Because of the 1929 financial crisis and a serious disruption of the banking system by wide-spread mortgage defaults by small farmers and corresponding bank failures there were fewer banks in 1930 than in 1920 (Fig. S.4) (Libecap and Hansen, 2002). In 1929 and 1930 alone almost 2,000 banks failed, mainly due to a run on banks during which millions of depositors throughout the country withdrew their savings (Wicker, 1996; Klein 2001).

[Table 6 about here]

To test for the effect of risk-mitigating technologies, I estimate Equation (3). Table 6 shows the results in each case with two alternative specifications regarding time effects. Cols. (1) and (2) show that the effect of rainfall risk on fertility is significantly reduced for women in farming households in counties where farms adopted irrigation systems when compared to counties where irrigation systems were not available. The size of the estimated coefficients in col. (2) implies that the fertility differential due to rainfall variability between farm and non-farm households disappears if the share of irrigated land in a county exceeds 23%. Among those counties that have irrigation systems in place, 23% corresponds to the level in the 30th percentile of the distribution. The fertility effect is also lower in counties where more machinery is used. The estimate col. (4) implies that the fertility differential shrinks by 50% if counties in the ninety-fifth percentile of the distribution of machinery are compared with counties in the fifth percentile. Finally, cols. (5) and (6) show the results where rainfall variability is interacted with the access to financial services. Although the sign of this interaction is also negative, the effect is economically small and statistically insignificant. The results do not change much if instead of the absolute number of banks per county the number of banks per farm per county is used as explanatory variable. Hence, based on this specification it is hard to say whether financial services could not or were not used for risk coping or whether the available measures of access to financial services are simply too crude. Yet, overall the results in Table 6 seem to support the idea that farming households used children to insure themselves against rainfall shocks but that this effect disappeared as other risk-mitigating technologies became available, at least this seems to be the case for irrigation and machinery.⁹ It is also interesting to note that in farm households the increasing adoption of irrigation and machinery reduced not only the effect of rainfall variability on fertility, it also reduced the effect of rainfall levels on fertility in farm households.

⁹ Guest and Tolnay (1985) show that in the early 1900s, increasing farm mechanization increased education investment suggesting that mechanization reduced the return on child labor (see also Goldin and Katz, 1999).

The results in this section could of course be biased if the emergence of these risk-mitigating technologies and services was endogenous to fertility decisions. This would be the case if, for instance, farming households with a preference for fewer children sorted themselves into areas where risk-mitigating technologies and institutions were available or if they at least, adopted these technologies and institutions earlier than others. The used controls can only imperfectly account for such unobserved heterogeneity. Further issues related to endogenous migration will be discussed below.

5.4 Endogenous migration

Unobserved preferences that may have determined both the destination of settlers and fertility present a threat to the identification used in this paper, i.e. if parents with a preference for fewer children migrated systematically to areas with lower rainfall variability. Dunlevy (1980) and Dunlevy and Saba (1992) highlight four factors explaining the choice of destination of settlers in the nineteenth century: population density, the availability of land, the distance to the port of entry and prevailing per capita income. The latter was generally seen as an indicator of expected income or job opportunities. Gallaway et al. (1974) provide some evidence that native-born Americans tended to migrate to the less densely populated states whereas immigrants were more inclined to locate in the more densely populated states. The presence of friends and relatives was also an attraction to immigrants (Gallaway et al., 1974). According to Dunlevy (1980), the exact weather conditions played only a minor role (see also Dunlevy and Saba, 1992). He shows that, if anything, some migrants were attracted by destinations that showed a climate like the one they had in their home country. Libecap and Hansen (2002) also argue that settlers had only little means of accessing systematic weather information from other regions. There were also no warnings of droughts. Moreover, the so-called dryfarming doctrine was presented to settlers as a remedy for drought (Libecap and Hansen, 2002). All this is of course not enough to rule out the potential concerns about endogeneity, but at least there is nothing that explicitly suggests that, conditional on other geographic characteristics including rainfall levels, rainfall variance was an important determinant for the destination choice of immigrants and native-born migrants.

Moreover, the estimates presented in Table 2 show that the rainfall variability effect is robust to the inclusion of variables controlling for “having been born in a different state” and “having been born abroad”. The results also hold if like in col. (8) all women that migrated are excluded from the sample. Hence, based on these findings, I believe that selective migration is not the main driver of the results shown in this paper.

6. Conclusion

This paper explored the role of rainfall risk in the American demographic transition. Risk exposure has so far only received little attention as a driver of fertility. My findings provide support for the hypothesis that in a context in which formal insurance devices are largely absent, fertility may respond to a need to insure risks ex-ante. I find that in the late nineteenth century in the United States, agricultural households that were exposed to extreme rainfall variability, controlling for rainfall levels, had higher fertility than agricultural households that were exposed to lower levels of rainfall variability. As expected, rainfall variability does not increase fertility in non-agricultural households. This effect is robust to a wide range of controls including county-group level heterogeneity, state-specific time effects and spatial lags. The effect is also found if changes in the climate, i.e. the variation of rainfall variability within county-groups over time are used for identification. Going from the tenth to the ninetieth percentile in the distribution of rainfall variability increases the fertility differential between farm and non-farm households by about 12% in the late 19th century. Interestingly, the effect starts to decrease at the beginning of the twentieth century, suggesting that the insurance function of children is diluted as more capital is used in agriculture and alternative risk management devices emerge. And indeed, using data on the use of irrigation systems and agricultural machinery, it can be shown that the fertility effect decreases as these aspects gain importance. Hence, access to risk-mitigating devices significantly contributed to the demographic transition in the US.

The observational character of the data do not allow me to deal with all possible confounding factors and hence the findings are not necessarily causal, but they are quite robust to alternative specifications and lead, overall, to a consistent story. I can also show that the effects are not driven by rainfall variability-induced child mortality or a

quantity-quality trade off triggered by differences in the returns to education between areas with low and high rainfall variability.

The findings from this paper cannot only contribute to a better understanding of the demographic transition in the US, they can also enrich demand-side theory of fertility and models of long-term growth with endogenous population. The findings also have potentially important implications for Sub-Saharan Africa, where many households must cope with rainfall shortages, crop diseases, price shocks, natural disasters, health shocks and conflicts. As formal risk management devices are usually absent, these risks may partly drive fertility and keep it at high levels. It may explain why, in some regions, especially in poor rural semi-arid or arid areas of Sub-Saharan Africa, the demographic transition has often not even started or, if it has started, progresses only slowly or has stalled.

Appendix

[Table A.1 about here]

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Tables and Figures

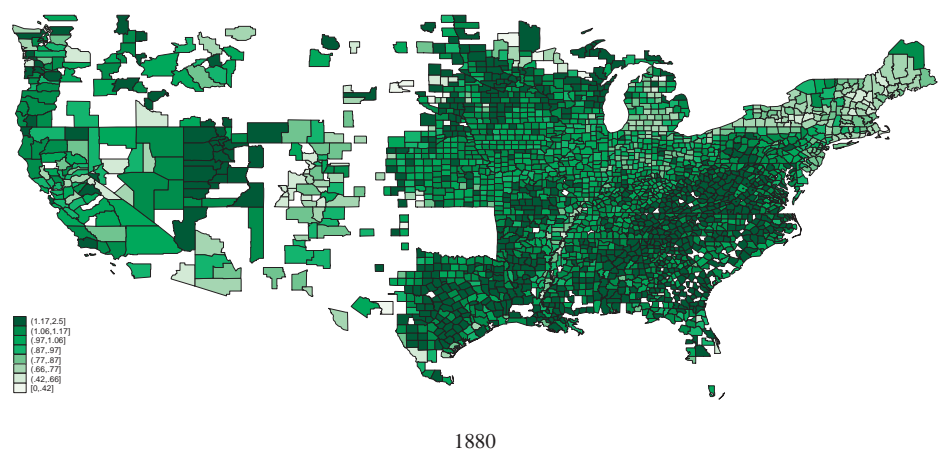
Table 1. Sample composition and descriptive statistics

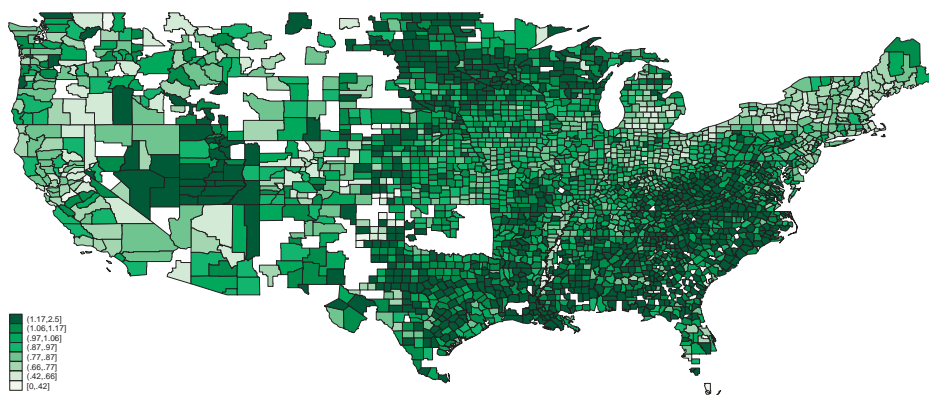
	1870	1880	1900	1910	1920	1930	Total
Sample composition							
Women ever married (15-39)	45,910	346,174	206,193	47,312	49,467	249,982	945,038
Share obs.	0.049	0.366	0.218	0.050	0.052	0.265	1
Counties	1,934	2,250	2,623	2,772	2,913	2,968	n.a.
County Groups	315	327	336	341	344	344	n.a.
States	36	38	44	46	48	48	n.a.
Descriptives							
# children under 5	1.041	1.032	0.990	0.956	0.902	0.804	0.932
Age	28.5	28.7	28.9	28.9	29.2	29.2	28.7
Literate	0.863	0.891	0.927	0.947	0.961	0.975	0.926
Head literate	0.869	0.893	0.919	0.931	0.941	0.953	0.918
Farm hh	0.569	0.575	0.567	0.539	0.570	0.511	0.554
Born in different state	0.273	0.290	0.216	0.233	0.227	0.222	0.249
Born in foreign country	0.109	0.116	0.107	0.096	0.085	0.050	0.094
Av. value farml. & build. p/a ^{a)}	19.9	17.2	21.0	40.6	73.0	57.3	40.6
Av. farm size (acres)	205.5	186.4	205.9	264.6	305.5	346.3	327.1
Av. value of impl. & machin. per farm ^{a)}	118.2	95.3	144.6	223.1	618.6	616.5	328.1
Share of land irrigated ^{a)}			0.040	0.049			0.045
Number of banks ^{a)}					9.7	6.9	8.3

Notes: White, rural population excluding Alaska, Hawaii and people living in military camps. ^{a)} County averages (values in constant US dollar, surface in acres), n.a. = not applicable.

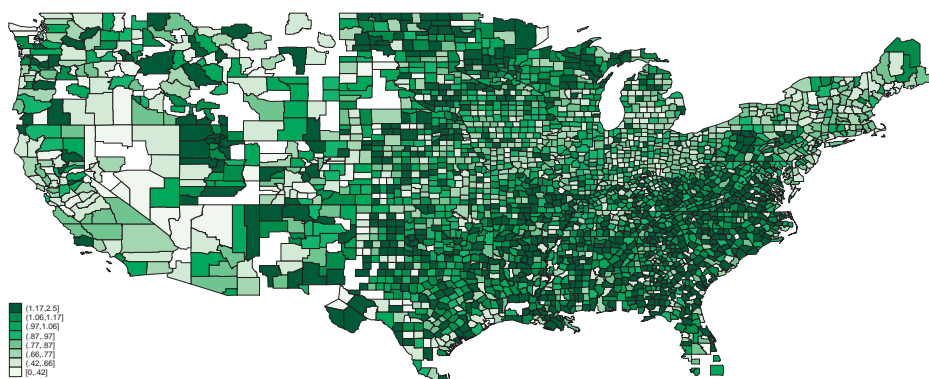
Source: US population census, agricultural census 1870-1930 (IPUMS, NHGIS); own estimations.

Figure 1. Children under five per woman ratios of ever married white women (rural areas)

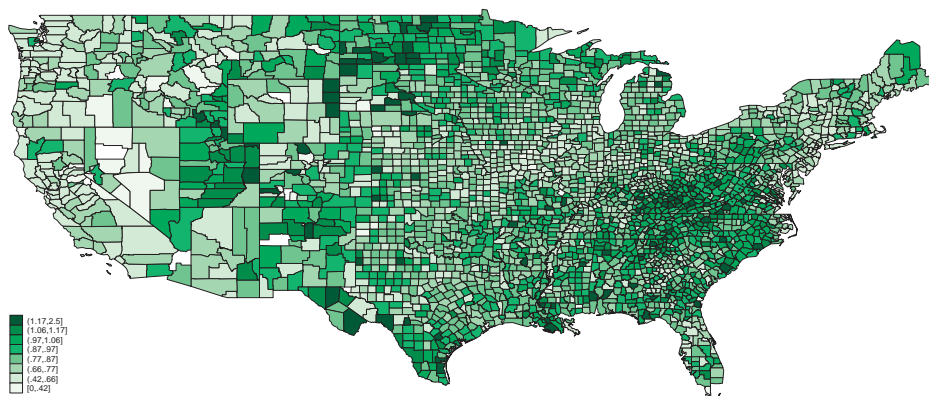




1900



1910

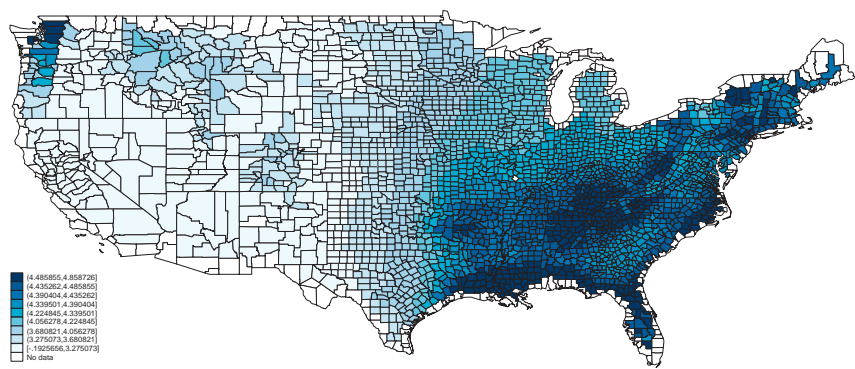


1930

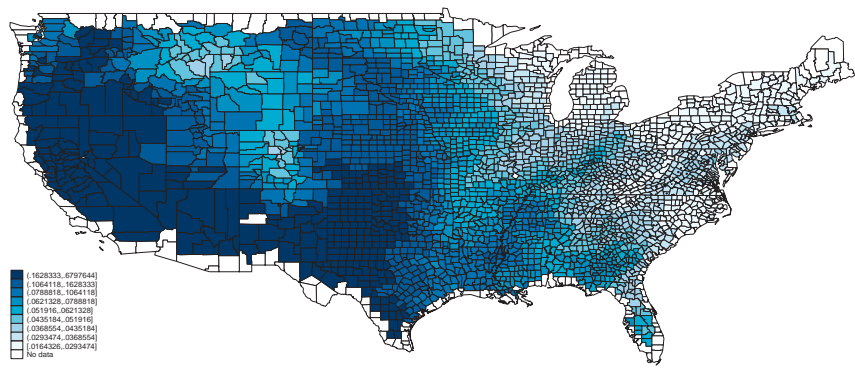
Notes: Each map uses the same scale. White spaces indicate areas where no census data was collected.

Source: US population census (IPUMS); own estimations.

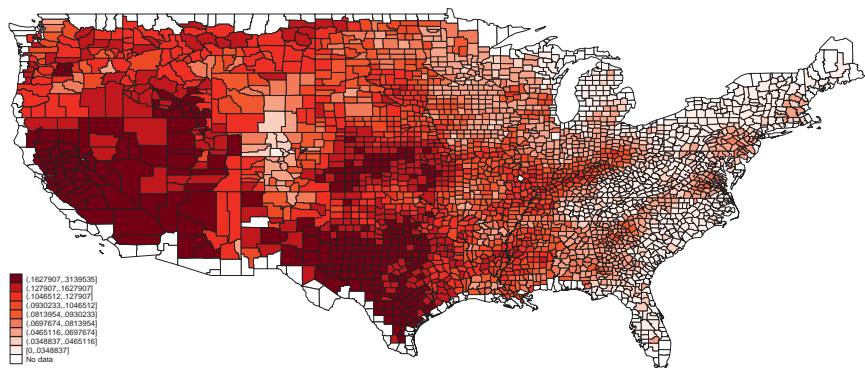
Figure 2. Rainfall levels and rainfall risk



Rainfall level



Rainfall risk



Risk of drought

Notes: Darker areas indicate higher rainfall levels, rainfall risk and risks of drought. White areas indicate areas without rainfall data.

Source: PRISM data set; own estimations.

Table 2. The effect of rainfall variability on fertility, main results

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	OLS	Basic FE	Year interact.	State-time FE	Spatial lag	Drought	Rural & Urb.	w/o migrants
Literate	-0.132*** (0.005)	-0.111*** (0.007)	-0.111*** (0.007)	-0.112*** (0.006)	-0.112*** (0.006)	-0.110*** (0.006)	-0.146*** (0.007)	-0.098*** (0.007)
Literate head	-0.012** (0.005)	-0.001 (0.005)	0.000 (0.005)	0.000 (0.005)	0.000 (0.005)	0.007 (0.005)	0.018*** (0.006)	-0.000 (0.006)
Farm hh	0.052 (0.070)	-0.138 (0.119)	-0.143 (0.113)	-0.143 (0.111)	-0.141 (0.110)	-0.052 (0.051)	-0.150 (0.106)	-0.385*** (0.116)
Born in a different state	-0.002 (0.004)	0.001 (0.004)	0.001 (0.004)	-0.003 (0.003)	-0.003 (0.003)	-0.001 (0.003)	-0.021*** (0.004)	
Born abroad	0.246*** (0.006)	0.246*** (0.007)	0.250*** (0.007)	0.246*** (0.007)	0.246*** (0.007)	0.250*** (0.007)	0.226*** (0.006)	
Val. land and build. p.a. (ln)	-0.052*** (0.006)	-0.068*** (0.008)	-0.057*** (0.008)	-0.057*** (0.009)	-0.053*** (0.008)	-0.051*** (0.008)	-0.059*** (0.009)	-0.055*** (0.010)
Av. farm size (ln)	0.012* (0.007)	-0.032*** (0.010)	-0.032*** (0.010)	-0.031*** (0.011)	-0.029*** (0.010)	-0.026*** (0.010)	-0.028*** (0.010)	-0.023*** (0.011)
Av. value machinery (ln)	-0.053*** (0.007)	0.006 (0.010)	-0.004 (0.011)	-0.008 (0.010)	-0.007 (0.009)	-0.011 (0.010)	-0.008 (0.010)	-0.021* (0.012)
Spatially lagged fertility					0.124*** (0.013)	0.114*** (0.014)		
Rainfall (ln)	0.023 (0.016)							
Var Rainfall (ln)	-0.234*** (0.097)							

Table 2 continued ...

	(1) OLS	(2) Basic FE	(3) Year interact.	(4) State-time FE	(5) Spatial lag	(6) Drought	(7) Rural & Urb.	(8) w/o migrants
Rainfall (ln) x Farm hh	0.014 (0.015)	0.054** (0.026)	0.030 (0.025)	0.032 (0.024)	0.031 (0.024)	0.002 (0.012)	0.038 (0.023)	0.075*** (0.026)
Var rainfall (ln) x Farm hh	0.443*** (0.105)	0.653*** (0.169)	0.992*** (0.247)	0.830*** (0.213)	0.839*** (0.211)	1.157*** (0.220)	0.857*** (0.204)	1.547*** (0.383)
Rainfall (ln) x Farm hh x 1880			0.020*** (0.003)	0.018*** (0.003)	0.018*** (0.003)	0.018*** (0.004)	0.020*** (0.003)	0.022*** (0.004)
Rainfall (ln) x Farm hh x 1900			0.030*** (0.003)	0.027*** (0.003)	0.028*** (0.003)	0.028*** (0.005)	0.034*** (0.003)	0.034*** (0.004)
Rainfall (ln) x Farm hh x 1910			0.031*** (0.004)	0.028*** (0.004)	0.028*** (0.004)	0.030*** (0.005)	0.038*** (0.003)	0.035*** (0.005)
Rainfall (ln) x Farm hh x 1920			0.030*** (0.004)	0.030*** (0.004)	0.030*** (0.004)	0.032*** (0.005)	0.039*** (0.003)	0.039*** (0.005)
Rainfall (ln) x Farm hh x 1930			0.031*** (0.003)	0.031*** (0.003)	0.031*** (0.003)	0.036*** (0.004)	0.041*** (0.003)	0.039*** (0.004)
Var rainfall (ln) x Farm hh x 1880			-0.052 (0.143)	0.117 (0.112)	0.102 (0.110)	0.061 (0.208)	0.102 (0.119)	-0.309 (0.343)
Var rainfall (ln) x Farm hh x 1900			-0.159 (0.160)	-0.074 (0.131)	-0.089 (0.131)	-0.154 (0.225)	0.006 (0.130)	-0.655* (0.357)
Var rainfall (ln) x Farm hh x 1910			-0.361** (0.178)	-0.238 (0.147)	-0.252* (0.147)	-0.337 (0.253)	-0.160 (0.153)	-0.918*** (0.407)
Var rainfall (ln) x Farm hh x 1920			-0.508*** (0.188)	-0.367*** (0.156)	-0.387*** (0.155)	-0.481** (0.235)	-0.214 (0.152)	-0.883*** (0.382)
Var rainfall (ln) x Farm hh x 1930			-0.638*** (0.199)	-0.492*** (0.158)	-0.504*** (0.157)	-0.703*** (0.216)	-0.421*** (0.154)	-0.893*** (0.378)

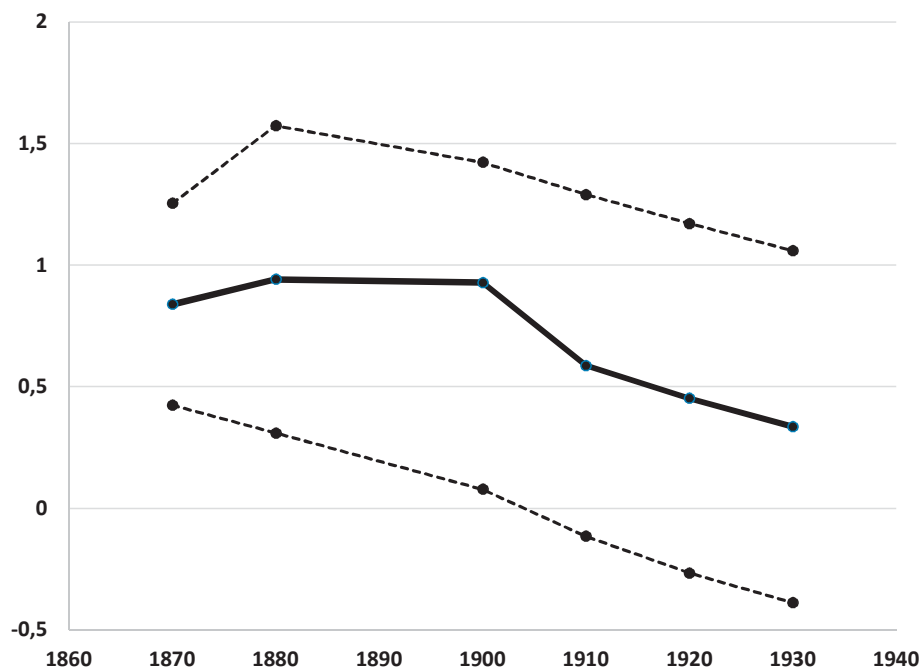
Table 2 continued ...

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	OLS	Basic FE	Year interact.	State-time FE	Spatial lag	Drought	Rural & Urb.	w/o migrants
Age effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
County-group fixed-effects		Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time fixed-effects	Yes	Yes	Yes					
Rainfall-time-interactions ^{a)}			Yes	Yes	Yes	Yes	Yes	Yes
State-specific time-effects				Yes	Yes	Yes	Yes	Yes
R-squared	0.078	0.076	0.077	0.081	0.082	0.084	0.090	0.086
Observations	945,038	945,038	945,038	945,038	945,038	945,038	1,532,791	621,393
County-groups		344	344	344	344	344	349	344

Notes: Standard errors in parentheses. "OLS" does not include county-group fixed effects. "Basic FE" includes county-group fixed-effects and time-effects. "Year interact." includes Rainfall-farm household-year interactions". "State-time FE" includes state-specific time effects. "Spatial lag" accounts for spatial correlation. "Drought" uses the probability of a drought as a measure of rainfall variance. "Rural & Urban" includes also urban households into the sample. "w/o migrants" excludes women from the sample who migrated to their current state from another state or from abroad. ^{a)} Rainfall-level time interactions and Rainfall-variance time interactions.

Source: US population census 1870-1930 (IPUMS, NHGIS); PRISM Precipitation dataset; own estimations.

Figure 3. The effect of rainfall variability on fertility over time (farm vs. non-farm households)



Notes: The left axis shows the regression coefficients along with the corresponding 95% confidence intervals drawn from Table 2, col. (5).

Source: US population census, agricultural census 1870-1930 (IPUMS, NHGIS); PRISM Precipitation dataset; own estimations.

Table 3. The effect of rainfall variability on fertility using decade-specific rainfall variability

	(1)	(2)	(3)	(4)
Rainfall (ln)	0.016 (0.044)	0.011 (0.044)	-0.048 (0.074)	-0.067 (0.070)
Var rainfall (ln)	0.543*** (0.145)	0.160 (0.188)	-0.167 (0.238)	-0.066 (0.209)
Rainfall (ln) x Farm hh		0.026 (0.044)	-0.033 (0.074)	0.015 (0.072)
Var rainfall (ln) x Farm hh		0.857*** (0.174)	0.440** (0.220)	0.395* (0.213)
Full set of controls	Yes	Yes	Yes	Yes
County-group fixed-effects	Yes	Yes	Yes	
County-group farm/nonfarm fixed-effects				Yes
Time fixed-effects	Yes	Yes		
State-specific time-effects			Yes	Yes
R-squared	0.060	0.060	0.062	0.056
Observations	552,954	552,954	552,954	552,954
County-groups	344	344	344	688

Notes: Standard errors in parentheses. The full set of controls includes age group dummies, literacy of the women and of her spouse, whether the household is a farm household, migration status (birth place), average land value per acre, average land size per farm and average value of machinery per farm.

Source: US population census 1900-1930, agricultural census (IPUMS, NHGIS); PRISM Precipitation dataset; own estimations.

Table 4. The effect of rainfall variability on fertility, ruling out child mortality as the main channel

	(1)	(2)	(3)	(4)
	Ch. born	Ch. born	Ch. born	Ch. mort.
Rainfall (ln) x Farm hh	0.172 (0.105)		0.169 (0.103)	0.004 (0.005)
Var rainfall (ln) x Farm hh	2.203*** (0.751)		2.185*** (0.743)	0.026 (0.036)
County-level child mort.		0.781*** (0.278)	0.747*** (0.283)	
Full set of controls	Yes	Yes	Yes	Yes
County-group fixed-effects	Yes	Yes	Yes	Yes
Rainfall level and Var rainfall time inter.	Yes	Yes	Yes	Yes
State-specific time-effects	Yes	Yes	Yes	Yes
R-squared	0.252	0.252	0.252	0.093
Observations	493,693	493,693	493,693	493,693
County-groups	341	341	341	341

Notes: Standard errors in parentheses. The estimates use all ever-married white women in rural areas, not just the age group 15-39 as in Table 2 and 3. “Ch. born” stands for the children ever born. “Ch. mort” stands for county-year-level farm and non-farm household-group-specific child mortality. The full set of controls includes age group dummies, literacy of the women and of her spouse, whether the household is a farm household, migration status (birth place), average land value per acre, average land size per farm and average value of machinery per farm.

Source: US population census 1900-1910 (IPUMS); PRISM Precipitation dataset; own estimations.

Table 5. The effect of rainfall variability on fertility, ruling out returns to education as the main channel

	(1)	(2)	(3)	(4)
	Fertility	Fertility	Fertility	Share enroll.
Rainfall (ln) x Farm hh	0.057** (0.025)		0.057** (0.025)	0.004 (0.003)
Var rainfall (ln) x Farm hh	0.648*** (0.166)		0.649*** (0.165)	0.016 (0.020)
Share enrolled (county)		-0.028 (0.018)	-0.028 (0.018)	
Full set of controls	Yes	Yes	Yes	Yes
County-group fixed-effects	Yes	Yes	Yes	Yes
Rainfall level and Var rainfall time inter.	Yes	Yes	Yes	Yes
State-specific time-effects	Yes	Yes	Yes	Yes
R-squared	0.074	0.074	0.074	0.793
Observations	945,038	945,038	945,038	945,038
County-groups	344	344	344	344

Notes: Standard errors in parentheses. The “share enrolled” measures the year and county-specific school enrolment rate of children 6 to 11 years old. The full set of controls includes age group dummies, literacy of the women and of her spouse, whether the household is a farm household, migration status (birth place), average land value per acre, average land size per farm and average value of machinery per farm.

Source: US population census, agricultural census 1870-1930 (IPUMS, NHGIS); PRISM Precipitation dataset; own estimations.

Table 6. The effect of rainfall variability on fertility, the role of risk mitigating technologies and institutions

	(1)	(2)	(3)	(4)	(5)	(6)
Rainfall (ln) x Farm hh	0.055 (0.046)	0.060 (0.047)	0.389*** (0.077)	0.445*** (0.074)	0.045 (0.031)	0.040 (0.032)
Var rainfall (ln) x Farm hh	0.850*** (0.291)	0.878*** (0.294)	4.308*** (0.528)	4.555*** (0.527)	0.369 (0.243)	0.391 (0.242)
Rainfall (ln) x Farm hh x Share irrig. land	-0.597*** (0.164)	-0.608*** (0.156)				
Var rainfall (ln) x Farm hh x Share irrig. land	-3.828*** (0.836)	-3.853*** (0.805)				
Rainfall (ln) x Share irrig. land	Yes	Yes				
Var rainfall (ln) x Share irrig. land	Yes	Yes				
Share irrig. land x Farm hh	Yes	Yes				
Rainfall (ln) x Farm hh x Value machinery (ln)			-0.071*** (0.012)	-0.080*** (0.012)		
Var rainfall (ln) x Farm hh x Value machinery (ln)			-0.696*** (0.085)	-0.738*** (0.084)		
Rainfall (ln) x Value machinery (ln)			Yes	Yes		
Var rainfall (ln) x Value machinery (ln)			Yes	Yes		
Value machinery (ln) x Farm hh			Yes	Yes		
Rainfall (ln) x Farm hh x Number of banks					-0.002 (0.003)	-0.002 (0.003)
Var rainfall (ln) x Farm hh x Number of banks					-0.012 (0.019)	-0.014 (0.019)
Rainfall (ln) x Number of banks					Yes	Yes
Var rainfall (ln) x Number of banks					Yes	Yes
Number of banks x Farm hh					Yes	Yes

Table 6 continued

Full set of controls	Yes	Yes	Yes	Yes	Yes	Yes
County-group fixed-effects	Yes	Yes	Yes	Yes	Yes	Yes
Time fixed-effects	Yes		Yes	Yes	Yes	
Rainfall level and Var rainfall time inter.	Yes	Yes	Yes	Yes	Yes	Yes
State-specific time-effects		Yes		Yes		Yes
R-squared	0.052	0.053	0.079	0.081	0.052	0.053
Observations	253,505	253,505	945,038	945,038	299,449	299,449
County-groups	341	341	344	344	344	344

Note: Standard errors in parentheses. Col. (1) and (2) uses data from the years 1900 and 1910. Col. (3) and (4) uses data from the years 1870 to 1930. Col. (5) and (6) uses data from the years 1920 and 1930. The full set of controls includes age group dummies, literacy of the women and of her spouse, whether the household is a farm household, migration status (birth place), average land value per acre, average land size per farm and average value of machinery per farm; in col. (1) and (2) also the share of irrigated land and in col. (5) and (6) also the total number of banks. *Source:* US population census (IPUMS, NHGIS); PRISM Precipitation dataset; Survey on Bank and Bank deposits, 1920 and 1930; own estimations.

Table A.1. The effect of rainfall and rainfall variability on agricultural production (county average value of production in constant US dollar per farm in t), county level estimates

	(1)	(2)	(3)	(4)	(5)	(6)
Rainfall (ln)	0.390*** (0.151)	0.350** (0.159)	0.370** (0.157)	0.394*** (0.132)	0.349** (0.140)	0.374*** (0.139)
Var Rainfall (ln)				0.208 (1.651)	-0.028 (1.657)	0.249 (1.560)
Val. land and build. p.a. (ln)	0.037 (0.048)	0.449*** (0.067)	0.114 (0.071)	0.037 (0.049)	0.449*** (0.067)	0.113 (0.070)
Av. farm size (ln)		0.629*** (0.031)	0.281*** (0.036)		0.629*** (0.031)	0.281*** (0.036)
Av. value machinery (ln)			0.505*** (0.040)			0.505*** (0.040)
County-group fixed-effects	Yes	Yes	Yes	Yes	Yes	Yes
State-specific time-effects	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	0.575	0.701	0.732	0.575	0.701	0.732
Observations	11,398	11,398	11,398	11,398	11,398	11,398
County-groups	344	344	344	344	344	344

Note: Standard errors in parentheses.

Source: US population census 1900-1930, agricultural census (IPUMS, NHGIS); PRISM Precipitation dataset; own estimations.

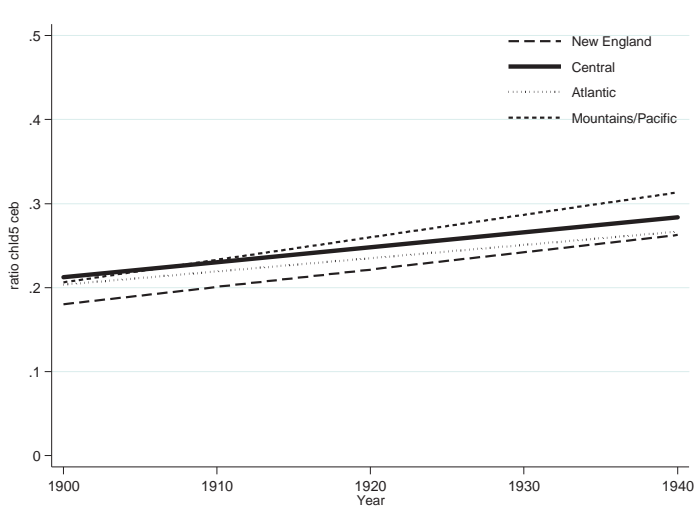
Rainfall risk, fertility and development: Evidence from farm settlements during the American demographic transition

Online appendix – Not intended for print publication

Checking the validity of using the child-woman ratio as a measure of fertility

The child woman ratio will follow a similar trend as that for the number of children ever born if, during the demographic transition, women start childbearing later and increase birth intervals proportionally. If, in contrast, as suggested by Tolnay and Guest (1984), women maintain their birth intervals but just stop earlier to end up with fewer children, the number of children below the age of five living in the household will somewhat underestimate the real fertility decline. To check whether this might be a concern I have computed the evolution between 1900 and 1940 for both variables and compared their trends. This is illustrated in Figure S.1 below separately for four regions which together represent the entire country. Indeed, the number of children below five seems to decline a little bit slower than the number of children ever born, but the difference is rather small. The analysis of timing effects in Section 5.2 does also suggest that stopping vs. delaying is not an important source of bias. Finally, it is important to emphasize that it is also less of a concern as I am more interested in fertility differences across space rather than in absolute fertility levels.

Figure S.1: The evolution of the ratio between children aged under five and children ever born over time



Source: US population census, 1900 and 1940 (IPUMS); own estimations.

Reference

Tolnay S.E. and A.M. Guest (1984), American Family Building Strategies in 1900: Stopping or Spacing. *Demography*, 21 (1): 9-18.

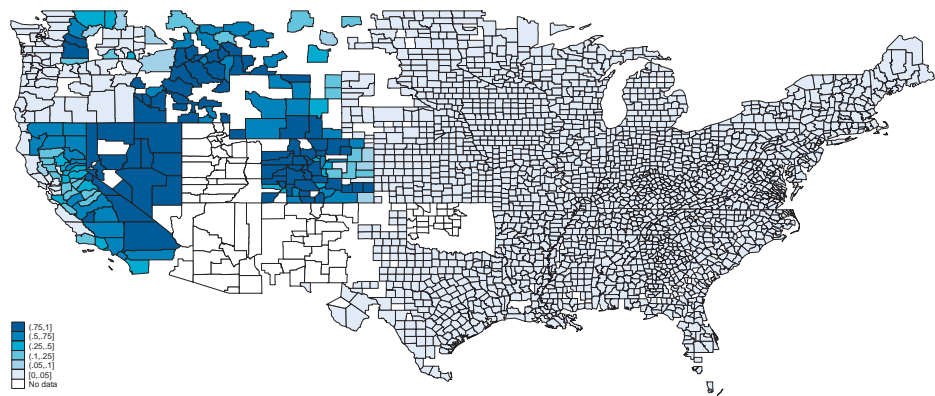
Table S.1. The effect of rainfall variability on fertility, ruling out timing effects

	(1)	(2)	(3)	(4)
	Younger	Younger	Older	Older
Rainfall (ln) x Farm hh	0.080*** (0.025)	0.068*** (0.024)	0.060** (0.028)	0.043 (0.027)
Var rainfall (ln) x Farm hh	0.808*** (0.173)	0.815*** (0.244)	0.701*** (0.186)	1.068*** (0.304)
Var rainfall (ln) x Farm hh x 1880		0.204 (0.187)		-0.034 (0.204)
Var rainfall (ln) x Farm hh x 1900		-0.143 (0.204)		-0.202 (0.228)
Var rainfall (ln) x Farm hh x 1910		0.110 (0.234)		-0.514** (0.242)
Var rainfall (ln) x Farm hh x 1920		0.028 (0.211)		-0.626** (0.251)
Var rainfall (ln) x Farm hh x 1930		-0.216 (0.181)		-0.725*** (0.269)
Full set of controls	Yes	Yes	Yes	Yes
County-group fixed-effects	Yes	Yes	Yes	Yes
Time fixed-effects	Yes		Yes	
Rainfall time interactions ^{a)}		Yes		Yes
State-specific time-effects		Yes		Yes
R-squared	0.106	0.109	0.060	0.064
Observations	270,182	270,182	674,856	674,856
County-groups	344	344	344	344

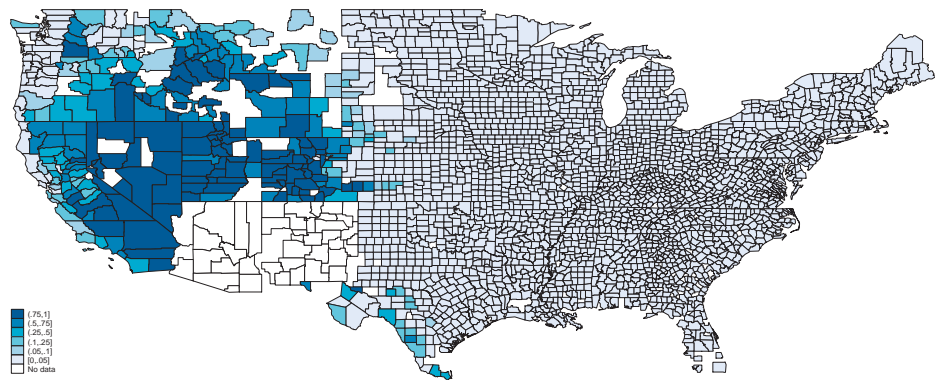
Notes: Standard errors in parentheses. The full set of controls includes age group dummies, literacy of the women and of her spouse, whether the household is a farm household, migrant status (birth place), average land value per acre, average land size per farm and average value of machinery per farm. ^{a)} Rainfall-level time interactions and Rainfall-variance time interactions.

Source: US population census, agricultural census (IPUMS, NHGIS); PRISM Precipitation dataset; own estimations.

Figure S.2. Share of irrigated agricultural land



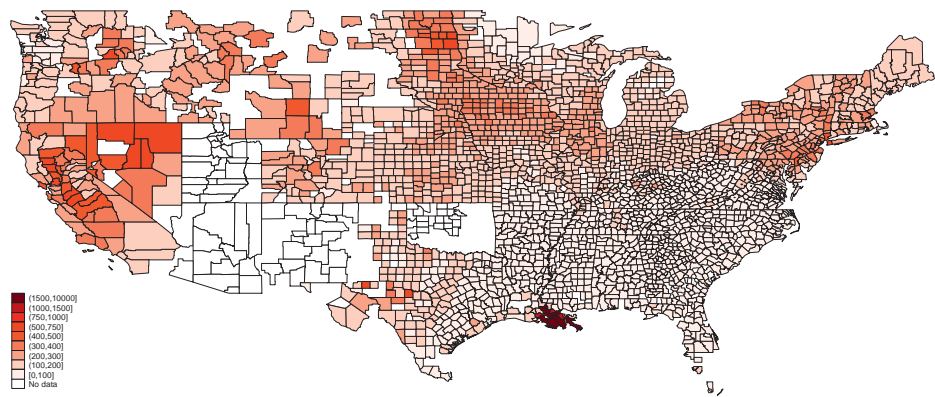
1900



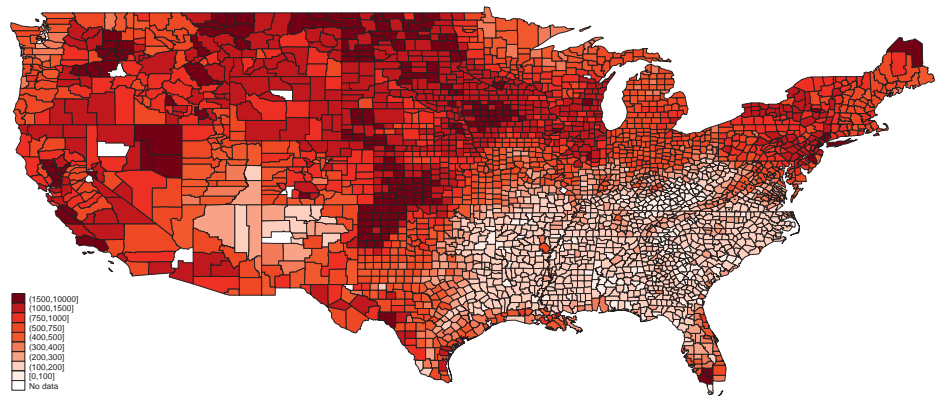
1910

Notes: Darker areas show areas with a higher share of irrigated land. Each map uses the same scale. White spaces indicate areas where no agricultural census data was collected.
Source: US agricultural census, 1900 and 1910 (NHGIS).

Figure S.3. Value of agricultural machinery in use (constant USD)



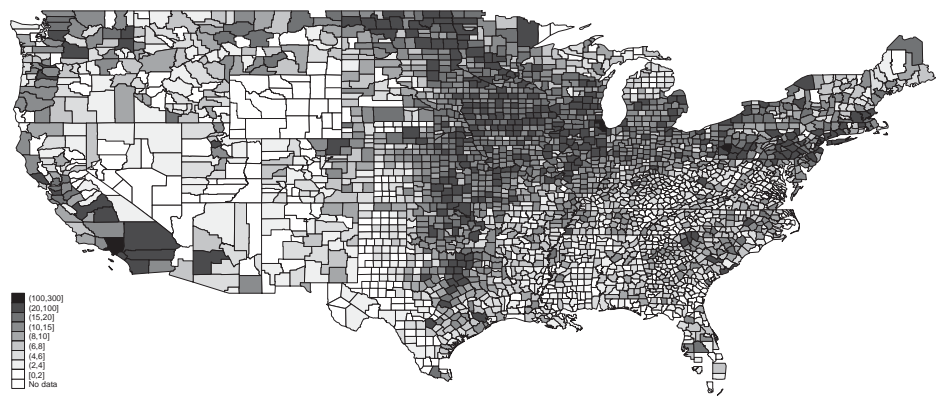
1900



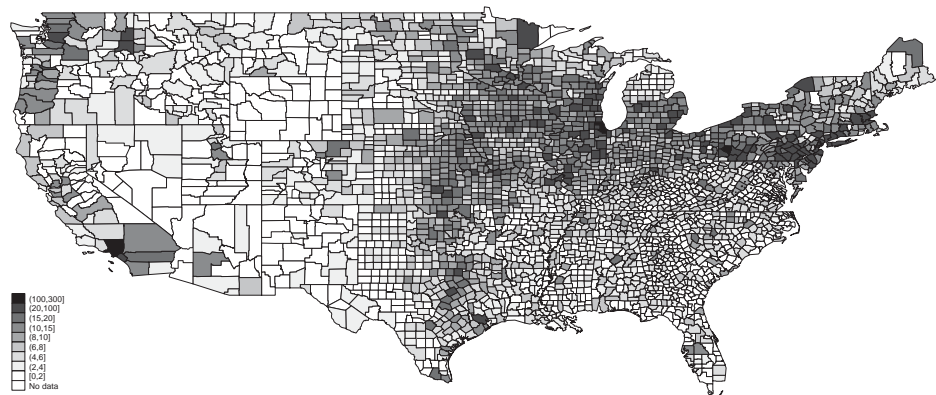
1930

Notes: Darker areas show areas with a higher value of machinery in use. Each map uses the same scale. White spaces indicate areas where no agricultural census data was collected.
Source: US agricultural census, 1900 and 1930 (NHGIS).

Figure S.4. Spread of banks



1920



1930

Notes: Darker areas show areas with more banks. Each map uses the same scale. White spaces indicate areas where no survey data was collected.

Source: Survey on Bank and Bank deposits, 1920 and 1930.