Drought and Migration during the Great Depression

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Abstract
America's worst drought in terms of economic implications stretched from 1930 to 1939. Related research focuses on dust storm and soil erosion to the exclusion of the underlying exogenous environmental shock of drought. This is a problem because dust storm and erosion were endogenous to farming practices, so the impact of the environmental shock itself is not clear. To study the impact of drought, I create a new dataset of yearly county-level drought and match this data with population census and Depression severity data. I focus on migration because the 1930s were a pivotal decade of internal migration and the literature on dust storm and soil erosion focuses on migration as a primary economic consequence. I find that the drought influenced county-level in and out-migration especially during and after 1934, which was the worst drought year in the last millennium. Counties that suffered *extreme* drought in 1934 witnessed an 8.1 percentage point decline in population (from 1930 to 1935) compared to *non-drought* counties within the same state. Migration from drought was not isolated to the Dust Bowl or the Great Plains. Instead, there was widespread migration out of and away from drought counties throughout the United States. These results provide a more complete accounting of the environmental forces that lead to mass migration and highlight the centrality of one devastating year.

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I. Introduction

Since its occurrence, the American Dust Bowl has been recognized as a turning point for internal migration, as it coincided with the end of the flow of migrants to (and the agricultural *development* of) the southern Great Plains.[1] But the Dust Bowl, most often defined as the area suffering repeated and severe dust storms, was small geographically (20 to 100 counties at the core) and research shows that poor environmental conditions (specifically soil erosion) stretched far beyond the traditional bounds of the Dust Bowl to include the Great Plains more broadly (Hansen and Libecap 2004; Hornbeck 2012; 2020). Still, dust storms and the soil erosion were endogenous to farming practices and the underlying environmental shock of drought remains virtually unstudied. I detail the importance of drought by utilizing advances in drought data (Cook et al. 2010) in connection with economic and census data (Manson et al. 2019; Ruggles et al. 2019; Abramitzky et al. 2020) to create a new dataset of county-level drought and migration.

The climactic underpinnings of perhaps the only mass environmental migration in US history are important because, despite much speculation about climate change and natural disasters inducing mass migration, the economic literature details few episodes of mass environmental migration. The geographic extent, severity, and length of the drought combined with the migration response, set the drought apart from other environmental shocks. Of equal importance, it is possible to construct individual-level migration data over the entire 1930s. That is, the magnitude of the disaster and migration response combined with detailed climatic and migration data create an opportunity to study environmental migration in detail and scale not possible at other times and places.

The climate or weather-induced migration literature focuses on the impact of relatively minor and temporally short deviations in weather.[2] These results are not directly applicable to understanding the consequences of severe and persistent shocks because the first month without rain is unlikely to have the same impact as the 50th. Moreover, out of research that studies longer-term shocks, there is little focus on when people move or the underlying economic impact of the shock that induces migration.[3]

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[1] Hurt (1981); Riney-Kehrberg (1989); Riney-Kehrberg (1994); Worster (2004); Hansen and Libecap (2004); McLeman et al. (2014); and Long and Siu (2018).
[2] See Boustan et al. (2012), Marchiori et al. (2012), Mueller et al. (2014), Bohra-Mishra et al. (2014), Cai et al. (2016), Jessoe et al. (2017), Kleemans and Magruder (2017), and Bonnier et al. (2019).
[3] For research on persistent environmental shocks, see Hornbeck (2012, 2020), Beine and Parsons (2015), Cattaneo and Peri (2016), Guttman et al. (2016), and Bazzi (2017).

I build a new dataset of county-level drought and census data to study net migration, out-migration, and in-migration. To create this dataset, I match linked census data of adult males from 1930 to 1940 (aggregated to the county level) to a dataset of drought conditions that I create by integrating the Living Blended Drought Atlas (LBDA) with the 1930s county map (Cook et al. 2010, Manson et al. 2019, Ruggles et al. 2019, Abramitzky et al. 2020). Moreover, to document geographic disparities in economic opportunities induced by drought, I match my census and drought data with county-level Depression severity (Fishback et al. 2005). This new dataset enables the study of migration from drought in the context of the Great Depression over the entire decade and country.

I find that additional drought years were correlated with decreased net migration (drought counties lost population) compared to similar non-drought counties from within the same state. By disaggregating migration into five-year intervals, I show that some migration away from drought occurred in the early 1930s.[4] But drought severity in 1934 specifically, the worst year of drought in the last millennium (Cook et al. 2014), was highly correlated with higher out-migration and lower in-migration in the early 1930s. Counties that experienced *extreme* drought in 1934 witnessed an 8.1 percentage point decline in their population between 1930 and 1935 compared to similar counties that experienced mild or no drought.

The result that drought-induced migration started in earnest in 1934, emphasizes the importance of persistence, severity, climate, and demographics in migration from climate shocks. It was not until *extreme* drought struck the semi-arid Great Plains region that large scale migration began. Migration from drought was common throughout the Plains and the western United States. That is, migration was not unique to the southern Great Plains nor the Dust Bowl counties.[5] Migration out of and away from drought counties continued through the late 1930s. Counties that suffered three or more drought years (in the late 1930s) experienced a net decline in population of 4.1 percentage points (from 1935 to 1940) compared to non-drought counties within the same state. The depopulation of drought counties in the middle and late 1930s was a function of

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[4] The migration response to drought in the early 1930s should be consider in the context of the linked census sample and false linkages potentially impacting the regression coefficients as is discussed in detail in the Section VI.

[5] This finding is consistent with recent literature showing that migration from environmental shocks was more widespread than the historic core of the Dust Bowl (Hornbeck 2012, Gutmann et al. 2016, Hornbeck 2020). Broadly, these findings move us towards a more comprehensive view of how environmental shocks influenced the migration and thereby the geographic population distribution of the modern United States.

increased out-migration and decreased in-migration.[6] This finding is important because migration research focuses on net or gross migration, and we tend to think of migration responses to shocks in terms of push factors. In the 1930s, both push and pull factors emanating from drought resulted in net population declines.

This paper principally estimates the impact of drought on migration. But because there is not much research on the economic impact of the widespread 1930s drought, I estimate the impact of drought on Depression severity.[7] I find that drought had a significant impact on economic activity during the Great Depression. Counties that suffered five or more drought years from 1930 to 1939 experienced 8.7 log percentage points lower growth in per capita retail spending over the decade. This was a large decline in retail spending as, on average, counties had returned to their 1929 spending levels by 1939 after the trough of the Great Depression in 1933. I disaggregate these results between *rural* and *urban* counties to show how drought differentially impacted sectors of the economy.[8] Drought had its most pronounced impact on rural counties but it also impacted retail spending in urban counties. My findings contribute to our understanding of how drought affected the economy at a particular time and place, and are consistent with literature concerning the impact of drought on both agricultural and non-agricultural sectors.

In total, the drought ebbed and flowed across the U.S. starting in 1930. But mass migration did not begin until drought settled on the Great Plains in the mid- and late-1930s. This was pivotal period, as initial U.S. based settlement of the Plains came to an end when the climate delivered a decisive correction to an economy that had overleveraged its natural resources in a climatically volatile region. The depopulation of the Plains echoed through the coming century, and this region remains among the most sparsely populated parts of the United States. The drought changed the popular perception of the Plains from a land of opportunity to an arid and featureless region that should be avoided: the view that dominates sentiment to this day. This perception, however, is not

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[6] This is a new finding in the context of the widespread drought, but is consistent with literature on the Dust Bowl, which shows that population declines arose from both increased out-migration and decreased in-migration (Long and Siu 2018).

[7] Droughts impact agriculture, industrial production, human health, and the overall habitability of locations.[7] Nonetheless, the impact depends on the economic and social structure of the affected area (including the agricultural and industrial workforce), the level of technology (such as irrigation and air conditioning), and the underlying demographics (average education, wealth, age, etc.). For the changing impact of climate shocks based on technology change see Hornbeck and Keskin (2014) and Barraca et al (2016). For research on the heterogeneous impact of climate shocks by demographics see Kleemans (2015), and Bazzi (2017).

[8] Rural counties are defined as counties with greater than 50 percent of their population living outside IPUMS designated cities in 1930. Urban counties are defined as counties with greater than 50 percent of their population living in cities in 1930.

representative of the inherent *value* of the Plains. As we strive towards economies that utilize and amplify the natural world rather than trying to dominate it, the Great Plains are primed for sustainable economic progress.

II. Background: Climate and migration in U.S. history

The 1930s were the worst ten-year period of drought in U.S. history, but remain largely unstudied in terms of the economic impact of widespread drought. Drought and migration primarily intersected on the Great Plains, which is a semi-arid ecological region dependent on temporal fluctuations in water availability. To understanding the migration response to drought, it is necessary to understand the economic preconditions of the Great Plains. This section explores U.S. settlement and economic development for the drought region with an emphasis on climate, migration, and the Great Depression.

Climate and settlement through 1930

The continental U.S. is composed of ecological regions defined by local climate conditions as displayed in Figure 2. Local climates result from weather patterns and topography, and the predominant movement of weather systems in North America occurs from west to east. This means that the Great Plains, which extend east from the foothills of the Rocky Mountains, sit in the rain shadow of the mountains. That is, the western mountains receive much of the precipitation that would otherwise be spread more equally over the United States. Yet, drought is not necessarily based on lack of precipitation but rather deviations from normal conditions. The Great Plains are dry and also have high variability in average precipitation, making this region prone to drought (Kraenzel 1942).

The aridity and variability of the Plains was important to migration historically. Because dryness was not conducive to the agricultural and town-based economy of the U.S., this region remained mostly unsettled by European-American U.S. residents as the population expanded westward. Instead, the Plains were largely bypassed for the west coast until the mid- and late-19th century (Webb 1959). During this time, the Plains and its native inhabitants, remained relatively outside of European and U.S. influence. Initially, some ranching operations were established but questions as to whether this region was conducive for widespread settlement and agriculture persisted (Webb 1959). Attitudes about the suitability of the Plains and the tide of settlement started to change in the mid-19th century, especially with the Homestead Act of the 1862, which allocated land to settlers who could make it *productive* (Cunfer and Krausmann 2015).

As with other land that incrementally came under the U.S. jurisdiction, settlers interacted with, fought, and eventually killed and displaced native people that lived and often prospered on the Plains. U.S. expansion eventually undercut the power of the tribes through settlement pressure and extermination of buffalo (Webb 1959). After decades of warfare collectively known as the *Plains War*, the remaining Natives Americans were mostly confined to reservations and the Plains were opened to further U.S. settlement (Wooster 2009).

Wheat, specifically the red queen and hard red varieties, was well suited to the Plains and became the primary cash crop (Olmstead and Rhode 2002, Egan 2006). When drought came, the crop struggled or failed. But despite some periods of drought and an understanding (still voiced by some) that the Plains would not support agriculture in the fashion of the eastern U.S., the population and agricultural development of the Plains expanded dramatically through the turn of the century.

In the early 20th century, U.S. settlement was buoyed by an unusually wet period, a growing belief that rainfall was endogenous to human activity, additional demand for agricultural produce during World War I, and agricultural mechanization (Alston 1983, Libecap and Hansen 2002). Between 1880 and 1925 over 1 million homesteads were started in western Kansas, Nebraska, the Dakotas, Colorado, and Montana (Libecap and Hansen 2002). Wheat prices quickly doubled with the outbreak of World War I (WWI) and the disruption of Russian wheat production (Hurt 1981). This increase in wheat prices led to more marginal land being put into agricultural production, increased mortgage debt, escalated land values, and coincided with the adoption of powered machinery, which greatly reduced the manual labor required to plant and harvest wheat (Hurt 1981, Alston 1983, Worster 2002). In short, the Great Plains experienced a swift and expansive integration into the market economy in the late 19th and early 20th century.

The economic expansion began to falter in the 1920s with the reintroduction of wheat from Russia following the end of WWI. Collapsing wheat prices made farm debt obligations difficult or impossible for farmers to meet, and spurred a vicious circle in which land values fell, farmer equity decreased, and farm foreclosures increased. This pattern occurred across much of the U.S. but was especially pronounced for many Great Plains states (Alston 1983). As bad as the 1920s were for farmers and the Plains, crop yields remained high and the broader U.S. economy grew rapidly. This changed starting 1929 when production and spending began a steep downward trend culminating in 1933 (Eichengreen 1992, Romer 1993, Bernanke 2000). Simultaneously, in 1930 and 1931, the U.S. experienced the first wave of a drought that would persist in some areas through 1939. The drought bore down on the Plains starting in 1932 and had devastating consequences until it subsided in late 1939. The geographic and temporal details of drought are further detailed in Section III using a new dataset of county-level drought conditions.

The Great Depression

The Great Depression was the worst economic downturn in U.S. history. The Depression started before drought so drought was not a spark. But the Depression stretched the decade and given the temporal overlap, there is sparse research on the relationship between the Depression and drought. For this reason, and to document the geographic differences in economic opportunity created by drought, I analyze how drought related to Depression severity in Sections IV and VI.

In contrast to the paucity of research on the impact of drought on the Great Depression, there is considerable research on the Depression and migration. Economic downturns typically decrease migration, and this was the case for the 1930s (Molloy et al. 2011, Saks and Wozniak 2011). Even with low overall mobility, changes in internal migration (including large numbers of distressed migrants arriving on the west coast) prompted the Census Bureau to record place of residence within a decade for the first time in 1940. The recording of individuals' 1935 location, combined with the innovation of linking between censuses, enables the study of migration from 1930 to 1935 and from 1935 to 1940, as I do.

Federal relief spending (allocated in response to the Great Depression) also impacted migration. New Deal grants were distributed after 1933 when Franklin D. Roosevelt took office. The two primary components of New Deal spending were public works and relief grants, and the Agricultural Adjustment Act (AAA). AAA spending aided the drought stricken agricultural communities of the Great Plains with the highest proportion of money targeted at the Dust Bowl. Public works and relief spending was associated with changing migration and, because AAA spending targeted farm-owners and large-scale farmers, AAA payments were associated with greater out-migration among tenants, sharecroppers, and farm workers (Fishback et al. 2006).

The Dust Bowl and associated migration

One portion of the drought, colloquially known as the Dust Bowl, has been studied extensively.[9] The Dust Bowl was categorized by drought, wind erosion, and dust storms, and was important for economic development and migration in the southern Great Plains. Relative to earlier and later droughts, the 1930s drought met the topsoil exposed by the agricultural boom of the early 20th century (Hansen and Libecap 2004). Given exposed topsoil and shallowly rooted crops, the strong and persistent winds of the Plains swept up billions of tons of soil, dried and decimated by drought, and culminated in massive dust storms. Dust storms occurred historically and still happen today, but the storms of the 1930s were more severe and common than ever before or since (Hansen and Libecap 2004).[10]

Migration has likely been the most studied consequence of the Dust Bowl (Hurt 1981, Riney-Kehrberg 1994, Worster 2004, Hornbeck 2012, Long and Siu 2018, Hornbeck 2020). For the 20 core Dust Bowl counties, migration rates were high during the 1930s but were also high during the 1920s (Long and Siu 2018). The net decline in population for these counties was largely due to a decrease in in-migration rather than an increase in out-migration. More broadly, counties suffering soil erosion throughout the Great Plains witnessed population declines extending through to the 1950s (Hornbeck 2012). Outside the bounds of the Dust Bowl, by its broadest definition, people left hot and dry areas through much of the western U.S. (Gutmann et al. 2016).

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[9] For economic history see Hansen and Libecap (2004), Hornbeck (2012, 2020), Long and Siu (2018) and Arthi (2018). For history see Bonnifield (1979), Hurt (1981), Gregory (1989), Riney-Kehrberg (1994), Worster (2002), and Cunfer (2008).

[10] After a devastating storm in 1935 "Black Sunday" the reporter Robert Geiger coined the term *Dust Bowl* in reference to the worst impacted area. The phrase *Dust Bowl* stuck and the southern Great Plains had a new identity (Worster 2002). The Soil Conservation Service (SCS) in the United States Department of Agriculture (USDA) adopted Geiger's Dust Bowl terminology to define 20 counties at the intersection of Colorado, Oklahoma, Kansas, Texas, and New Mexico as the area most adversely affected by dust storms and wind erosion (Joel 1937, Cunfer 2008). These 20 counties became the epicenter of interest in environmental degradation in the 1930s. As we expand from these counties, we know less and less about how environmental shocks impacted the economy. The SCS later designated roughly 100 more counties in the southern Great Plains as having suffered severe wind erosion (Natural Resources Conservation Service 2012). This area is outlined and labeled as the Dust Bowl in Figure 1. While the Dust Bowl terminology was adopted by the SCS in reference to specific counties, the Dust Bowl has never been a precise scholarly term. Instead, the term Dust Bowl has been used in a variety of ways. Most often *Dust Bowl* is used to describe the southern Great Plains (Hurt 1981, Worster 2001, Riney-Kehrberg 1994, Cunfer 2011, Long and Siu 2018). Sometimes the term is used to designate the entire Great Plains (Hornbeck 2012, Arthi 2018, Hornbeck 2020). Social science research related to the 1930s drought has focused on the southern Great Plains and to a lesser extent on soil erosion through the Great Plains. Only Gutmann et al. (2016) consider the impact of variation in heat and precipitation for the U.S. as a whole. Porter and Finchum (2009) likely provide the most complete accounting for what constituted the Dust Bowl in terms of historical vernacular.

It is not clear why the southern Great Plains became the center of interest, while the larger drought has been neglected. Most likely, the dust storms reached their greatest frequency and force on the southern Great Plains. The geographic distribution of the storms, combined with the fact that these were an early and extreme example of devastation caused by natural resource exploitation, likely captured the imaginations of novelists, photographers, musicians, researchers, and the nation as a whole to a greater extent than heat, lack of rain, and decimated soil alone.

For whatever reason, the larger drought has been understudied. Furthermore, only recently has research started to use variation in local intensity to isolate the impact of environmental shocks relative to other factors (Hornbeck 2012, Gutmann et al. 2016, Arthi 2018, Hornbeck 2020). Much of the existing research on the economic responses to 1930s environmental degradation is qualitative, rich in details and personal accounts, but not aimed at measuring how environmental conditions impacted economic outcomes relative to other variables. My research contributes to climate-induce migration literature by estimating how the widespread drought influenced migration and thereby altered the population distribution of the United States.

III. Data

Linked census data

I use data linked between the 1930 and 1940 censuses, which enable me to study migration over the entire decade, and provide detailed demographics of the same men in both 1930 and 1940.[11] This section outlines the procedure for linking between censuses, potential issues when using linked census data, and the steps I take to mitigate these issues.

The goal of linking censuses is to match an observation of an individual in one census to the corresponding observation in another census using information that did not change between censuses. Census linkage is complicated by the fact that many people in each census cannot be uniquely identified, which leads to the two primary concerns when using linked census data. The first problem is that census linking algorithms link only a fraction of individuals between censuses. This means that the linked sample may not be representative of the population.[12] The second

[11] The individual-level data is aggregated to the county-level measures to provide a higher-level perspective of how drought impacted migration patterns.

[12] That is, there is *selection into linking*. A stark example of selection into linkage is that women are much harder to match between censuses because they frequently changed their last name at marriage. Therefore, most research using linked census data studies only men.

problem with census-linking algorithms is that they are subject to false positives: linking a 1930 census record to the wrong 1940 census record (Bailey et al. 2020). False positives are especially problematic for migration studies because false positives create spurious migration (Zimran 2021).

A number of linking and statistical techniques mitigate potential bias from both selection into linkage and false positives. The linked data used in this paper are from the Census Linking Project and are designed to minimize both selection into linkage and false positives while linking as many men as possible. The Census Linking Project links based on name, birth year, and place of birth with four different linking algorithms (Abramitzky et al. 2020). In total, the Census linking Project links 22.4 million men between the 1930 and 1940 censuses out of 62.1 million men in the 1930 census.

Because this paper focuses on migration and because false linkages create spurious migrations, I mitigate the risk of false linkages with two steps beyond the careful work of Abramitzky et al. (2020). First, I use only linkages that are linked by both of the two most conservative linking algorithms.[13] Second, I keep only linkages of men who reported the exact same age (plus 10 years) in the 1940 census compared to the 1930 census. This brings the linked sample to 6.3 million men. This is an extremely conservative linking criteria that minimizes the number of false links. It is not possible to know the exact portion of false matches, but given the strict criteria and the computed false linkage rates in Abramitzky et al. (2019), it is likely that the false linkage rate for my dataset does not exceed ten percent.

The second concern in using linked census data is that the linked sample is not representative of the entire population.[14] To document selection into linkage, Table 1 compares the demographics of the linked sample to the full count censuses of men in the relevant age range. The linked sample consists of 2.8 million men aged 20 to 60 in 1930 (column 1) compared to 33.4 million men in this age range in the 1930 census (column 3). The linked sample is similar to the full count census in terms of demographics but because a number of variables differ substantially (*fraction white* for example), I reweight the linked sample with inverse probability weights based on a probit regression for successful linkage. This regression and the weighting are discussed in

[13] These linking algorithms require individuals to have a unique name and birthplace combination within a five-year age band for each census and are effective in reducing false matches (Abramitzky et al. 2019). This step brings the linked sample down to 9.1 million men.

[14] For example, men with better education may be more likely to report consistent information to census enumerators, and name uniqueness varies by country of origin and other characteristics (Collins and Zimran 2019).

the Appendix. The demographics of the weighted linked sample in column 2 align closely with the demographics of the full sample of adult men. Columns 4 through 6 make the same comparisons between the linked sample and the 1940 full count census. All analyses in this paper that use the linked census sample, use the weighted linked sample.[15]

Drought data

I create a dataset of county-level drought by linking local historic drought conditions with the 1930 county map (Cook et al. 2010, Manson et al. 2019). Data measuring yearly drought intensity are from The Living Blended Drought Atlas (LBDA) (Cook et al. 2010), which is publicly available from the U.S. National Atmospheric and Oceanic Administration (NOAA).[16] Meteorological drought is an anomaly of prolonged and abnormally low soil moisture relative to the local average (Palmer 1965).[17] The LBDA estimates yearly drought conditions in the 20th century based on instrument records of heat, rain, wind, soil, runoff, and evaporation for a grid of 11 thousand points across North America and relative to conditions measured during the calibration period of 1928 to 1978 (Cook et al. 2010).

The LBDA data measure drought but contain no geographic variables that enable direct linkage to census data. To use the LBDA in connection with census data, I calculate the average drought by year and county by geospatially matching the LBDA to U.S. county maps (Manson et al. 2019) using Global Information Systems (GIS) software. First, the grid of drought conditions is interpolated using inverse distance weighting. Then, I calculate the average drought recorded within the boundary lines of each county for each year. I algorithmically repeat this process for every year from 1850 to 1949 to show that the 1930s were an outstanding decade of drought and in anticipation of further research on the economic impact of drought.

I supplement census and drought data with a number of other datasets. These datasets include county-level measures of Great Depression severity, New Deal spending, and agricultural variables 1940 (Fishback et al. 2005, Haines et al. 2018, Manson et al. 2019). I use Great

[15] I validate the main results of this paper in the Appendix with alternate linking criteria.

[16] The LBDA is a recent iteration of the Palmer Drought Severity Index (PDSI). The PDSI has become the standard method for measuring variation in drought severity across time and space since its creation in 1969 (Palmer 1969). Alley (1984) offers a complete detailing of the calculations that create the PDSI. Alley (1984) also critiques aspects of the PDSI as it was used in the 1980s. Most of these criticisms are fixed in later computations of the index including the LBDA.

[17] Therefore, a moderate drought in Boulder, Colorado, with low average annual rainfall, is characterized by dryer soil relative to a moderate drought in Nashville, Tennessee, with high average annual rainfall.

Depression severity data (Fishback et al. 2005) to examine the relationship between the Depression and drought. These are the standard microdata used to study variation in Great Depression severity.

IV. Variable creation and descriptive statistics

Drought

Drought categories are designed in terms of how such a deviation is expected to impact the economy. For example, a moderate drought, index value of -2.00 to -2.99 as seen in Table 2, damages crops and pastures, and decreases the volume of streams, reservoirs, and wells to the point of developing water shortages (U.S. Drought Monitor).[18] The defined thresholds hold true for the 1930s. Figure 3 is a binned scatter plot of county-level drought and crop failure in 1934. At an index value of two, a moderate drought, crop failures start to increase. I use this threshold to define a measure of multi-year drought intensity below.

Figure 4 displays maps of yearly drought conditions, to show the extent and changing geographic distribution of drought. The initial drought years, 1930 and 1931, impacted the eastern U.S. and the northern mountain west (including Washington, Oregon, Idaho, and Montana). Moderate and worse drought conditions appeared, then persisted, throughout the Great Plains starting in 1933, and the drought was exceptionally severe and widespread in 1934.

The impact of drought is typically considered on an annual basis, but I observe individuals' locations only in 1930, 1935, and 1940. Therefore, I develop a drought variable that measures exposure over multiple years. For the primary independent drought variable, I use the number of moderate or worse drought years experienced by a county over five- and ten-year time horizons. This definition is motivated by the threshold of moderate yearly drought having quantifiable economic impacts as shown in Figure 3.[19]

With an understanding of what drought means on an annual basis and a variable defined to measure drought over a multi-year period, Figure 5 shows that the 1930s were an outstanding decade by displaying the number of moderate or worse drought years for each decade from the

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[18] *The* U.S. Drought Monitor is jointly produced by the National Drought Mitigation Center at the University of Nebraska-Lincoln, the United States Department of Agriculture, and the National Oceanic and Atmospheric Administration.

[19] The count of moderate or worse drought years is a straightforward definition of drought exposure over multiple years, and is based on the established yearly definitions of drought. Nonetheless, other definitions of drought severity over multi-year time horizons (such as the summation of total yearly drought) are also reasonable measures of drought exposure. Measuring multi-year drought with the summation of yearly drought is discussed further in the Appendix. The results of this paper are robust to this alternate measure of drought severity.

1850s to the 1940s. It is not unusual for some counties to suffer three or four drought years and a few counties to have five or more drought years in a decade. But the five or more drought years that stretched the Great Plains and northern mountain west during the 1930s were exceptional. The 1930s were the worst decade of drought through this 100-year time period (and in U.S. history), motivating the temporal focus of this paper.

Finally, the analysis in this paper distinguishes between the 1930 to 1935 period and the 1935 to 1940 period. The drought of the early and late 1930s impacted different geographic regions as shown in Figure 6. The drought of the early 1930s impacted the northern mountain west, the southeast, and north through the Ohio River Valley. By contrast, the drought of the late 1930s came to center on the Great Plains and a portion of the northern mountain west.

Migration

There was a net depopulation of the Great Plains with migrants primarily relocating to more western counties over the decade. Figure 7 depicts three different measures of migration. First, Figure 7.a. displays net migration from 1930 to 1940.[20] Figures 7.b. and 7.c. disaggregate net migration into out-migration and in-migration.[21] The net depopulation of the Plains was a function of both high out-migration and low in-migration. The dual migration response is important because often only the net migration response to environmental shocks is considered. Here, the depopulation of the Plains was a function of both people leaving and few people moving in to replace the migrants.[22]

Figure 8 displays in- and out-migration for the 1930 to 1935 period and the 1935 to 1940 periods separately. In comparing the early- and late-1930s, the first aspect to note is the similarity between migration. In both time periods there was a net decline in the population for the Plains

[20] Net migration is defined as the number of migrants who entered a county minus the number of migrants who left over the decade as a fraction of the 1930 population:

$$Net\ Migration_{c(1930-1940)} = (Migrants\ enter\ by\ 1940\ - Migrants\ left\ by\ 1940)/Population_{c1930}$$

[21] Out-migration is defined as the fraction of the 1930s population to have left by 1940. In-migration is defined as the number of new residents to have entered as a fraction of 1930s population:

$$Out\text{-}Migration_{c(1930-1940)} = (Migrants\ Left_{c(1930-1940)})/Population_{c1930}$$

$$In\text{-}Migration_{c(1930-1940)} = (Migrants\ Entered_{c(1930-1940)})/Population_{c1930}$$

[22] This result is consistent with research on the 20 counties at the core of the Dust Bowl, which shows that much of the net decline in the population for Dust Bowl counties was due to high out-migration and low in-migration (Long and Siu 2018). Figure 7 expands on this result by showing that the depopulation of the Plains more broadly was a result of both high out-migration and low in-migration. By contrast the same pattern of low in-migration for counties with high out-migration does not hold outside of the drought region. Specifically, while much of the Southwest, and parts of the Pacific Coast, had high out-migration, counties in these regions also had high in-migration.

driven by high out-migration and low in-migration. The second aspect to note is the difference in the intensity of migration between the early and late 1930s. Subfigures (a) and (b) are darker in color than (c) and (d), indicating that there was more migration in the early 1930s. But this finding should be considered in the context of the limitations of linked census data. The potential for false linkages biasing the migration measures from 1930 to 1935 is discussed in more detail in section VI.

Table 3 moves to considering migration and drought together. Over the decade, there was a correlation between drought years and migration. At the extremes, counties that experienced five or more drought years witnessed a decline in population of 6 percent, while counties with two or fewer drought years saw an increase in population of 3 percent on average.

Table 4 displays migration in terms of drought years for the early and late 1930s separately, and indicates that the relationship between drought years and migration over for the decade as a whole was driven by the second half of the decade. This makes sense when considering the migration maps (Figures 7 and 8) in connection with the distribution of drought in the early and late 1930s (Figure 6). The drought of the early 1930s (measured in terms of drought years) was concentrated to the northern mountain west, the southeast, and north through the Ohio River Valley. These regions did not see large population declines in the early 1930s. While there is no obvious descriptive relationship between drought *years* and migration during the early 1930s, Section VI shows that the intensity of drought in 1934 specifically was correlated with high out-migration and low in-migration in the early 1930s.

Tables 3 and 4 show a correlation between drought years and migration over the decade and the late 1930s. But drought was not randomly distributed and migration should be considering in the context of the covariates in Table 5. The drought region was rural compared to the rest of the United States.[23] Moreover, men living in the drought region were relatively geographically mobile, or at least were more likely to be living in a state other than their birth state and to have been foreign born. Finally, as discussed more below, the Depression was more severe in drought counties and New Deal spending, especially the Agricultural Adjustment Act (AAA), was allocated to drought counties.

[23] This relationship is seen by comparing the fraction of men living in cities and on farms as drought years increased (as in the first two rows) and by comparing average county populations.

In light of the differences between drought and non-drought counties, it is possible that underlying migration rates among men with different backgrounds led to the descriptive differences in migration rates between drought and non-drought areas rather than drought itself. These confounding factors motivate the formal estimation of the relationship between drought and migration in the next section.

Great Depression

Figure 9 displays county-level Depression severity in 1933, 1935, and 1939 as measured by *log growth in per capita retail spending*. There was geographic and temporal variation in Depression intensity. Comparing Depression severity with drought years (Figure 6), drought and the Depression severity appear to vary together, especially in the second half of the decade (Figure 6.b. and Figure 9.c.). Because no previous research focuses on how drought impacted Depression severity and to motivate why people wanted to move away from drought, I analyze the impact of drought on Depression severity in the Section VI.

V. Empirical framework

I estimate the relationship between drought and migration using Equation 1:

$$(1)\ M_c = \alpha + \beta_1 D_c + \theta_1 X_{c1930} + \gamma_{s1930} + \varepsilon_c$$

Formally, the outcome variable M_c measures migration at the county-level over five- and ten-year time periods. Net migration, out-migration, and in-migration are each outcome variables in separate regressions.[24] Each migration variable is regressed on a vector of indicator variables for the number of drought years for each county (D_c), a vector of county characteristics (X_{c1930}), state fixed effects (γ_{s1930}), and an error term (ε_c). The vector of county characteristics (X_{c1930}) includes: average age, fraction of population white, fraction living in a city, fraction living in their birth state, fraction foreign born, fraction of men employed, fraction of men employed in farming, and the county population.

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[24] For more information on these migration measures see Section IV. The definitions are relisted here for convenience. For the period from 1930 to 1940 the migration measures using the linked data are defined as follows:

$Net\ Migration_{c(1930-1940)} = (Migrants\ enter\ by\ 1940_c - Migrants\ left\ by\ 1940_c)/Population_{c1930}$

$Out\text{-}Migration_{c(1930-1940)} = (Migrants\ Left_{c(1930-1940)})/Population_{c1930}$

$In\text{-}Migration_{c(1930-1940)} = (Migrants\ Entered_{c(1930-1940)})/Population_{c1930}$

For the 1930 to 1935 and 1935 to 1940 these variables are defined in the same way but over the designated time period.

I estimate Equation 1 for three different time periods. First, I estimate the impact of drought years on migration over the decade as a whole. Then, I separately estimate the impact of drought years on migration for the early and late 1930s.[25] Because of potential bias from the linked census sample, I supplement result with a measure of net migration using the full-count censuses. When using the full count censuses, net-migration is defined as in the following footnote.[26]

VI. Results

Migration results

Results on the relationship between drought and migration over the decade are displayed in Table 6. Column 1 uses the full count censuses and shows that there was a negative relationship between the number of drought years over the decade and the net migration. The relationship between drought and population declines is at the margin of statistical significance using both the full count census data (column 1) and the linked census data (column 2).

Net migration is a function of out-migration and in-migration and the linked census data enable the disaggregation of the net migration result. Column 3 shows that there was a statistically significant relationship between droughts years and county-level out-migration, meaning that as drought years increased for a county so did the fraction of people who left that county. On the other hand, column 4 shows that, when considering the decade as a whole, there does not appear to be a relationship between drought years and in-migration. Note, however, that this in-migration measure only indicates that people were not avoiding counties with more drought compared to other counties with less drought *within* the same state. Section IV shows that there was low in-migration to the drought region as a whole. Moreover, the results using the linked sample should be interpreted in the context of the possibility of false positives biasing the coefficients towards zero.

Disaggregating the migration response between the early and late 1930s is informative to how drought impacted migration. Table 7 column 1 shows some depopulation of drought counties

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[25] The subscripts and descriptions in Equation 1 include 1930 as the year in which county controls and state fixed effects are included. For regressions on the 1935 to 1940 period, county controls are included for both 1930 and 1935 characteristics and state fixed effects are included based on 1935 county and state.

[26] For the 1930 to 1940 period:

$$Full\ Count\ Net\ Migration_{c(1930-1940)} = (Population_{\ c1940} - Population_{\ c1930})/Population_{c1930}$$

This alternate measure of migration is a robustness check to net migration measured with the linked census sample. A problem with this measure of net migration is that it does not account for county-level deaths. The estimates using this alternate measure are largely consistent with the net migration as measured by the linked sample.

when the relationship is measured with the full count census in the early 1930s. This relationship becomes smaller in magnitude and insignificant when the linked census data is used in column 2, indicating that false linkages are biasing the results from 1930 to 1935. Therefore, while column 1 of Table 7 shows that there was a relationship between drought years and migration during the early 1930s, I am not able to disaggregate this result into impacts on out- and in-migration given the current limitations of linked census data.[27]

The nature and intensity of yearly drought elucidates how drought impacted migration in the early 1930s. As displayed in Figure 4, 1934 was the worst year of drought in the decade. To show how drought in 1934 impacted migration in the early 1930s, Table 8 displays the results of regressing migration on 1934 drought severity. Column 1 shows that 1934 drought was highly correlated with net migration from 1930 to 1935. Counties that suffered extreme drought conditions in 1934 witnessed a decline in total population of 8.1 percent compared to similar counties with no drought or mild drought. Column 2 shows that this relationship holds in the linked census dataset, and columns 3 and 4 disaggregate the result into out- and in-migration, showing that depopulation was a function of increased out-migration and decreased in-migration. Drought severity in 1934 specifically was central to migration during the early 1930s.

Table 8 shows that one exceptionally bad year had large impacts on migration while additional moderate or worse drought years had little impact during the early 1930s. In the Appendix, I measure the migration response to *total drought* over the five-year intervals, which puts more weight on the impact of particularly bad drought years. The migration response to *total drought* is mostly larger and more significant than the migration response to the number of moderate or worse drought years, underscoring the importance of yearly drought intensity beyond moderate drought.

The migration response to drought continued through the late 1930s as shown in Table 9. There was a negative relationship between net migration and drought years (column 1). For the late 1930s, there is no concern about false linkages biasing the migration results because 1935 locations are from the 1940 census. As such, the estimated coefficients between the full count and

[27] False linkages are most problematic for the 1930 to 1935 compared to both the 1930 to 1940 and the 1935 to 1940 periods. False linkages are not a problem for the 1935 to 1940 period because location in both 1935 and 1940 come from the 1940 census. This means that when evaluating migration from 1930 to 1940 only the portion of the moves that occurred from 1930 to 1935 are subject to false linkages.

linked sample (columns 1 and 2) are similar.[28] The consistency between columns 1 and 2 suggests that the estimates for out- and in-migration are close to their true values for the 1935 to 1940 period. Columns 3 and 4 show that the net migration from drought in the late 1930s was a function of increased out-migration and decreased in-migration.

Depression severity

I estimate the impact of drought on Depression severity using a linear regression as specified in Equation 2.

(2) $ln(G)_c = \alpha + \beta_1 D_c + \theta_1 X_{c1930} + \gamma_{s1930} + \varepsilon_c$

The outcome $ln\ (G_c)$ is a continuous variable measuring county-level growth in retail sales per capita measured from 1929 to 1939. Growth in retail sales is regressed on a vector of indicator variables for the number of drought years for each county (D_c), a vector of county characteristics in 1930 (X_{c1930}), state fixed effects (γ_{s1930}), and an error term (ε_c). Further details on the right-hand-side variables are discussed in the context of Equation 1.

The results for estimating Equation 2 are reported in Table 10. The primary result (column 1) is that growth in per capita retail sales in counties that experienced five or more drought years was 8.7 log percentage points lower than similar counties that experienced two or fewer drought years. This was a large impact on growth in per capita retail spending as the average county-level growth in per capita retail spending was -2.2 log percentage points over the decade.

The impact of drought was not uniformly spread across the economy. Instead, drought disproportionately impacted retail spending in rural counties compared urban counties (columns 2 and 3). This outcome is expected as we tend to think of droughts primarily impacting agricultural production and the agricultural sector. Nevertheless, the results of column 3 show that drought also impacted the urban sector. Beyond impacting the agricultural supply chain, drought (or the associated heat) potentially impacted the economy outside of the agricultural sector through heat related morbidity and mortality.[29] This is consistent with recent research documenting the impact

[28] Moreover, the similarity of the results in columns 1 and 2 are reassuring that selection into linkage is not a large problem. Some differences in "net-migration" as estimated by county population tabulations from the full count census and the linked sample are expected. I am not able to account for deaths in the relevant age range at the county level in the full count tabulations. Therefore, if drought was correlated with mortality at the county level, then the results in column 1 overstate net migration away from drought counties.

[29] The heat impacts of drought may have been more pronounced in cities through an effect known as the urban heat island in which cities are hotter on average than the surrounding countryside (Wouters et al. 2017). The excess heat

of heat on industrial production and human health, especially in communities without widespread adoption of air conditioning (Deshchenes and Moretti 2009, Hsiang 2010, Dell et al. 2012, and Barreca et al. 2016). The impact of drought on migration distinguishing between city and rural origins is explored in a related paper focused on who moved and where they went (Sichko 2021a).

VII. Conclusion

My research contributes to our understanding of the interaction between humans, the economy, and the environment. Much of the existing research centers on how humans impact the environment. Yet there is growing interest in how the environment influences economic activity. Adaptation methods, such as migration, are vital to the overall impact of environmental shocks. Compared to most weather and climate shocks, the 1930s drought was a long and widespread shock that impacted an ecologically and economically diverse country. The exceptional drought, in connection with excellent data records, situates this drought among the most informative episodes concerning mass climate migration.

My results are novel in the context of the widespread drought but are consistent with previous research related to environmental degradation during the 1930s. First, the result that the depopulation was function of both increased out-migration and decreased in-migration is similar to findings on the core of the Dust Bowl (Long and Siu 2018). My findings are important to climate-migration literature because they show that environmental shocks impact both the push and pull factors. In the mid- and late-1930s, half of the depopulation related to drought was the result of people not moving into drought counties to replace migrants who had left.

The depopulation of the Great Plains was one episode in a boom-and-bust cycle of a climatically volatile region. The underlying climate and history are central to the story of drought and migration. The Plains were, and remain, a drought prone and semi-arid environment. These conditions led to the late European-American settlement and to a demographically distinct region in 1930. Generally, the demographics and economic circumstances of locations are deeply tied to the environment and the casual impact of shocks must be considered in this context.

Much of modern microeconomics is centered on moving past statistical correlations to estimate causal impacts. In fact, environmental shocks, such as drought and variations in rainfall

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of cities, perhaps combined with a higher fraction of the population working in buildings, might have led to heat related morbidity and mortality.

and heat, are often used as exogenous variation to isolate the causal impact of other variables.[30] I use county-level variation in drought intensity to estimate how drought was related to migration while controlling for extensive county-level covariates and state fixed effects. That is, I use detailed microdata and modern econometrics to isolate the impact of drought to the greatest extent possible. Still, my estimates should be considered in the context of migration from a region defined by persistent variations in precipitation and heat. Broadly, local weather and climate conditions and fluctuations are unlikely to be plausibly uncorrelated with other underlying economic circumstances.

Understanding the timing of migration from climate shocks is key because temporal length and intensity are central factors in explaining why migration responses vary widely depending on the time and place of shocks. I show that 1934 was a definitive drought year and that the widespread migration from drought started in and continued after 1934. The result that drought exposure was correlated with depopulation primarily in the mid- and late-1930s is consistent with literature on the core of the Dust Bowl (Riney-Kerhberg 1989, 1994), and with state-level tabulations of migrants from popular destinations (Taylor and Vaset 1936, Hoffman 1938).

Prior to 1934, the drought was severe and prolonged in some areas but not unprecedented as a whole. The devastation of 1934 changed peoples' circumstances and was the year that the 1930s became an important period of climate-induced migration. This is a key insight for literature that seeks to identify why people move from some environmental shocks but not others. In the 1930s, an exceptionally bad drought year, centered on a semi-arid and recently settled region, induced mass migration from drought.

In the 1930s, drought contributed to the size and frequency of dust storms on the Great Plains. Today, drought contributes to the size and frequency of wildfires across the western United States. What year in the 21st century will mirror 1934 as a tipping point, after which people move *en masse* rather than face another year of drought, wildfires, and smoke? When this migration occurs, the foremost questions will be: what fraction of the population will move, who will move, where will people go, and what job opportunities will they have? The 1930s is the most direct historic corollary concerning mass environmental migration in the United States. I answers the

[30] That is, weather and climate deviations are used as instrumental variables. See Rosenzweig and Wolpin (2000) for a review of literature.

first of these questions in this paper, and I study the last three questions in related research using the data developed here (Sichko 2021a, Sichko 2021b).

Appendix

Census linkage weighting

Linked samples between censuses are typically not representative of the demographics of the full count census. Therefore, it is common practice to estimate a probability model for how likely each individual is to be linked, and weight the linked sample by the inverse probability of being linked. This procedure has the effect of making the linked sample as close to possible to the demographic composition of full count censuses.

Equation A1 is the probability model that I use to estimate how likely each individual was to be linked.

(A1) $L_i = \alpha + \beta_1 A_{i1930} + \beta_2 O_{i1930} + \beta_3 E_{i1940} + \theta_1 X_{i1930} + \varepsilon_i$

The outcome variable (L_i) is an indicator variable equal to one if individual i was linked between the 1930 and 1940. Linkage status is regressed on a vector on indicator variables for individual i's age (A_{i1930}), a vector of indicator variables for occupation score in 1930 (O_{i1930}), a vector of indicator variables for education in 1940 (E_{i1940}), and a vector of indicator variables for individual characteristics: whether they were white, a home owner, married, lived in a city, employed, their income wage in 1940, lived on a farm, and were a house hold head. This technique and the calculations are equivalent to those used and recommended by Abramitzky et al. (2020) for their published linked sample.

Using the results of Equation A1, I estimate the likelihood that each man aged (20 to 60) in the 1930 census was linked between census based on their characteristics. I weight linked observations by the inverse of the probability that they were linked for all tables and analysis. This process weights the linked sample so that it is representative of the full count census as displayed in Table 1.

Alternate census linking criteria

The linked data set used in this paper uses very strict linking criteria. Such strict linking was chosen for the main linked sample to minimize the number of and bias from false linkages. The risk with such strict linking criteria is that results might be driven by heightened selection into linkage. This possibility is mitigated by the fact that all results in this paper that use the linked sample are weighted by the inverse probability of linkage. Nonetheless, Tables A1 replicate Table 6 with a sample linked on less strict criteria.

The data underlying Tables A1 are a linked sample from Abramitzky et al. (2020). The data in this sample are linked by both of the two most conservative linking algorithms but without the additional linking criteria that I impose in the Section III (links do not have to report the exact same age (plus ten years) in the 1940 census). This increases the number of observations in the linked sample from 2.6 million (used in the main text) to 4.2 million men aged 20 to 60 in 1930. The results in Table A1 are similar to the results in the main text of this paper, indicating that the results of this paper that rely on the linked data set are robust to alternate linking criteria.

Alternate drought measure

I use the number of moderate or worse drought years for the primary independent variable in this paper. The number of drought years is a simple and straightforward measure of exposure to drought over multi-year time periods. But there are other ways to measure drought intensity over multi-year time horizons. Another measure of drought intensity is to sum the total index value of drought each county experienced over five- and ten-years periods. The *number of drought years* was chosen as the most intuitive way to measure drought over multiple years and the primary independent variation in this paper because it corresponds directly with the more commonly used and defined measures of drought intensity at the yearly level, whereas *total drought* relies on somewhat arbitrary cutoffs for the thresholds of *mild*, *moderate*, and *severe drought* over multiple years. The results of this paper are similar (and mostly larger and more significant) when using *total drought* instead of *number of drought years.*

To show that the main results of this paper are robust to an alternate measure of drought, Equation A2 defines a measure of total drought over five-year periods.

(A2) $Total\ Drought_c = -(\sum_{y=0}^{5} Drought\ Severity_{cy} \mid Drought\ Severity_{cy} < 0)$

I then create a series of indicator variables for drought severity in A3:

(A3) $Normal\ Conditions_c = 1\ if\ Total\ Drought_c < 5$

$$Mild\ Drought_c = 1\ if\ 5 <= Total\ Drought_c < 8$$

$$Moderate\ Drought_c = 1\ if\ 8 <= Total\ Drought_c < 11$$

$$Severe\ Drought_c = 1\ if\ 11 <= Total\ Drought_c$$

Normal Conditions are defined as having an average yearly drought index of less than one for the five-year time period. Referring to Table 1, yearly index values of less than 1 are classified as *near* *normal* or *incipient dry spell*. Each subsequent drought category is defined by adding a standard deviation in average drought severity over the five-year period.

I use this alternate definition of drought in estimating the main migration results over five-year periods. Tables A2 and A3 report the results of estimating Equation 1 with the total drought measure instead of drought years and correspond to Tables 7 and 9. The results are similar but there are two notable differences. First, *total drought* severity in the early 1930s is correlation with declines in in-migration in Table A1. This result is consistent with the results and discussion concerning the importance of 1934 as the regressions with total drought as the main independent variable put more weight on the severity of drought in single years. Second, the migration response is more pronounced in the late 1930s when using total drought. This indicates that drought beyond moderate drought at the yearly level had additional impacts on migration as is expected.

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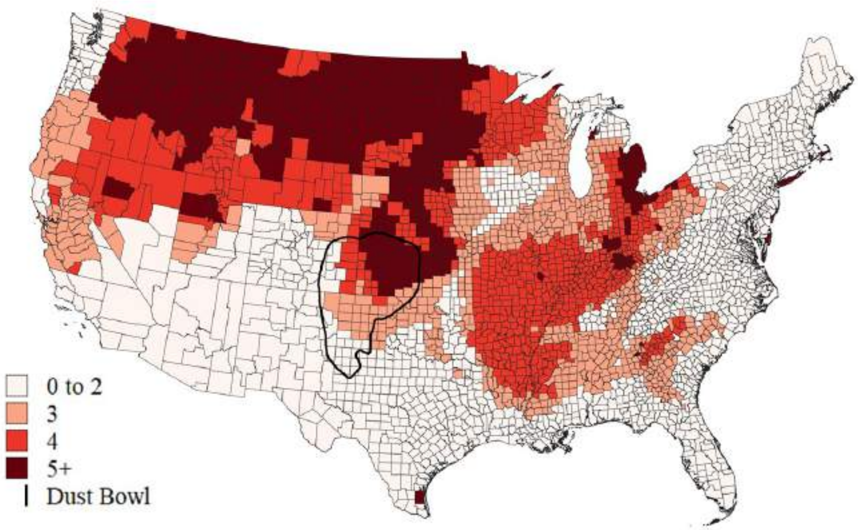
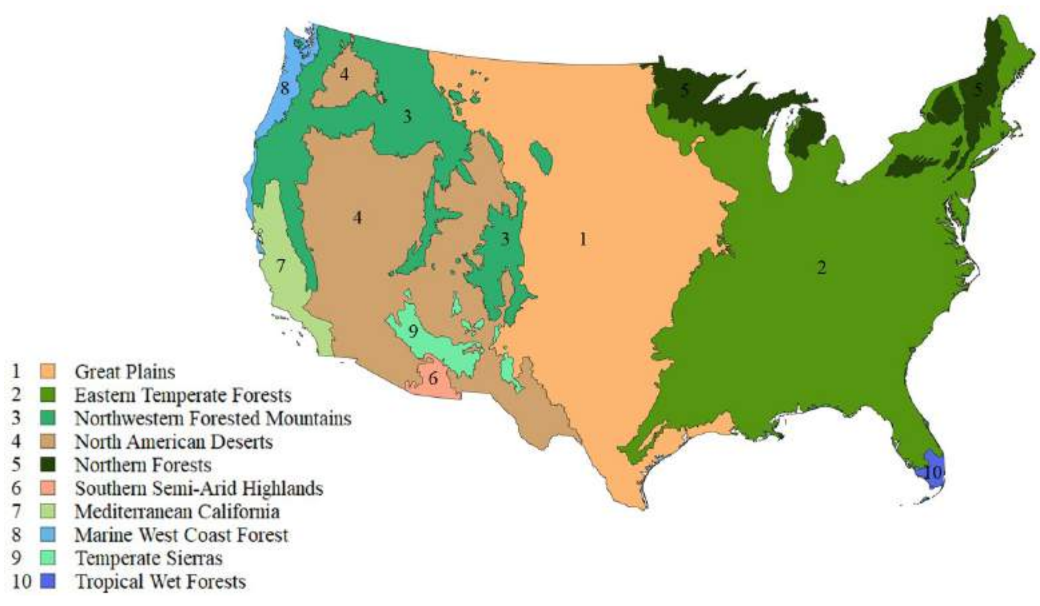
Figure 1: Number of drought years 1930 to 1939



Notes: The drought of the 1930s was the worst ten-year period of drought in U.S. history. Years of moderate or worse drought are defined using the Living Blended Drought Atlas (Cook et al. 2010). The roughly 100 Dust Bowl counties outlined are the largest set of counties defined by the Soil Conservation Service as counties severely impacted by wind erosion during the 1930s (Natural Resources Conservation Service 2012). The *Dust Bowl* has never been a precise scholarly term as discussed in Section II. This outline is simply intended to give an idea of the region of focus for previous literature. Data sources: Cook et al. (2010) and Manson et al. (2019).

Figure 2: Ecological zones



Notes: This figure displays the ecological zones of the United States. The Great Plains (zone 1) are where drought came to center in the middle and late 1930s. This region is a semi-arid grassland that is prone to variation annual precipitation and temperature. Data source: Omernik (2004).

Table 1: Demographics of men in linked and full samples

	(1) 1930 linked sample unweighted	(2) 1930 linked sample weighted	(3) 1930 full count	(4) 1940 linked sample unweighted	(5) 1940 linked sample weighted	(6) 1940 full count
Average age	36.2	36.5	37.2	46.2	46.5	46.5
Fraction employed	90.1	88.7	88.4	86.6	82.4	82.7
Average occupation score	20.0	19.5	19.8	24.1	22.8	22.8
Fraction home owner	51.2	46.9	47.3	53.9	45.6	45.3
Fraction house hold head	73.2	70.3	71.3	86.7	80.2	80.5
Fraction married	74.7	71.7	73.7	85.8	79.5	79.7
Fraction white	97.3	90.8	91.7	97.4	90.4	90.6
Fraction in city	46.8	50.4	50.6	43.8	49.6	49.5
Fraction on farm	24.9	22.7	21.9	24.0	20.4	20.7
Average highest grade				8.7	8.1	7.8
Average wage income				$999	$929	$890
Observations	2,811,829	2,811,829	33,368,029	2,811,829	2,811,829	28,776,391

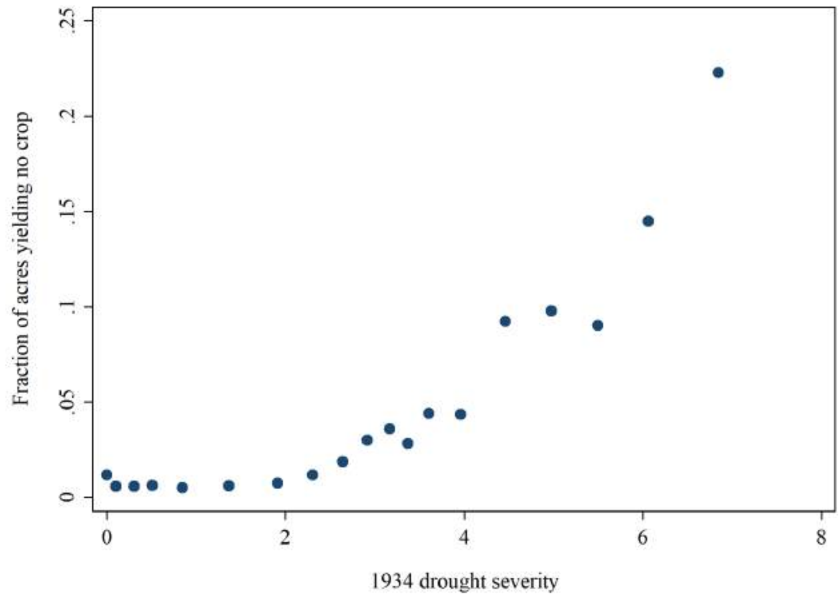
Notes: This table shows the demographics of the linked census sample from 1930 to 1940 and the demographics for the full count 1930 and 1940 censuses of men aged 20 to 60 in 1930. Because some variables (*fraction white* for example) vary considerably between the linked sample and the full count, I weight the linked sample with the inverse probability of the likelihood of being linked. The weighted linked sample is very similar to the full count census demographics in both 1930 and 1940. Data sources: Ruggles et al. (2019) and Abramitzky et al. (2020).

Table 2: Classification of wet and dry conditions for yearly drought index values

Qualitative description	Index value
Extreme drought	-4.00 or less
Severe drought	-3.00 to -3.99
Moderate drought	-2.00 to -2.99
Mild drought	-1.00 to -1.99
Incipient dry spell	-0.50 to -0.99
Near normal	0.49 to -0.49
Incipient wet spell	0.50 to 0.99
Slightly wet	1.00 to 1.99
Moderately wet	2.00 to 2.99
Very wet	3.00 to 3.99
Extremely wet	4.00 or more

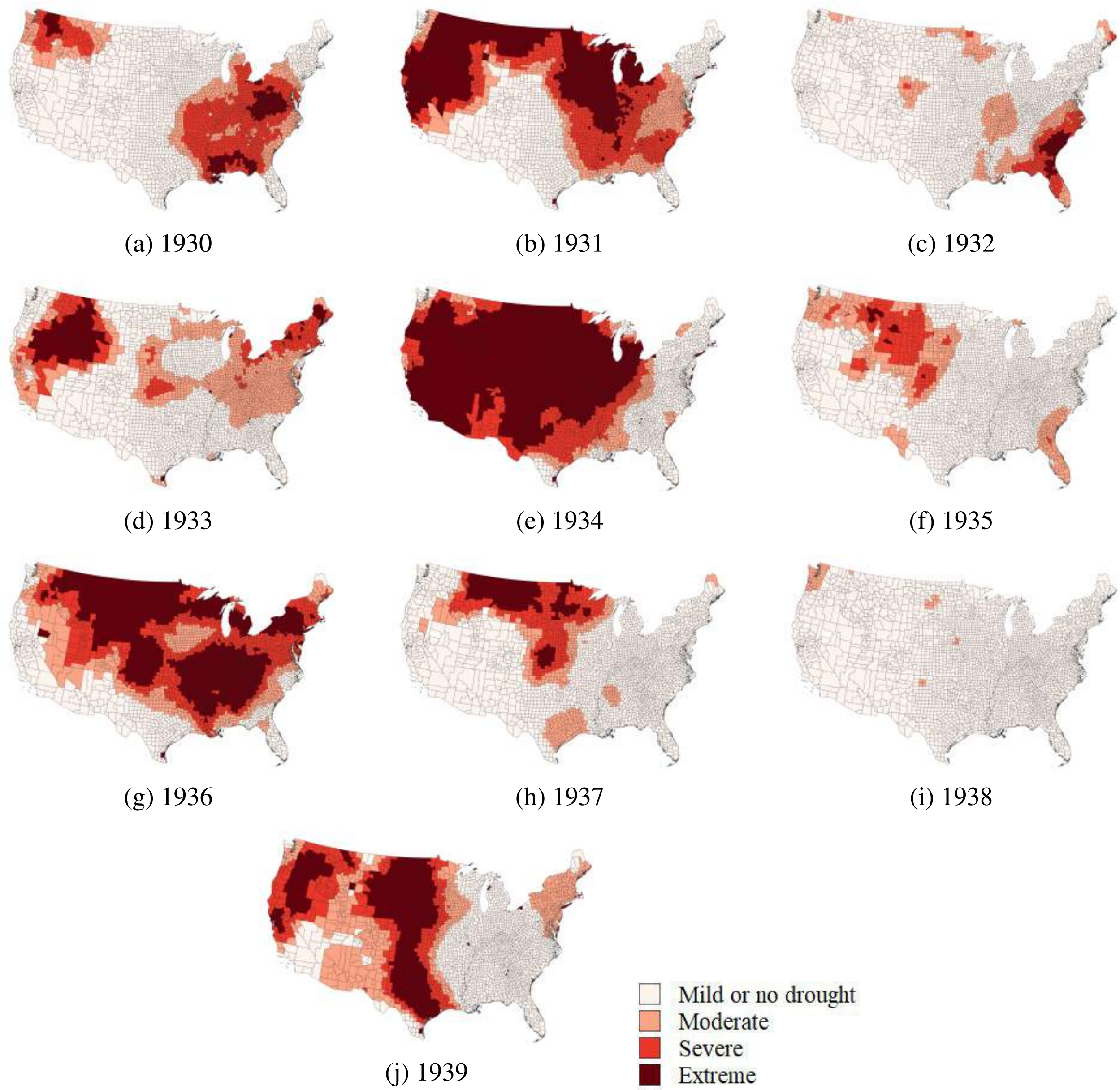
Note: This table displays the qualitative definitions of index values in terms of drought severity. The Living Blended Drought Atlas (LBDA), as a recent iteration of the Palmer Drought Severity Index (PDSI), defines drought severity at the yearly level as an index value. Source: Cook et al. (2007).

Figure 3: Binned scatter plot of 1934 county crop failure and drought index



Notes: This figures displays the correlation between drought severity and crop failure in 1934. Each point in this figure represents the average of roughly 150 counties. Drought index values of two (*moderate* drought as shown in Table 2) and higher induced crop failures. Crop failures were assessed at the acre level. For an acre to have *failed* it must have produced no crop. Therefore, overall declines in output were much higher than fraction failed suggests on the surface. Data sources: Cook et al. (2010) and Manson et al. (2019).

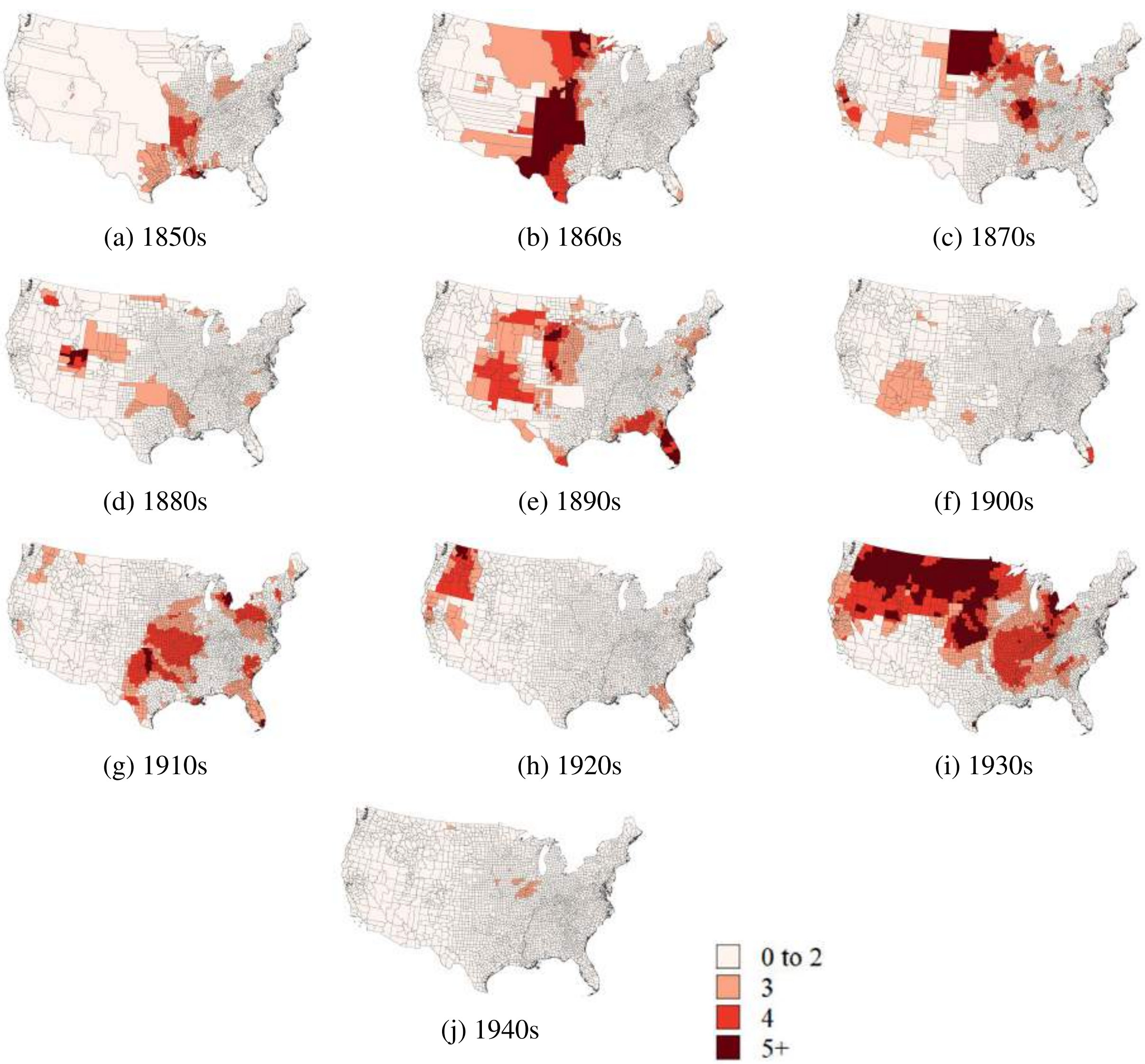
Figure 4: Drought by county and year 1930 to 1939



(a) 1930 (b) 1931 (c) 1932 (d) 1933 (e) 1934 (f) 1935 (g) 1936 (h) 1937 (i) 1938 (j) 1939

Notes: This figure displays yearly drought conditions. Drought conditions in 1930 and 1931 mostly did not impact the Great Plains but by 1933 moderate drought had developed on the Plains. These conditions persisted in many counties through 1939 (with the exception of 1938). The worst single year of drought in the decade was 1934. Data sources: Cook et al. (2010) and Manson et al. (2019).

Figure 5: Number of drought years by decade



(a) 1850s (b) 1860s (c) 1870s

(d) 1880s (e) 1890s (f) 1900s

(g) 1910s (h) 1920s (i) 1930s

(j) 1940s

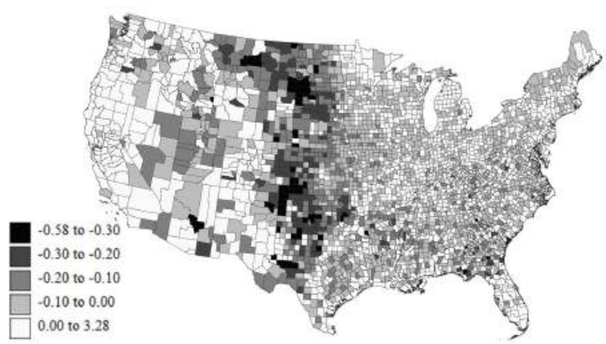
Notes: This figure shows the number of moderate or worse drought years for each decade from 1850 to 1949. The 1930s were the worst decade of drought during this 100 year period and for U.S. history more broadly. The severity of drought during the 1930s motivates the focus of this dissertation on studying the impact of drought during the 1930s. Data sources: Cook et al. (2010) and Manson et al. (2019).

Figure 6: Number of moderate or worse drought years in five-year intervals

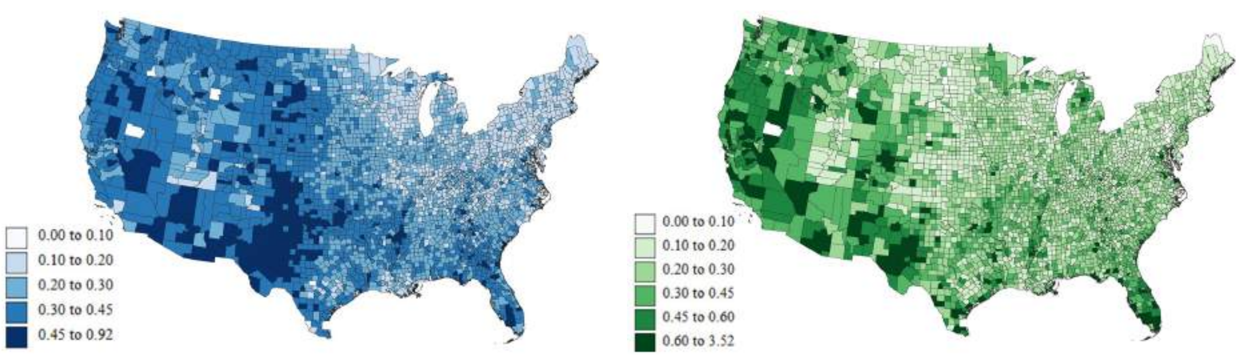
(a) 1930 to 1934 (b) 1935 to 1939

Notes: This figure shows the number of moderate or worse drought years from 1930 to 1934 and from 1935 to 1939 separately. The drought of the early 1930s centered on the northwest as well as the Ohio and Mississippi Valleys and the southern United States. The drought of the late 1930s centered on the Great Plains but extended into the northern mountain west and the prairies to the east. Data sources: Cook et al. (2010) and Manson et al. (2019).

Figure 7: Migration: 1930 to 1940



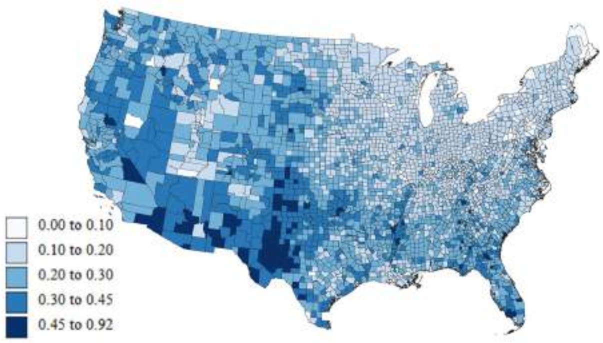
(a) Net migration



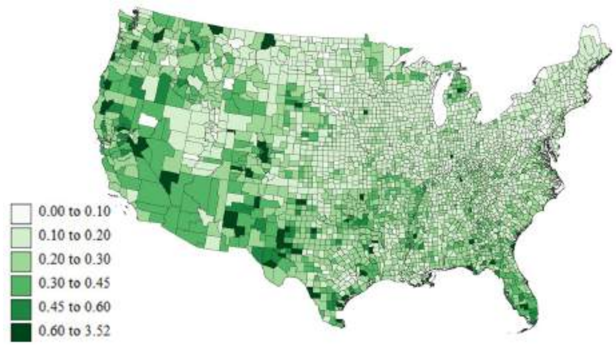
(b) Out-migration (c) In-migration

Notes: This figure shows migration from 1930 to 1940. The overarching migration trend was a depopulation of the Great Plains region as seen in (a). The depopulation of the Great Plains was a function of both high out-migration and low in-migration to the region and seen in (b) and (c). Migration measures appear correlated with the number of drought years over the decade. Linked sample of adult men (20 to 60 in 1930). Data sources: Ruggles et al. (2019), Manson et al. (2019), and Abramitzky et al. (2020).

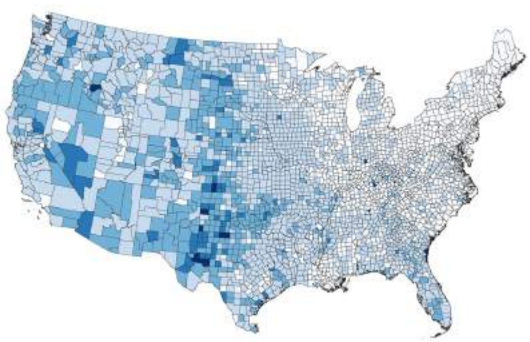
Figure 8: Migration in five-year intervals



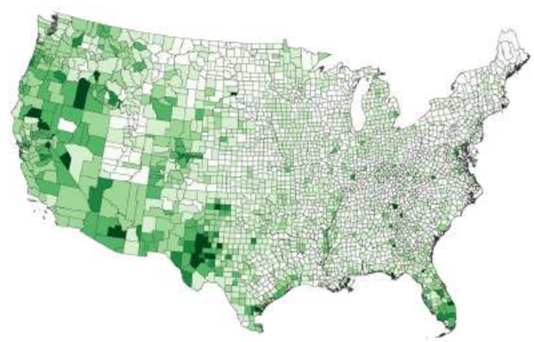
(a) Out-migration: 1930 to 1935



(b) In-migration: 1930 to 1935



(c) Out-migration: 1935 to 1940



(d) In-migration: 1935 to 1940

Note: This figure shows migration from 1930 to 1935 and 1935 to 1940. The migration patterns of the early and late 1930s look similar to those over the decade as whole. Migration was not clearly correlated with additional drought years in the early 1930s (Figure 7.a). But migration in the early 1930s was correlated with drought severity in 1934 in particular as discussed in Section VI. Migration in the late 1930s appears correlated with drought years in the late 1930s (Figure 7.b.). Linked sample of adult men (20 to 60 in 1930). Data sources: Ruggles et al. (2019), Manson et al. (2019), and Abramitzky et al. (2020).

Table 3: Migration by number of drought years 1930 to 1940

Drought years	0 to 2	3	4	5+
Fraction of individuals				
Net migration	0.03	-0.01	0.00	-0.06
Migrated out	0.29	0.28	0.28	0.31
Migrated in	0.32	0.28	0.27	0.25

Notes: This table shows migration rates by drought years over the entire 1930s. There was net migration from counties with five or more years of drought. The last column in the first row shows that counties with five or more drought years witnessed a 6 percent decline from their 1930 population on average by 1940. This net decline in population was a function of both higher out-migraiton and lower in-migration. Linked sample of adult men (20 to 60 in 1930) weighted by the inverse probability of linkage. Data sources: Cook et al. (2010), Ruggles et al. (2019), Manson et al. (2019), and Abramitzky et al. (2020).

Table 4: Migration by number of drought years for early and late 1930s

Drought years	0 or 1	2	3+
Panel A: Fraction of individuals 1930 to 1935			
Net migration	0.00	0.00	0.01
Migrated out	0.24	0.21	0.22
Migrated in	0.25	0.21	0.23
Panel B: Fraction of individuals 1935 to 1940			
Net migration	0.01	-0.01	-0.06
Migrated out	0.13	0.17	0.18
Migrated in	0.14	0.16	0.12

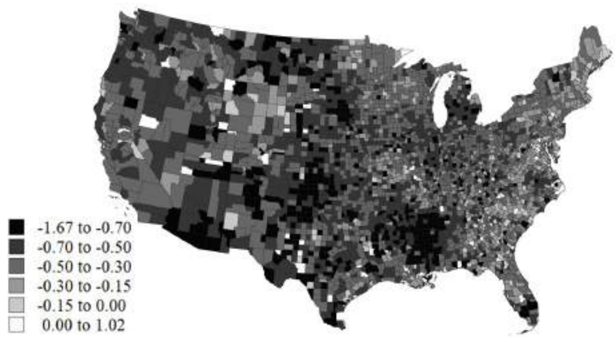
Note: This table shows migration rates by drought years separately for the early and late 1930s. There was not a clear relationship between drought years and migration during the early 1930s. There was a description relationship between drought years and migration in the late 1930s. Drought years in this table refer to the number of drought years experienced during the given five-year period. Linked sample of adult men (20 to 60 in 1930) weighted by the inverse probability of linkage. Data sources: Cook et al. (2010), Ruggles et al. (2019), Manson et al. (2019), and Abramitzky et al. (2020).

Table 5: 1930 county demographics by drought years from 1930 to 1940

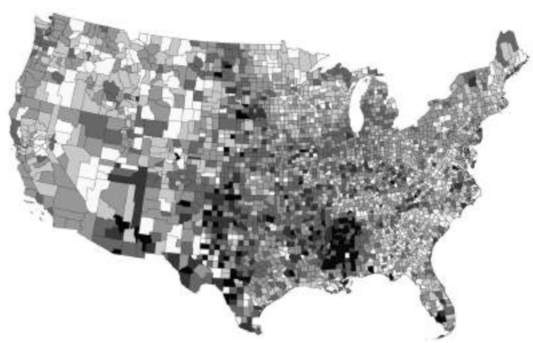
Drought years	0 to 2	3	4	5+
Fraction				
In city	0.13	0.11	0.08	0.08
On farm	0.42	0.49	0.54	0.54
Farms mortgaged	0.35	0.43	0.44	0.56
Men employed	0.94	0.94	0.95	0.95
White	0.85	0.87	0.90	0.97
In birth state	0.68	0.70	0.69	0.46
Foreign born	0.08	0.06	0.06	0.14
Average				
Population	12,889	11,222	7,975	6,500
Occupational score	18.2	17.9	17.3	16.9
Age	37.2	37.6	37.8	37.7
Per capita				
Growth in spending	0.03	-0.04	-0.06	-0.09
Public works and relief spending	$132	$120	$128	$161
AAA spending	$41	$82	$86	$189

Notes: This table shows average of demographic variables based on the drought exposure from 1930 to 1939. Multiple covariates to migration varied with drought exposure as discussed in Section IV. Linked sample of adult men (20 to 60 in 1930) weighted by the inverse probability of linkage. County populations are weighted to be representative of total county population of adult men (20 to 60). Data sources: Fishback et al. (2005), Cook et al. (2010), Ruggles et al. (2019), Manson et al. (2019), and Abramitzky et al. (2020).

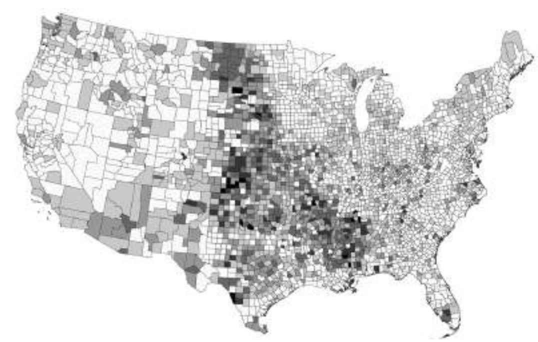
Figure 9: Depression severity: log growth in per capita retail sales



(a) 1929 to 1933



(b) 1929 to 1935



(c) 1929 to 1939

Notes: This figures shows county-level Depression as measured by the log growth of per capita retail sales for different points in time. The trough of the Great Depression was in 1933 as indicated by how dark figure (a) is compared to (b) and (c). By the late 1930s, retail spending had recovered in many areas. But, the Great Plains, the core of the drought region, had a slower recovery. Data sources: Fishback et al. (2005) and Manson et al. (2019).

Table 6: County-level migration from drought 1930 to 1940

	(1) Net migration	(2) Net migration	(3) Out-migration	(4) In-migration
3 drought years (1930 to 1939)	-0.020	-0.025*	0.009*	-0.016
	(0.012)	(0.012)	(0.005)	(0.012)
4 drought years (1930 to 1939	-0.028*	-0.022	0.015**	-0.006
	(0.015)	(0.015)	(0.007)	(0.016)
5+ drought years (1930 to 1939)	-0.020	-0.017	0.017**	-0.001
	(0.019)	(0.017)	(0.007)	(0.017)
Sample	Full count	Linked sample	Linked sample	Linked sample
Observations	3,093	3,093	3,093	3,093

Standard errors clustered by 1930 state in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Notes: This table displays the results of regressing migration measures on drought years. The first column uses the total population change of men (aged 20 to 60) for each county calculated with the full count censuses. Columns 2, 3, and 4 use the linked sample of men weighted by the inverse probability of linkage. The last coefficient in column 1 estimates that counties with five or more drought years witnessed a net population decline of 2.0 percentage points compared to similar non-drought counties. The net migration away from drought counties was driven by higher out-migration (column 3). Regressions include state fixed effects and county-level controls as detailed in Equation 1.

Table 7: County-level migration from drought 1930 to 1935

	(1) Net migration	(2) Net migration	(3) Out-migration	(4) In-migration
2 drought years (1930 to 1934)	-0.009	-0.009	0.003	-0.005
	(0.010)	(0.010)	(0.006)	(0.009)
3+ drought years (1930 to 1934)	-0.026**	-0.012	0.012*	0.000
	(0.012)	(0.011)	(0.007)	(0.010)
Sample	Full count	Linked sample	Linked sample	Linked sample
Observations	3,093	3,093	3,093	3,093

Standard errors clustered by 1930 state in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Notes: This table displays the results of regressing migration measures on drought years from 1930 to 1934. The first column uses the total population change of men (aged 20 to 60) for each county calculated with the full count censuses. Columns 2, 3, and 4 use the linked sample of men weighted by the inverse probability of linkage. The last coefficient in column 1 estimates that counties with three or more drought years witnessed a net population decline of 2.6 percentage points from 1930 to 1935 compared to similar non-drought counties. This relationship does not hold when using the linked census data, possibly because of false linkages biasing the results towards zero. Regressions include state fixed effects and county-level controls as detailed in Equation 1.

Table 8: County-level migration from drought severity in 1934

	(1) Net migration	(2) Net migration	(3) Out-migration	(4) In-migration
Moderate drought 1934	-0.027**	-0.015*	0.011	-0.004
	(0.010)	(0.009)	(0.008)	(0.014)
Severe drought 1934	-0.033*	-0.041**	0.044**	0.004
	(0.019)	(0.020)	(0.022)	(0.012)
Extreme drought 1934	-0.081***	-0.097***	0.047***	-0.049***
	(0.022)	(0.020)	(0.016)	(0.017)
Sample	Full count	Linked sample	Linked sample	Linked sample
Observations	3,093	3,093	3,093	3,093

Standard errors clustered by 1930 state in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Notes: This table displays the results of regressing county-level migration measures on drought severity in 1934. The first column uses the total population change of men (aged 20 to 60) for each county calculated with the full count censuses. Columns 2, 3, and 4 use the linked sample of men weighted by the inverse probability of linkage. The last coefficient in column 1 estimates that counties with extreme drought in 1934 witnessed a net population decline of 8.1 percentage points from 1930 to 1935 compared to similar non-drought counties. This relationship holds both with the full count migration measure and linked sample migration measures. The net migration from counties that suffered the worst drought in 1934 was a function of both higher out-migration and lower in-migration (columns 3 and 4). Regressions include state fixed effects and county-level controls as detailed in Equation 1.

Table 9: County-level migration from drought 1935 to 1940

	(1) Net migration	(2) Net migration	(3) Out-migration	(4) In-migration
2 drought years (1935 to 1939)	-0.028**	-0.020	0.004	-0.016
	(0.012)	(0.015)	(0.004)	(0.014)
3+ drought years (1935 to 1939)	-0.041**	-0.036*	0.018**	-0.017
	(0.020)	(0.021)	(0.008)	(0.019)
Sample	Full count	Linked sample	Linked sample	Linked sample
Observations	3,093	3,093	3,093	3,093

Standard errors clustered by 1935 state in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Notes: This table displays the results of regressing county-level migration measures on drought years from 1935 to 1939. The first column uses the total population change of men (aged 20 to 60) for each county calculated with the full count censuses. Columns 2, 3, and 4 used the linked sample of men weighted by the inverse probability of linkage. The last coefficient in column 1 estimates that counties with three or more drought years witnessed a net population decline of 4.1 percentage points from 1935 to 1940 compared to similar non-drought counties. This relationship holds both with the full count and linked sample migration measures. The net migration from counties that suffered the more drought years in the late 1930s was a function of both higher out-migration and lower in-migration (columns 3 and 4). Regressions include state fixed effects and county-level controls as detailed in Equation 1.

Table 10: Drought years and Depression severity

	(1) Growth in per capita retail sales 1929 to 1939	(2) Growth in per capita retail sales 1929 to 1939	(3) Growth in per capita retail sales 1929 to 1939
3 drought years (1930 to 1939)	-0.057***	-0.061***	-0.022
	(0.020)	(0.021)	(0.019)
4 drought years (1930 to 1939)	-0.074***	-0.077***	-0.036
	(0.023)	(0.024)	(0.026)
5+ drought years (1930 to 1939)	-0.087***	-0.091**	-0.037*
	(0.031)	(0.035)	(0.020)
Sample	All counties	Rural counties	Urban counties
Observations	3,083	2,747	332

Standard errors clustered by 1930 state in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Notes: This table displays the results of regressing Depression severity on drought years from 1930 to 1939. As drought years increased, so did Depression severity as measured in 1939. The last coefficient in column 1 estimates that counties with five or more drought years witnessed 8.7 log percentage points less growth in per capita retail spending compared to similar non-drought counties. Columns 2 and 3 disaggregate the results between rural and urban counties to show that the drought impacted retail spending most dramatically in rural counties but also impacted urban counties. Rural counties are defined as counties with greater than 50 percent of the population living outside IPUMS designated cities. Urban counties are defined as counties with greater than 50 percent of the population living in IPUMS designated cities. Regressions include state fixed effects and county-level controls.

Appendix

Table A1: County-level migration from drought 1930 to 1940: alternate census linkage

	(1) Net migration	(2) Out-migration	(3) In-migration
3 drought years (1930 to 1939)	-0.024*	0.009*	-0.015
	(0.012)	(0.005)	(0.012)
4 drought years (1930 to 1939)	-0.020	0.016**	-0.004
	(0.015)	(0.007)	(0.016)
5+ drought years (1930 to 1939)	-0.015	0.017**	0.002
	(0.018)	(0.008)	(0.017)
Observations	3,093	3,093	3,093

Standard errors clustered by 1930 state in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Notes: This table displays the results of regressing county-level migration measures against drought severity for the entire decade using alternate census linkage criteria. These results are similar to the results in Table 6 indicating that the results are robust to alternate linkage criteria. These regressions use the alternate linked sample of adult men (aged 20 to 60 in 1930) describe in the Appendix. Regressions include state fixed effects and county-level controls as detailed in Equation 1.

Table A2: County-level migration from drought 1930 to 1935: alternate drought measure

	(1) Net migration	(2) Net migration	(3) Out-migration	(4) In-migration
Moderate drought	-0.006	-0.010	-0.006	-0.016*
	(0.011)	(0.008)	(0.004)	(0.008)
Severe drought	-0.025*	-0.020*	-0.000	-0.020*
	(0.013)	(0.012)	(0.007)	(0.011)
Sample	Full count	Linked sample	Linked sample	Linked sample
Observations	3,093	3,093	3,093	3,093

Standard errors clustered by 1930 state in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Notes: This table displays the results of regressing county-level migration measures against drought severity for the first half of the decade as a robustness check on the measure of multi-year drought exposure. The first column uses the total population change of men (aged 20 to 60) for each county calculated with the full count censuses. Columns 2, 3, and 4 used the linked sample of men weighted by the inverse probability of linkage. There was a stronger relationship between in-migration and drought severity in the early 1930s using the alternate measure of drought. This indicates that drought in the early 1930s (and specifically the intensity of yearly drought beyond moderate) might have impacted destination choices to a greater extent than the primary specifications of the paper estimates. Regressions include state fixed effects and county-level controls as detailed in Equation 1.

Table A3: County-level migration from drought 1935 to 1940: alternate drought measure

	(1) Net migration	(2) Net migration	(3) Out-migration	(4) In-migration
Moderate drought	-0.022	-0.014	0.005	-0.007
	(0.016)	(0.017)	(0.007)	(0.016)
Severe drought	-0.061***	-0.064***	0.031**	-0.033**
	(0.018)	(0.020)	(0.014)	(0.015)
Sample	Full count	Linked sample	Linked sample	Linked sample
Observations	3,093	3,093	3,093	3,093

Standard errors clustered by 1935 state in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Notes: This table displays the results of regressing county-level migration measures against drought severity for the second half of the decade as a robustness check on the measure of multi-year drought exposure. The first column uses the total population change of men (aged 20 to 60) for each county calculated with the full count censuses. Columns 2, 3, and 4 used the linked sample of men weighted by the inverse probability of linkage. These results are similar (and stronger than the results reported in Table 9) indicating that severe or worse drought years had an added impact on migration beyond the impact of only a moderate drought year. Regressions include state fixed effects and county-level controls as detailed in Equation 1.