*Online Appendix: Mechanisms of Agricultural Adaptation to the Weather*

This section revisits the adaptation of farm productivity to weather to discuss its potential mechanisms. We provide suggestive evidence that shows some dimensions of adaptation. The mechanisms we examine would have worked to mitigate the effect of weather not individually but in combination. It is difficult to identify specific adaptation using limited historical data. The possibility that the selection of specific technologies was more likely endogenous makes the identification more difficult. In addition, there is a variety of mechanisms in addition to those we examine in this section. The following section must be interpreted with such limitations in mind.

*Farmland Improvement and Drainage*

Possible mechanisms and their measures are listed in Table A1 (Appendix tables are found at the end of the article). They cover various aspects of agricultural technologies, economic conditions, and ecological environments, including control of water source and soil (e.g., drainage and irrigation), allocative efficiency (e.g., crop concentration), production factors (e.g., mortgage rate, agricultural wages, and fertilizer use), and ecological environments promoted by weather (e.g., malaria).[[1]](#footnote-2) These variables are more or less related with local weather conditions.

One barrier to this analysis is that the availability of each variable is limited. Some variables are consistently reported in historical censuses for all the sample years, but many are obtainable only for limited years. Considering this limitation, we designed a regression model to comparably estimate the significance of each mechanism in adapting to hot and rainy weather. In the model, we first quantify each county’s technological, economic, or ecological condition at a certain point from 1870 to 1900, when improvements of these conditions were not yet large-scale. Then, we estimate the disparity in the level of adaptation to hot and rainy weather by the predetermined condition. This allows us to examine which agricultural aspects might account for adaptation. To better understand this approach, we investigate adaptation through farmland improvement later in detail, discussing the role of drainage and soil control.

Historically, drainage has been the key technology for improving the productivity of farmland by preventing damage from heavy rainfalls and frequent flooding, increasing areas for cultivation, changing the hydrology of the soil system, and reducing erosion. As population pressures and demand for better farmland increased, drainage practices and wetland conversion expanded eastward in the colonial periods and early nineteenth century, to the Midwest and Mississippi river valleys in the mid-nineteenth century, and to the South and West in the late nineteenth century. However, the scale and effectiveness of drainage efforts in local areas depended not only on the size of local population and demand for arable land, but also on the level of federal and state governments’ policy and support, costs of land reclamation, and drainage technology. In particular, substantial drainage practice in the Southern states was delayed until the early twentieth century, when more advanced and lower-cost technologies were introduced. Consequently, the farm productivity of less-drained areas in the nineteenth century was weakened to a greater extent by rainy weather.

Measuring the scale of historical drainage at the county level is quite limited because a nationwide survey of drainage was not conducted until the 1920s. Therefore, we employ the ratio of farmland improvement as a proxy of drainage, which measures the ratio of improved acres out of total farmland acres available countywide. Improving farmland requires clearing land for cultivating crops, pasture, or grassland, so that it generally needs drainage. Although this variable is reported in historical censuses for every sample year, we adopt the 1880 value to measure its predetermined condition for 1870 to 1900. The condition of farmland improvement would change over the years, but the use of another year’s value does not significantly change the following result.

The predetermined-condition variables are incorporated into equation (2) as follows:

 (4)

where *i*, *j*, and *t* denote county, state, and census year, respectively. In the model, we classify counties into five groups evenly according to predetermined condition—that is, farmland improvement ratio. Each group is denoted by *PREg*, a dummy variable. For instance, *PRE*1 indicates the counties with the bottom 20 percent values for farmland improvement (in other words, the least-improved counties); *PRE*5 includes those with top 20 percent values (in other words, the most-improved counties). Then, we interact the dummies with weather variable (*Wijt*), weather variable interacted with the nineteenth century dummy (*WijtD*19), and the nineteenth century dummy (*D*19). The variables interacted with *PRE*1 are dropped due to multicollinearity, so that the bottom 20 percent of counties work as a reference group. We focus on the role of farmland improvement in adapting to short-term rainy weather. Thus, we use farm output value per acre for *Yijt* and annual accumulated precipitation for *Wijt*.

The coefficients and standard errors of the key variables are reported in column (1) of Table A2. One of the main results is that the coefficients of the variables interacted with *PREg* systematically change as the ratio of farmland improvement c.1880 increases. This suggests that adaptation to short-term rainy weather was stronger among counties with a lower level of past farmland improvement.

For a clearer interpretation of the estimation results, in column (2), we contrast adaptation to the weather between two extreme county groups: least-improved (bottom 20 percent) versus most-improved (top 20 percent) counties. Specifically, we evaluate the marginal effect of precipitation on farm output value for the two pre-condition county groups and for each century by combining the coefficients and standard errors estimated in column (1).

First, panel A of column (2) shows that the least-improved counties from 1870 to 1900 had significantly lower farm values as precipitation increased. However, the most-improved counties did not experience damage from high precipitation.[[2]](#footnote-3) Second, the estimation for 1970 to 2000 shows quite different figures. Counties in the 1970 to 2000 period with the worst predetermined conditions had significantly higher farm output values with more precipitation, while those with the best predetermined condition were not influenced by precipitation. Consequently, the estimates in panel B indicate that adaptation to rainy weather occurred significantly among the bottom 20 percent counties over the century (from negative to positive marginal effect). Finally, panel C shows that the cross-century change in adaptation was more substantial among least improved counties.

The above evaluation by predetermined condition and by century suggests that farmland improvement was a key mechanism through which counties could overcome the adverse effects of rainy weather over the centuries. According to Table A1, the average farmland improvement ratio of the bottom 20 percent counties changed from 21 percent in 1880 to 67 percent in 1980, while that of the top 20 percent counties changed from 82 percent in 1880 to 91 percent in 1980. As discussed earlier, the bottom 20 percent counties had achieved farmland improvement over the first half of the twentieth century as more advanced and lower-cost technologies for drainage and water source controls were introduced. The top 20 percent counties already achieved farmland improvement in 1880 to nearly the same extent as their 1980 high point, and thus they have been minimally affected by rainy weather over the centuries.[[3]](#footnote-4)

Using the approach noted earlier, we examine various potential mechanisms listed in Table A1. The main result is summarized in Tables C3 and C4. In each table, we report the three estimates corresponding to those in panels B and C of Table A2’s column (2). As seen in the case of farmland improvement, the three estimates will measure the level of adaptation to hot and rainy weather by contrasting two groups of predetermined conditions. In addition, as shown in the previous section, farm value will be linked to decadal average weather variables, and farm output value will be matched with annual average weather variables in each survey year. We estimate equation (4) for temperature and precipitation separately, and examine each type of potential mechanism in a separate regression.

*Controls for Water Source and Soil*

According to column (1) of Table A3, the significance of farmland improvement in adapting to rainy weather is found not only in the short-term analysis (Table A2 and panel D of Table A3) but also in the long-term analysis based on decadal average precipitation and farm value (panel B). The magnitude of both results is similar. However, farmland improvement seems to be less effective in adapting to hot weather (panels A and C).

The significance of controlling water source and soil is also found when an alternative measure, the ratio of cropland to farmland acres, is employed in column (2). Similar to farmland improvement, the expansion of cropland requires drainage technologies to convert wetland and swamps into arable land. Moreover, irrigation systems must be installed to assist the growing of crops, protect drought condition, and help crops endure hot weather conditions. According to historical statistics, total cropland rose steadily throughout most of American history and reached a peak during the 1940s (Carter et al. 2006). A substantial expansion of irrigated cropland occurred from the 1880s through about 1920, and again after 1945 with technological developments such as center-pivot irrigation. The spread of tractors, trucks, and autos played a role in reducing the use of animal power in agriculture and thus in the cultivation of pasture land for feeding the animals. This change was considerable in the early twentieth century and arrived in the south later (U.S. Bureau of the Census 1952).

Table A1 illustrates that the average ratio of cropland in counties with a bottom 20 percent predetermined condition increased 2.4 times (from 12 percent in 1880 to 41 percent in 1980). Although those with top 20 percent values in the past experienced a similar increase in terms of absolute level, the rate of increase was much smaller (from 52 percent in 1880 to 80 percent in 1980). This pattern well supports the finding in column (2) that the bottom 20 percent counties became capable of adapting to rainy weather in both the long and short term. It is also estimated that the increased ratio of cropland was effective in overcoming the negative effect of hot weather on short-term farm productivity. This partly reflects the role of irrigation, which is another key technology for improving cropland.

In column (3), we employ a direct measure of drainage. Because the measure is not available for the sample period of 1870 to 1900, we use the ratio of drained area to total county area c.1930 that we calculated from a map in the 1930 Census Volume using the GIS technique.[[4]](#footnote-5) Although this measure does not precisely represent the predetermined drainage conditions from 1870 to 1900, drainage was delayed or still in progress up to 1930 in many hot and wet southern areas. According to the 1930 and 1978 Census of Drainage, artificially drained acres increased by 104 percent in the South but declined slightly by 9 percent in the north central region.[[5]](#footnote-6) This suggests that a substantial technological adaptation through drainage occurred in the south over the first half of the twentieth century. The result in column (3) supports this hypothesis. A substantial increase in the marginal effect of temperature and precipitation on both farm value and output value is significantly estimated in the bottom 20 percent counties, relative to the top 20 percent. It is noteworthy that drainage is also helpful under high temperatures as well: drainage can affect the growth of crops by balancing soil temperature, improving the nutrient uptake ability of roots, and preventing plant diseases.

*Crop Concentration*

Column (4) in Table A3 demonstrates the significance of crop concentration. Local weather conditions can limit farmers’ choice of crops to cultivate, particularly if agricultural technologies for exceeding the constraint of weather are unavailable. However, crop selection would be less successful if weather was less predictable or if scientific information on crops suitable to local weather condition was deficient. In this case, farmers would diversify crops to minimize the risk arising from uncertainties and insufficient information. Accordingly, as accurate weather prediction and agronomic knowledge on the most suitable crops become more available, farming practice will change from crop diversification to concentration. Moreover, the expected productivity of farms specializing in one crop in the past could be lower than that of diversified farms, and this would be reversed over the course of the century.

To measure the level of crop concentration as a predetermined condition, we estimate a Herfindahl–Hirschman Index (HHI) for the combination of 10 major crops for each county c.1880.[[6]](#footnote-7) Higher values indicate that the selection of crops is more concentrated. The regression result in column (4) indicates that counties with the highest HHI in 1880 are better adapted to hot and rainy weather than are those with lowest HHI, particularly in the short term. According to Appendix Table 1, the average HHI of the top 20 percent counties in the late nineteenth century was already around its peak in 1980, changing from 0.54 in 1880 to 0.61 in 1980, while the average HHI of the bottom 20 percent counties substantially increased from 0.19 to 0.50. This suggests that the farming practice of crop concentration was ineffective in adapting to the weather in the late nineteenth century but has been effective in the modern period through the efficient management of the risk of crop concentration.

The result noted earlier can be related with cotton production. Throughout the late nineteenth century after the Civil War, Southern states experienced an increasing concentration on cotton, especially by sharecroppers and tenant farmers. Some argued that the concentration was associated with southern farmers’ poverty and abandonment of self-sufficiency (Wright and Kunreuther 1975; Ransom and Sutch 1979).[[7]](#footnote-8) As far as we know, however, whether the concentration substantially improved southern states’ agricultural economy is arguable. It is generally thought that the pattern reduced cotton prices in the 1890s (Wright and Kunreuther 1975).

In column (5), we use the ratio of cotton acres to total farmland acres in 1880 as the predetermined condition. Its estimation result suggests that as hot and rainy counties more reduced cotton fields from the late nineteenth century to the late twentieth century, they experienced increasing farm value and farm output value. Although total cotton production did not decline, previous cotton fields in the counties began to be replaced with other crops such as corn, wheat, and soybean from the 1930s—by the Great Depression—and agricultural modernization in the mid-twentieth century. This change largely relied on technological adaptation, including the use of better machinery, soil conservation, fertilization, improved farm management, and scientific agricultural techniques (Fite 1984).

*Production Factors*

In columns (1) to (3) of Table A4, we examine the role of production factors such as mortgage rate, farm wage, and fertilizer use. For column (1), the predetermined condition is measured by interest paid on farm per mortgage value of farms in 1890. Mortgage rate might be important because higher rates can lower demand for farmland and thus the value of the farmland. If the rate was higher in hot and rainy counties from 1870 to 1900, this mechanism may account for the cross-century trend of farmland value by weather condition. Moreover, if higher mortgage rates represent prevailing interest rates in those hot and rainy counties, their investment for overcoming adverse weather conditions would be significantly limited. Two mechanisms lead to the expectation that counties with higher mortgage rates in 1880 would adapt to hot and rainy weather over the century better than otherwise.

We found in Table A1 that mortgage rates were higher on average in hotter and wetter counties. However, the result in column (1) of Table A4 refutes the earlier hypothesis. Regarding the analysis of farm value, a greater adaptation is estimated among counties with lower mortgage rates in 1880. In fact, many counties in Virginia, Kentucky, Maryland, Tennessee, and West Virginia were included in the bottom 20 percent group. Although they were hot and rainy and had lower farm values relative to other northeastern counties in the group, their mortgage rates were as low as were northeastern counties’ rates, probably because they were located near a major capital market. Thus, including those counties in the bottom 20 percent group may confound the actual role of mortgage rates. When they are excluded from the analysis, we do not find any significant adaptation in the bottom 20 percent group.[[8]](#footnote-9) Thus, we conclude that the observed difference in mortgage rates by weather condition is not the key factor accounting for adaptation to weather over the centuries. As seen in Table A1, the gap in mortgage rates between the two pre-condition groups is not sufficiently large to affect the demand for farmland or agricultural investment.

Additionally, the use of farm laborers does not seem to be a crucial mechanism for adaptation. In column (2), we employ total wages paid during the year (including the value of board) divided by farmland acres in 1870 as the predetermined condition. The estimation result shows that the top 20 percent and bottom 20 percent counties experienced a similar level of improvement over the centuries. Although the estimated differences in panels B and D are statistically significant, the magnitudes are too small to indicate a considerable impact. Above all, this variable is not highly correlated with county weather variables, as presented in Table A1.

Another key factor for crop production is fertilizer, which can supply important nutrients essential to the growth of crops. Soil loses key nutrients through heavy rainfall and flooding; thus, the use of fertilizer is more important in rainy regions. To investigate adaptation through the use of fertilizer, we use the log value of fertilizer cost per farmland acre in 1880 as the predetermined condition. The result in column (3) suggests that counties with top 20 percent fertilizer use in 1880 adapted well to rainy weather in terms of farm output value. Because the use of fertilizer would more directly affect the production of crops in the same farming year, finding significant results only in panels C and D seem reasonable. According to Table A1, the level of fertilizer use in 1880 was very small in both pre-condition groups, making the difference miniscule. The 1880 distribution of fertilizer use is positively skewed. Thus, even though hot and rainy counties used slightly more fertilizer in the past, its level would not be enough to significantly change farm output value. After one century, both counties used greater amounts of fertilizer per acre. This would be more effective in those heavy-rain and hot counties categorized as top 20 percent in 1880.

*Ecology, Health, and Labor Productivity*

Besides the agronomic factors noted earlier, farm productivity can depend heavily on farm laborers’ health status and their labor productivity. This is more likely during the periods when the environment was infectious and knowledge of disease control lacking. Various infectious diseases frequently broke out in warm and wet regions, damaging the population’s health and productivity. Some diseases (e.g., cholera) were fatal, but others (e.g., malaria, hookworm, and pellagra) were more prevalent and had long-lasting impacts on rural populations despite being less serious. Of these less-serious diseases, malaria was notable. Its pathogen, spread via mosquitoes, is strongly associated with high temperatures and rainfall. Some historical studies have found that exposure to malaria—especially in early life—can degrade nutritional status and the immune system in developmental years, accelerate the onset of various chronic conditions, and thereby weaken productivity in adulthood (Hong 2007, 2011, 2013). Therefore, the eradication of malaria, completed from 1920 through 1950, played a substantial role in improving economic productivity. Bleakley (2010) estimates that cohorts born after eradication achieved higher incomes in adulthood. He also estimates the significance of hookworm eradication in the 1910s for the improvement of income and educational level (Bleakley 2007).

Three factors reported in the literature—the relevance of weather conditions to those diseases, their impact on rural life and productivity, and the timing of their eradication—suggest that the adaptation of farm productivity to hot and rainy weather could be achieved through the eradication of climate-related diseases in the first half of the twentieth century. In column (4) of Table 6, we consider the significance of malaria eradication. For the predetermined condition of malarial environment, we estimated a nineteenth-century malaria ecology index following Hong (2007). The index approximates the annual probability of being infected with malarial fever across counties. The average index of the top 20 percent counties is 0.42, and that of the bottom 20 percent counties is 0.09. The estimates in column (4) clearly indicate that adaptation to high temperature and rainfalls occurred more prominently among those counties with high malaria rates in the past.

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| Table A1  MEASURING PREDETERMINED CONDITIONS FROM 1870–1900 AND THEIR CHANGE OVER THE CENTURIES | | | | | | | | | | | | | |
| Mechanism | Variable | Definition | Predetermined Condition | | |  | Correlation Coefficient with Weather Variables | |  | Values in Modern Period by Predetermined Condition | | | Source |
| Census year | Bottom 20 Percent | Top 20 Percent |  | Temp- erature | Preci- pitation |  |  | Pre Bottom 20 Percent | Pre Top 20 Percent |
| Control of water source and soil | Land improvement | Improved acres / farmland acres | 1880 | 0.21 | 0.82 |  | –0.58 | –0.47 |  | 1980 | 0.67 | 0.91 | ICPSR 2896 |
| Cropland | Crop-land acres / farmland acres | 1880 | 0.12 | 0.52 |  | –0.46 | –0.25 |  | 1980 | 0.41 | 0.80 | ICPSR 2896 |
| Drainage | Drained area / county area | 1930 | 0.00 | 0.66 |  | –0.23 | –0.14 |  |  |  |  | 1930 Census |
| Allocative efficiency:  crop mix | Crop concentration | Herfindahl-Hirschman index | 1880 | 0.19 | 0.54 |  | 0.20 | 0.18 |  | 1980 | 0.50 | 0.61 | ICPSR 2896 |
| Cotton | Cotton acres / farmland acres | 1880 | 0.00 | 0.47 |  | 0.70 | 0.55 |  | 1980 | 0.00 | 0.21 | ICPSR 2896 |
| Production factor and factor price | Mortgage rate | Interest paid on farm / mortgage value of farms | 1890 | 0.06 | 0.10 |  | 0.45 | –0.07 |  |  |  |  | ICPSR 2896 |
| Wage in agriculture | Annual agricultural wage / farmland acres | 1870 | 0.40 | 5.15 |  | 0.13 | 0.00 |  |  |  |  | ICPSR 2896 |
| Fertilizer use | ln(Fertilizer cost / farmland acres) | 1880 | 0.00 | 0.06 |  | 0.22 | 0.33 |  | 1960 | 1.98 | 0.85 | ICPSR 2896 |
| Ecology and health | Malaria | Malaria ecology index | Nineteenth century | 0.09 | 0.42 |  | 0.83 | 0.63 |  | Twentieth century | 0.00 | 0.00 | Hong(2007) |
| *Notes*: This table presents summary statistics and sources of variables that measure possible channels through which adaptation to weather took place. The predetermined condition is the status of technological or ecological level around the late nineteenth century. Many variables are calculated from the data found in ICPSR 2896 (Historical, Demographic, Economic, and Social Data: The United States, 1790–2002); the variable of drainage is estimated from a drainage map found in the 1930 census volume, using GIS technique; malaria ecology index is adopted from Hong (2007). We report the sample mean of each predetermined condition for two county groups: those with bottom 20 percent or top 20 percent values. The correlation coefficient is calculated as the correlation between predetermined condition and average weather condition in the 1870s. We also report average values for each mechanism variable around the late twentieth century by two predetermined condition groups.  *Sources*: Authors’ calculation based on historical records listed in the last column. | | | | | | | | | | | | | |

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| Table A2  ESTIMATES OF THE LEVEL OF ADAPTATION TO HIGH PRECIPITATION THROUGH FARMLAND IMPROVEMENT OVER THE CENTURIES | | | | |
| Dependent Variable: ln(county farm output value per acre) | | | | |
|  | (1) |  | (2) | |
| *W* [=*α*] | 0.0138\*\*\* |  | Panel A: Marginal Effect of Weather Variable | |
|  | (0.0034) |  | Nineteenth century |  |
| *W*×*PE*2 | –0.0209\*\*\* |  | Bottom 20 percent | –0.0071\*\* |
|  | (0.0051) |  | (= *α* + *β*) | (0.0030) |
| *W*×*PE*3 | –0.0088\*\* |  | Top 20 percent | 0.0032 |
|  | (0.0036) |  | (= *α* + *β* + *α* 5 + *β* 5) | (0.0020) |
| *W*×*PE*4 | –0.0103\*\*\* |  | Twentieth century |  |
|  | (0.0038) |  | Bottom 20 percent | 0.0138\*\*\* |
| *W*×*PE*5 [=*α* 5] | –0.0130\*\*\* |  | (= *α*) | (0.0034) |
|  | (0.0042) |  | Top 20 percent | –0.0034 |
| *W*×*D*19 [=*β*] | –0.0173\*\*\* |  | (= *α* + *α* 5) | (0.0029) |
|  | (0.0042) |  |  |  |
| *W*×*D*19×*PE*2 | 0.0083 |  | *Panel B: Adaptation by Predetermined Condition* | |
|  | (0.0051) |  | Δ(twentieth century - nineteenth century) | |
| *W*×*D*19×*PE*3 | 0.0132\*\* |  | Bottom 20 percent | 0.0209\*\*\* |
|  | (0.0054) |  | (= - *β*) | (0.0051) |
| *W*×*D*19×*PE*4 | 0.0190\*\*\* |  | Top 20 percent | –0.0067 |
|  | (0.0060) |  | (= - *β* - *β* 5) | (0.0043) |
| *W*×*D*19×*PE*5 [=*β* 5] | 0.0276\*\*\* |  |  |  |
|  | (0.0063) |  | *Panel C: Advantage in Bottom 20 Percent Counties* | |
| Observations | 16,864 |  | (= *β* 5) | 0.0276\*\*\* |
| Adj. R2 | 0.8493 |  |  | (0.0063) |
| *\** = Significant at the 90 percent level.  *\*\** = Significant at the 95 percent level.  *\*\*\** = Significant at the 99 percent level.  *Notes*: This table presents how to measure the level of adaptation by examining the significance of farmland improvement in adapting to rainy weather condition from a short-term perspective. Thus, the dependent variable is the logarithm of county farm output value per acre; the weather variable is annual accumulated precipitation (denoted by *W*). We estimate column (1) based on equation (4). Out of various controls in equation (4), we report only the coefficients of some key control variables. As explained in the text, *PEi* denotes the dummy variables that indicate county groups according to the level of predetermined condition, which is farmland improvement ratio in this table. *D*19 denotes a dummy variable that indicates the census year in the nineteenth century. A weighted regression is used as done in Tables 1 and 2. In panel A of column (2), we calculate the marginal effect of short-term precipitation on farm output value by century and by bottom 20 percent and top 20 percent county groups in terms of the predetermined condition. Panel B calculates the level of adaptation over the centuries by the predetermined condition. Panel C measures the difference in adaptation between two county groups. The calculations in column (2) are based on the estimated coefficients in column (1). The standard errors of estimated coefficients, which are clustered on county, are reported in parentheses.  *Sources*: Authors’ calculations. | | | | |

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| Table A3  ESTIMATES OF THE LEVEL OF ADAPTATION TO WEATHER BY PREDETERMINED CONDITION: WATER SOURCE CONTROL, LAND USE, AND CROP CONCENTRATION | | | | | |
|  | (1) | (2) | (3) | (4) | (5) |
| Predetermined condition | Farmland Improvement | Cropland | Drainage | Crop Concentration | Cotton |
| Panel A: Decadal Temperature and Farmland Value | | | | | |
| Bottom 20 percent counties | 0.0403\*\*\* | 0.0380\*\*\* | 0.0556\*\*\* | 0.0320\*\*\* | 0.0312\*\*\* |
|  | (0.0061) | (0.0061) | (0.0060) | (0.0096) | (0.0066) |
| Top 20 percent counties | 0.0311\*\*\* | 0.0296\*\*\* | 0.0245\*\*\* | 0.0451\*\*\* | 0.0727\*\*\* |
|  | (0.0076) | (0.0070) | (0.0066) | (0.0063) | (0.0107) |
| Bottom - Top | 0.0092 | 0.0084 | 0.0311\*\*\* | –0.0131 | –0.0415\*\*\* |
|  | (0.0075) | (0.0070) | (0.0058) | (0.0082) | (0.0127) |
| Panel B: Decadal Precipitation and Farmland Value | | | | | |
| Bottom 20 percent counties | 0.0207\*\*\* | 0.0193\*\*\* | 0.0204\*\*\* | 0.0076 | 0.0100\*\* |
|  | (0.0035) | (0.0032) | (0.0031) | (0.0055) | (0.0039) |
| Top 20 percent counties | –0.0043 | 0.0052 | –0.0017 | 0.0109\*\*\* | 0.0365\*\*\* |
|  | (0.0044) | (0.0044) | (0.0037) | (0.0034) | (0.0049) |
| Bottom - Top | 0.0250\*\*\* | 0.0141\*\*\* | 0.0221\*\*\* | –0.0033 | –0.0264\*\*\* |
|  | (0.0049) | (0.0044) | (0.0036) | (0.0055) | (0.0063) |
| Panel C: Annual Temperature and Farm Output Value | | | | | |
| Bottom 20 percent counties | 0.0417\*\*\* | 0.0471\*\*\* | 0.0379\*\*\* | 0.0241\* | 0.0277\*\*\* |
|  | (0.0099) | (0.0092) | (0.0101) | (0.0141) | (0.0096) |
| Top 20 percent counties | 0.0309\*\*\* | –0.0057 | 0.0236\*\*\* | 0.0511\*\*\* | 0.0626\*\*\* |
|  | (0.0118) | (0.0095) | (0.0089) | (0.0090) | (0.0166) |
| Bottom - Top | 0.0108 | 0.0528\*\*\* | 0.0144 | –0.0270\*\* | –0.0349\* |
|  | (0.0114) | (0.0086) | (0.0088) | (0.0121) | (0.0186) |
| Panel D: Annual Precipitation and Farm Output Value | | | | | |
| Bottom 20 percent counties | 0.0209\*\*\* | 0.0158\*\*\* | 0.0163\*\*\* | –0.0044 | 0.0048 |
|  | (0.0051) | (0.0043) | (0.0032) | (0.0058) | (0.0042) |
| Top 20 percent counties | –0.0067 | –0.0072\* | –0.0022 | 0.0113\*\* | 0.0275\*\*\* |
|  | (0.0043) | (0.0038) | (0.0033) | (0.0044) | (0.0045) |
| Bottom - Top | 0.0276\*\*\* | 0.0230\*\*\* | 0.0185\*\*\* | –0.0157\*\* | –0.0227\*\*\* |
|  | (0.0063) | (0.0051) | (0.0040) | (0.0068) | (0.0061) |
| *\** = Significant at the 90 percent level.  *\*\** = Significant at the 95 percent level.  *\*\*\** = Significant at the 99 percent level.  *Notes*: We extend the regression analysis of column (2) in Table A2 adding two types of weather variables and farm productivity variables (specified in the panel title) and alternative mechanism variables (listed in the heading of each regression model and presented in Table A1). We first run the regression per equation (4) using those specified variables, and then estimate the level of adaptation by the predetermined condition as done in column (2) in Table A2. The table above reports only three main coefficients that correspond to those in panels B and C of column (2) in Table A2. The first two coefficients in each panel and column measure the level of adaptation in bottom 20 percent counties in terms of the predetermined condition and in top 20 percent counties, respectively. The third coefficient estimates the significance of the difference between the first two coefficients. The standard errors of estimated coefficients are reported in parentheses.  *Sources*: Authors’ calculations. | | | | | |

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| Table A4  Estimates of the Level of Adaptation to Weather by Predetermined Condition: Production Factor and Ecology | | | | |
|  | (1) | (2) | (3) | (4) |
| Pre-existing condition | Mortgage Rate | Wage in Agriculture | Fertilizer Use | Malaria |
| Panel A: Decadal Temperature and Farmland Value | | | | |
| Bottom-20 percent counties | 0.0817\*\*\* | 0.0464\*\*\* | 0.0407\*\*\* | 0.0206\*\* |
|  | (0.0100) | (0.0066) | (0.0065) | (0.0098) |
| Top-20 percent counties | 0.0389\*\*\* | 0.0420\*\*\* | 0.0464\*\*\* | 0.0610\*\*\* |
|  | (0.0087) | (0.0066) | (0.0086) | (0.0124) |
| Bottom - Top | 0.0428\*\*\* | 0.0044 | –0.0056 | –0.0404\*\* |
|  | (0.0119) | (0.0052) | (0.0085) | (0.0158) |
| Panel B: Decadal Precipitation and Farmland Value | | | | |
| Bottom-20 percent counties | 0.0302\*\*\* | 0.0182\*\*\* | 0.0105\*\*\* | 0.0083\*\* |
|  | (0.0054) | (0.0036) | (0.0032) | (0.0041) |
| Top-20 percent counties | 0.0138\*\*\* | 0.0106\*\*\* | 0.0189\*\*\* | 0.0343\*\*\* |
|  | (0.0036) | (0.0038) | (0.0063) | (0.0061) |
| Bottom - Top | 0.0163\*\*\* | 0.0075\* | –0.0084 | –0.0260\*\*\* |
|  | (0.0057) | (0.0039) | (0.0061) | (0.0073) |
| Panel C: Annual Temperature and Farm Output Value | | | | |
| Bottom-20 percent counties | 0.0645\*\*\* | 0.0502\*\*\* | 0.0306\*\*\* | 0.0349\*\* |
|  | (0.0123) | (0.0106) | (0.0099) | (0.0142) |
| Top-20 percent counties | 0.0600\*\*\* | 0.0412\*\*\* | 0.0512\*\*\* | 0.0557\*\* |
|  | (0.0127) | (0.0103) | (0.0131) | (0.0244) |
| Bottom - Top | 0.0045 | 0.0091 | –0.0206\* | –0.0208 |
|  | (0.0160) | (0.0081) | (0.0114) | (0.0273) |
| Panel D: Annual Precipitation and Farm Output Value | | | | |
| Bottom-20 percent counties | 0.0171\*\*\* | 0.0126\*\*\* | 0.0015 | 0.0075 |
|  | (0.0038) | (0.0043) | (0.0045) | (0.0054) |
| Top-20 percent counties | 0.0107\*\* | 0.0028 | 0.0250\*\*\* | 0.0328\*\*\* |
|  | (0.0053) | (0.0047) | (0.0064) | (0.0062) |
| Bottom - Top | 0.0064 | 0.0098\* | –0.0235\*\*\* | –0.0253\*\*\* |
|  | (0.0060) | (0.0054) | (0.0072) | (0.0082) |
| *\** = Significant at the 90 percent level.  *\*\** = Significant at the 95 percent level.  *\*\*\** = Significant at the 99 percent level.  *Notes*: We extend the regression analysis of column (2) in Table A2 adding two types of weather variables and farm productivity variables (specified in the panel title) and alternative mechanism variables (listed in the heading of each regression model and presented in Table 3). We first run the regression per equation (4) using those specified variables, and then estimate the level of adaptation by the predetermined condition as done in column (2) in Table A2. The table above reports only three main coefficients that correspond to those in panels B and C of column (2) in Table A2. The first two coefficients in each panel and column measure the level of adaptation in bottom 20 percent counties in terms of the predetermined condition and in top 20 percent counties, respectively. The third coefficient estimates the significance of the difference between the first two coefficients. The standard errors of estimated coefficients are reported in parentheses.  *Sources*: Authors’ calculations. | | | | |

1. Allocative efficiency can be achieved by farm organization as well as crop concentration. Throughout the nineteenth century, the proportion of sharecroppers and tenants increased. This change might aid adaptation to weather because the tenant-based organization could efficiently manage the risk of hot and rainy weather, but this needs further investigation. [↑](#footnote-ref-2)
2. Note that even the most improved group included many counties with rainy weather conditions, though farmland improvement in 1880 and decadal precipitation are positively correlated, as seen in Appendix Table 1. [↑](#footnote-ref-3)
3. The average farmland improvement ratio among the 1880 top 20 percent counties (= 0.82) was greater than that for all counties in 1980 (= 0.78). [↑](#footnote-ref-4)
4. Source: 1930 Census Volume for Drainage of Agricultural Lands, Map of the United States Showing Approximate Location in Drainage Enterprises. [↑](#footnote-ref-5)
5. Source: 1930 Census Volume for Drainage of Agricultural Lands, Table 1; 1978 Census of Agriculture, Volume 5, Part 5, Drainage of Agricultural Lands, Table 2. [↑](#footnote-ref-6)
6. The crops include barley, corn, cotton, hay, oats, potato, rice, rye, tobacco, and wheat. [↑](#footnote-ref-7)
7. Wright and Kunreuther (1975) argued that the freemen were too poor to maintain stable crops and thus took a riskier strategy of growing more cotton. Ransom and Sutch (1979) maintained that poor farmers were forced to borrow from merchants who wanted more cotton. [↑](#footnote-ref-8)
8. In this setup, the coefficients (standard errors) for the bottom-top differences in adaptation level are estimated as 0.0030 (0.0116) for panel A and 0.0099 (0.0062) for panel C. [↑](#footnote-ref-9)