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Climate Variability and Human Migration in the Netherlands, 1865–1937

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Abstract

Human migration is frequently cited as a potential social outcome of climate change and variability, and these effects are often assumed to be stronger in the past when economies were less developed and markets more localized. Yet, few studies have used historical data to test the relationship between climate and migration directly. In addition, the results of recent studies that link demographic and climate data are not consistent with conventional narratives of displacement responses. Using longitudinal individual-level demographic data from the Historical Sample of the Netherlands (HSN) and climate data that cover the same period, we examine the effects of climate variability on migration using event history models. Only internal moves in the later period and for certain social groups are associated with negative climate conditions, and the strength and direction of the observed effects change over time. International moves decrease with extreme rainfall, suggesting that the complex relationships between climate and migration that have been observed for contemporary populations extend into the nineteenth century.

Keywords

Internal migration; International migration; Climate variation; Netherlands; Event history analysis

Introduction

Climate and Migration

Human migration and involuntary displacement are frequently identified as likely social outcomes of climate change and variability (Black et al. 2011). A small number of recent studies have linked population and climate data to directly test these effects (Dillon et al. 2011; Fussell et al. 2010; Gray & Mueller 2012a, 2012b; Hunter et al. 2013; Mueller at al. 2014), with results that are not consistent with common Malthusian narratives of large-scale, long-term displacement (e.g., Myers 2002). These effects are often presumed to have been even stronger in the past, especially for periods when people were more vulnerable to climate variation because economies were less developed, markets were more localized, and institutions (welfare, insurance, etc.) that offer protection against risk were weak. Climate

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variability is also frequently invoked to explain historical population movements (Eriksson et al. 2012; Zhang et al. 2011). To date, however, few studies of the historical past have directly tested the effects of climate variability on human migration, in part due to data limitations (for an exception see Gutmann et al. 2005). To address this issue, we combine historical climate data with a unique dataset capturing the migration of 24,835 individuals in the Netherlands spanning the period 1865–1937. This allows for the estimation of a discrete-time event history model of migration as influenced by climatic, social and economic variables. This work responds to calls for additional quantitative studies of climate and migration (Gemenne 2011) and climate and history (Le Roy Ladurie 1988; Rotberg & Rabb 1981), as well as calls for research on the vulnerability of past societies to climate variation (Pfister 2010).

Migration in 19th and early 20th century Europe: social and economic variation

The study of migration in the past is often hampered by data limitations, as large datasets with individual data on the timing and location of moves are rare. Yet, at times it is possible to reconstruct migration histories through the use of historical census, population register, or family reconstitution data. Large-scale studies have examined aggregate migration trends over time while individual-level studies have typically been limited to small areas. Both individual and aggregate studies of human migration have provided insight into some of the important social and economic predictors of mobility in the past, including urbanization, marriage patterns, age, gender, occupation, and household composition. The Historical Sample of the Netherlands (HSN) avoids many of these shortcomings as it allows for individual-level analyses that cover the whole of the Netherlands and includes both time-varying and static information on many potential predictors of migration.

Studies of migration in preindustrial Europe have revealed that cities drew migrants from the surrounding countryside (Landers 1993) and migration contributed to the growth of urban areas in the 19th and 20th centuries as rural workers were drawn to new opportunities in industrial centers. It is often posited that the primary motivations for migration were economic (Whyte 2008), with individuals moving to seek upward socioeconomic mobility (Long 2005) or as a coping strategy during times of hardship (Kok, Mandemakers & Wals 2005). Temporary labor migration was also common (Kok 1997), whether as part of an age-structured pattern of life cycle service (Kussmaul 1981) or seasonal employment (Silvestre 2007).

It is also important to understand mobility within the context of individual life events such as marriage (Pooley & D’Cruze 1994). In Northwest Europe, including the Netherlands, marriage was primarily neo-local, meaning that both the bride and groom would move to establish a separate independent household at the time of marriage (Hajnal 1982). Indeed, distances between the birthplaces of spouses have been used to reconstruct Dutch marriage markets (Ekamper, van Poppel & Mandemakers 2011). Gender also shapes migration patterns, as men and women may undertake moves at different times and for different reasons. For instance, men may be more invested in long-distance labor migration (Brettell 1986) while women may be drawn to domestic work in cities (Bras 2003). Family and household composition also influence migration decisions, as they are important determinants of household strategies and economic fortunes. For example, the presence and activities of siblings has been shown to shape migration behavior in Belgium and the Netherlands (Bras and Neven 2007).

Climate, agriculture, and economy

Climate has been linked to economic crises in the past (Zhang et al. 2011). One of the ways climate affects the pre-modern economy is through the agricultural sector. Grain prices are closely associated with climatic conditions, although this relationship weakens as global markets develop (Holopainen, Rickard & Helama 2012). Grain prices, in turn, have been used as proxies for short-term economic stress, which has been shown to affect a variety of demographic outcomes, including mortality and fertility (Allen, Bengtsson & Dribe 2005; Bengtsson, Campbell & Lee 2004; Tsuya et al. 2010). Other climatic events, such as storms and flooding, may disrupt economic activity in addition to decreasing agricultural output. The Netherlands was particularly vulnerable to flooding (de Kraker 2006; de Moel et al. 2011) but also experienced significant droughts over the past century (Beersma & Buishand 2004).

Malthusian narratives, vulnerability, risk, and adaptation

In discussions of the relationships between climate variability and human migration in the modern world, Malthusian narratives of "climate refugees" are common and assume that these movements will be large-scale, long-distance, permanent, and concentrated among the poor (Myers 2002; Warner et al. 2009). However, contrary to these common assumptions, recent studies suggest that climate-linked movements are likely to be predominantly short-distance and temporary, and that long-distance migration can at times be reduced by climate shocks (Gray & Mueller 2012a & 2012b). These effects are consistent with theoretical perspectives on migration and climate adaptation that emphasize the many possibilities for *in situ* adaption and the many social and economic barriers to migration in low-resource settings (Gray & Mueller 2012b). Related theoretical perspectives combine climate change and migration literature to provide a broader context in which migration responses to climate conditions can be placed. For example, migration may be viewed as an adaptive response to climate conditions, in which individual- and household-level characteristics are important determinants of vulnerability to climate variation, as they contribute to both the risk of exposure to climate hazards and adaptive capacity, as well as economic decision-making and social capital (McLeman & Smit 2006). Migration as a response to environmental hazards varies by setting, type of hazard, and household traits, but climate can contribute to migration behavior, especially as it interacts with the drivers identified in migration theory, including cost-benefit analyses of moves, family strategies regarding risk management and resource allocation, and local "push and pull" factors (Hunter 2005).

Much like the climate-migration literature, many studies of historical populations use Malthusian perspectives as a starting point, but refine expected responses as more is learned about the role of individual- and household-level characteristics in determining responses to shocks or stressors. Work with aggregate economic (price or wage), mortality, and fertility data explore when and where the Malthusian responses to economic conditions operated in the past. Industrialization is sometimes viewed as the breaking point between a past characterized by demographic and economic stagnation and the period of modern economic growth and population expansion (Goldstone 1986; Wrigley & Schofield 1983), although the precise timing of this transition has been called into question (Clark 2005; Nicolini 2007).

However, some studies have failed to find consistent evidence for Malthusian relationships among living standards and vital rates from pre-modern Europe (Crafts & Mills 2009; Lee & Anderson 2002; Weir 1984). Rather, it appears that the relationships between economic conditions and demographic responses may vary by the specific mechanisms, length of period, and context examined (Reher & Ortega 2000). Studies using individual-level data have also added nuance to the Malthusian paradigm. For example, comparative research challenges claims that non-Western populations were more subject to exogenous pressure and presents a picture of complex demographic responses to short-term economic stress driven, in part, by human agency (Bengtsson, Campbell & Lee 2004; Tsuya et al. 2010). In the Netherlands, it has been demonstrated that among the very young and the elderly, short-term climate shocks, specifically hot or cold spells, resulted in increases in mortality (Ekamper et al. 2009, 2010). Mortality risks are elevated during hot spells through direct exposure to heat (hyperthermia) and indirect effects, such as the spread of infectious disease through contaminated water. In very cold conditions, direct exposure can contribute to arterial thrombosis, behavior changes (staying indoors) increase exposure to respiratory disease, psychological stress increases, and diet composition changes (fewer fruits and vegetables or lower total caloric intake). In addition to short-term shocks, the presence of some effects of climate variation, although often small, on both economic and demographic measures in both the short and long term has been demonstrated with historical data from the Netherlands (de Vries 1980). Even with a relatively advanced and diverse economy, individuals in the 19th and 20th century Netherlands were not completely sheltered from negative demographic responses to climate variability, so we might expect to observe migration responses to climate variation as well.

Despite the strong interest in the relationships between historical populations and the economy, few studies have used statistical methods to link migration responses to climate variation in the past, although some have examined long term, aggregate trends (Galloway 1986). A notable exception is a study of migration and environment in the US Great Plains that demonstrates that the relationships between the environment and migration at the county level can change and become “less Malthusian” over time as early migration in the Great Plains responded to Dust Bowl conditions, but later migration related more to recreation and lifestyle considerations (Gutmann et al. 2005). We significantly extend that study through the use of a large sample of individual-level data, and we do so over a 70-year period in which the Netherlands was experiencing dramatic demographic and economic change.

We expect the mobility of certain groups to be more sensitive, or at-risk in the Malthusian sense, to the effects of climate variation than others. Put in the terms of climate change theories, we expect variation in vulnerability to climate variation, as some groups will be at greater risk of experiencing negative climate conditions and groups will vary in their ability to adapt to changes in climate. For example, rural dwellers, whose livelihoods are more dependent on climate conditions, primarily through effects on agriculture, than urban dwellers, may be more likely to migrate after unfavorable climate shocks. Unmarried adults, who are less encumbered by family ties, can more easily respond to migration than married adults with children. The poor, who live closer to the margins of subsistence, may respond to unfavorable conditions through migration, provided that the move is not prohibitively costly.

The case of the Netherlands in the late 19th and early 20th centuries

The first half of the nineteenth century was a time of economic expansion and prosperity for Dutch farmers. Dairy farming grew and dairy products became an important export. Agricultural improvements and land reclamation increased agricultural productivity, which rivaled parts of England (Van Zanden 1994). Despite the Netherlands's status as one of the most urbanized European countries of the time, agriculture remained the largest single economic sector, with rye as the most important staple grain (De Vries & Van Der Woude 1997). This period of growth ended with the international agriculture crisis of 1878–1895, created by competition from imports from the United States and Canada (Bieleman 2010). The crisis affected the Netherlands by lowering grain prices and it contributed to the accelerated development of modern agricultural practices, such as mechanization and the adoption of new fertilizers (Van Zanden 1994). Aside from international competition, important risks to Dutch agriculture included flooding and soil subsidence. While some specialization in the agricultural sector was occurring, especially in dairy and export gardening, the majority of agricultural output relied on unspecialized household producers, although farm sizes began to increase by the end of the study period.

The nineteenth century Dutch economy was among the most advanced in Europe. Although agriculture was the largest sector, the Dutch economy was more diversified than that of most of its neighbors. In 1849, about 41% of the population worked in agriculture, while 32% were employed in industry and 16% in services, including trade and transport (De Vries & Van Der Woude 1997, p. 524). Only England's occupational structure had a comparable level of differentiation in this period. Regional variation in occupational structure was driven largely by variation in urbanization, with urban areas most heavily concentrated in Holland. Rural occupations also varied regionally, as different regions placed varying emphasis on pasturing and dairy, arable cultivation, and market gardening. Industrialization occurred later than in Britain, placing the Netherlands in the uncommon state of possessing an advanced and growing economy before widespread industrial production, a situation that some attribute to the development of Dutch mercantile capitalism (De Vries & Van Der Woude 1997). It has been argued that despite an advanced economy, adjustment to climate variability was not always possible, particularly in the short-run (De Vries & Van Der Woude 1997). However, as transportation networks improved around the turn of the century, the importance of local demand in determining economic growth declined (Van Zanden 1994).

During the study period, 1865–1937, urbanization increased and rural labor became less important, especially for women, as life cycle and agricultural service became less common (Bras 2003; Kok 1997). The Dutch population grew in this period as mortality decline outstripped fertility decline. The twin pressures of population growth and agricultural crisis drove rural out-migration from the late 1870s on, whereas before this time, inter-provincial migration was rare (Wintle 2000). Studies of Dutch migration in the late nineteenth and early twentieth century demonstrate that youth migration was common, especially among the unmarried, even while life cycle service declined (Adams, Kasakoff, & Kok 2002). This labor migration featured a seasonal component, as employers preferred to hire in May and, to a lesser extent, in November (Van Poppel 1995). Migration for marriage was also highly seasonal; May was a very popular month for weddings. Other work shows that migration in the Netherlands was not linked to social mobility as measured by occupational status. Instead, short-term, short-distance moves were an economic coping strategy, especially among poorer urban dwellers (Kok, Mandemakers & Wals 2005). Long-distance moves, in contrast, did not appear to be connected with economic deprivation. There is some evidence for a seasonal pattern in international migration, as data from international passenger shipping from 1899–1911 shows increased passenger flows out of Dutch ports in the third and fourth quarters (Deltas, Sciotte & Tomczak 2008). In this context of changing economic, demographic, and social conditions, migration responded to both individual and aggregate circumstances. Climate variability contributes to individual, household, and national economic prospects, as it affects agricultural output, food prices, and labor market conditions, but to date its role in migration during this period remains unclear.

Data

The Historical Sample of the Netherlands

The Historical Sample of the Netherlands (HSN)[1] is a random sample (0.25–0.75%, depending on birth cohort) of all people born in the Netherlands between 1812 and 1922 (Mandemakers 2002). There is slight oversampling in urban areas, such as Utrecht (Mandemakers 2000). A total of 78,105 individuals, identified in birth records, are included in the database. From this sample of births, 37,137 life courses have been reconstructed in this data release.[2] Standardized civil registration of births, deaths, and marriages in the Netherlands began in 1812. While the exact information varies by type of certificate, civil records typically include the name, age, occupation, literacy (can sign or not), place of birth, and marital status of individuals, as well as information on their spouse, parents, and witnesses. These certificates have been linked together to provide both static (birth date) and dynamic (marital status, occupation, place of residence) information. The state of data preservation in the Netherlands is excellent, as two copies of all certificates were made, one for local (municipal) officials and one for the province. Thus, nearly every civil record of birth, death, or marriage filed in the Netherlands remains available to researchers.

In addition to information gathered from certificates of birth, death, and marriage, the HSN has also collected, standardized, and linked all instances in which an individual was found in a population register, making it possible to draw upon all of these sources to reconstruct the life history of an individual. Population registers, begun in the Netherlands in 1850, are

[1]Historical Sample of the Netherlands (HSN) Data Set Life Courses Release 2010.01.

[2]The difference between the birth record sample and the sample of reconstructed life courses is attributable to the progress of record linkage in contents of this data release as well as loss to follow-up.

continuous records of households (and by the 1930s, individuals) and are the source of the dynamic data used in this study. Household (or population) registers record relationship to the household head, date and place of birth, sex, marital status, occupation, literacy, and religion. The date of entry and exit into the municipality is recorded, and all changes to the household are updated as they occur, usually within a month. Typically, these updates are dated, but in some instances the timing of the event must be inferred through the order of events or by crosschecking with vital registers. For example, if a household member died, their entry would be crossed out of the register and a note would record the date of death. If an individual moved out of the household, their entry would be crossed out and a note would detail when they left and sometimes the destination. New household members were added to the end of the household list, with notes about when and how they came to be in the household. Comparable systems of household registration were rare in the past (Mandemakers 2002) but are a valuable source of demographic data, as they combined many of the characteristics of vital registration (timing of events) and census data (household location and composition) in a longitudinal form, yet did not replace these types of record keeping. In most regions, a household register began during a census year and was updated until the next census year, after which the information was transferred to a new register book.

Household registers have several advantages over linked birth, death, and marriage records and linked census micro-data (see Campbell 2004 for a comparison of historical demographic data types). First, the continuous nature of population registers allows for more precise dating of events, such as entry and exit from a household, which improves data analysis, including the estimation of event-history models, which must be interval-censored in the case of linked decennial censuses. Continuous population registers also provide more information about the changing nature of household composition, much of which could not otherwise be observed between census years. Finally, population registers give some indication of the nature of entries and exits from the household. Thus, it is possible to know whether an individual exited the household because of death, marriage, or migration, while with linked census records, these distinctions may be inferred in only the best cases.

The population registers and civil records included in the HSN allow researchers to track individuals over the life course. With detailed information on moves into and out of households, this dataset is well suited to the study of migration in the past. In cases when the individual moved within the Netherlands, HSN researchers have found their subsequent entries in the population registers. Thus, it is possible to track the distance and the nature (rural-urban, etc.) of the move. If the individual leaves the Netherlands, it is typically noted in the register. In addition, the HSN database provides time-varying information on covariates relevant to the study of migration including occupation, marital status, fertility, and household composition.

Climate Data

To place these population movements in their environmental and economic contexts, time-varying data on precipitation, temperature, flooding, grain prices, and economic activity were derived from various sources. Monthly station data on precipitation for this time period is available from four locations (De Bilt, Den Helder, Groningen, and Hoofdorp) from the Royal Netherlands Meteorological Institute (KNMI 2013) and was aggregated to total annual rainfall (dL/year). Daily temperature data from five locations (De Bilt/Utrecht[3], Den Helder, Groningen, Maastricht, and Vlissingen) is also available for the study period from the same source. We have adjusted these values for the within-day time of measurement using the method developed by Ekamper et al. (2009; 2010). We aggregate adjusted values of average daily temperature to produce three annual measures: the mean annual temperature (°C), the number of days with an average temperature greater than 20 °C, and the number of days with an average temperature less than 0 °C. Individuals were linked to precipitation and temperature values from the closest weather station to their municipality of current residence[4]. The time series of precipitation and temperature, along with various forms of migration, are displayed in Figure 1.

To capture exposure to riverine flooding for a subsample of our study population, we extracted daily data on water levels from all river stations from the Dutch Ministry of Infrastructure and the Environment (Rijkswaterstaat 2013) that had data available for at least part of our study period. These data were aggregated to the annual scale by deriving the maximum water level in each year (in meters above Amsterdam baseline), capturing both flooding and persistent low flows due to upstream drought. Stations were linked to individuals based on co-location in the same municipality[5], and stations with less than 10 years of flood data or linked to less than 50 person-years of migration data were excluded, leaving 47 stations for our analysis. This creates a linked subsample of 27,215 person-years for which we observe riverine flooding over at least a three year period. To additionally capture exposure to coastal flooding for the full sample, we generate a dichotomous indicator variable for residence in a province that was affected by the severe coastal flooding in 1906 (a storm surge) and 1916 (a Zuiderzee flood) (Delta Works Online Foundation 2014; de Kraker 2006). Finally, to test whether the effects are mediated by agriculture, we extracted annual data over the study period at the national scale from Smits et al. (2000) on the price of rye and the size of the agricultural economy.

Analysis

Person-year Dataset

To investigate the influence of climate variation on migration, the HSN data were used to create a person-year dataset on both migrants and non-migrants[6]. The dataset contains time-varying and time-invariant variables at the individual, household, municipality, and national levels (Table 1). Each case represents a year in the life of a person at risk for migration. Non-climate predictors are lagged by one year to avoid endogeneity with the migration

[3]The station was located in the city of Utrecht until 1897 and then moved to the nearby village of De Bilt.

[4]The mean distance from municipality of residence to weather station was 48 km for rainfall stations and 44 km for temperature stations. The main results are robust to the exclusion of municipalities more than 50 km from a weather station.

[5]When data from two stations was available in the same municipality, we used data from the station that covered more years within our study period.

[6]Approximately 2.6 percent of moves occur during the same year as another move. Our person-year data does not account for this small percentage of instances in which individuals move more than once per year. These cases are coded the same as single moves per year, which are identified by a difference in location from the start of one year to the start of the next year. However, we believe that our choice of annual resolution does not overlook a significant amount of detail in migration.

decision. Following preliminary analyses (described below) and consistent with previous studies (e.g., Gray & Mueller 2012b), climate variables were averaged over a three-year period (*t* to *t*-2) to allow the potential for various time lags. Individuals age 15 and over are considered to be at risk for migration. Individuals that are no longer at risk for migration, such as those who have died, are lost to follow-up, or have moved to a different system of registration,[7] are right-censored. After exclusions for age and missing person-years, the dataset comprises 24,835 individuals at risk for migration during the study period, totaling 511,211 person-years of observation.

Consistent with common practice in this literature, migration is defined as a change of residence that crosses a municipal-level boundary, which is then decomposed into four mutually exclusive outcomes at the person-year scale[8]. Location was measured by linking household register data to a database of Dutch place names that contains the latitude and longitude of the centroids of municipalities (Huijsmans 2013), and the geodetic distance of each move was calculated between centroids. Short moves (N=12,240) are moves between municipalities, but less than 25 km in distance. Long moves (N=8,352) are moves between municipalities that are greater than 25 km in distance, which is roughly equivalent to crossing a provincial-level boundary. International moves (N=670) occur when an individual is noted in the register to have left the Netherlands for a foreign location. Attrition (N=5,895) occurs when an individual cannot be located in historical records, but without a corresponding change in registration system. Non-migration (N=484,054 person-years) includes individuals with a constant place of residence and those who moved, but remained within the same municipality.

Statistical Models

The data are analyzed using a multinomial, discrete-time event history model. This model is appropriate to examine a mutually exclusive set of competing risks using discrete measurements of time (Allison 1984). Multinomial outcomes include short moves (between municipalities and within 25 km), long moves (between municipalities and greater than 25 km), international moves, and attrition, while the reference category is non-migration. The log-odds of experiencing a migration event of type *r* relative to no migration (event *s*) are given by

$$\log\left(\frac{\pi_{rit}}{\pi_{sit}}\right)=\beta_r X_{it-1}+t+t^2$$

where π_{rit} are the odds of migration type *r* for individual *i* in year *t*; π_{sit} are the odds of no migration; X_{it-1} is a vector of predictor variables for individual *i* in year *t-1;* β_r is a vector of parameters for the effects of the independent variables on migration type *r*; and the

[7]The models specified in this paper include household-level variables. When individuals are transferred to a system of registration that does not include household information, such as personal rather than household cards, they are right-censored.
[8]We also explored alternative methods to decompose these moves, including into non-return and return moves (defined as having returned to a municipality inhabited in the last 10 years - approximately 20 percent of moves), and urban/rural migration, defined by whether the destination was urban or rural. These alternative definitions did not provide any insight beyond the main specification and are not presented here.

migration types, *r*, are short moves, long moves, international moves, and attrition. The parameters of this model are presented in exponentiated form (e^{β}) as odds ratios. The odds ratios can be interpreted as the multiplicative effects of a one-unit increase in the predictor variable on the odds of that type of migration relative to the odds of no migration. To account for the approximate scale of the measurement of the environmental variables, models including precipitation, temperature and coastal flooding are corrected for clustering at the province scale, whereas models including riverine flooding are clustered at the municipality scale (Huber 1981). To account for time-invariant spatial variation (such as in baseline climate), all models include province-level fixed effects, i.e. an indicator variable for each province. All models also include a non-linear (quadratic) time trend to account for gradual changes in the national context over time[9]. We extend this model by testing alternative specifications of the climate variables and estimating separate models by sex, age groups, residence in municipality of birth, occupational groups, rural/urban location, region, and period[10]. Control variables include social and economic factors that may influence migration behavior, including sex, age, marital status, household composition, occupation, and place of residence.

Results

Table 2 presents results for the main model and the riverine flooding model. Table 3 presents alternate specifications of the climate variables along with models estimated separately by selected sub-groups (controls not shown). We first discuss the climate variables in both the main model and alternate specifications. Then, we briefly discuss the results for the control variables.

Climate variation is a significant predictor of migration, with models including temperature, rainfall, and coastal flooding representing the best climate specifications using a joint F-test (Table 2 and 3, Models 1, 3, 4). Mean temperature in the preceding 3 years has a significant negative effect on short and international moves, with the odds of short moves decreasing by 7% with each 1 C° increase ($p = 0.052$) and the odds of international moves decreasing by 18% with each one-degree increase ($p = 0.020$) (Table 2, Model 1). Mean rainfall in the preceding 3 years has a negative significant effect on international migration, with the odds decreasing by 9% with each 1 dL increase ($p < 0.001$). Single-year specifications of temperature and rainfall (Table 3, Model 6) suggest that the effects of temperature extend over multiple yearly lags, supporting our use of a three-year average. A non-linear specification of temperature and rainfall (Table 3, Model 5) is compatible with the results of the models that include a three-year average: short moves are negatively associated with temperature, with odds ratios decreasing with increases in temperature, and international moves are negatively associated with rainfall. However, while international migration remains negatively associated with temperature in the non-linear model, the effects are not monotonic (Table 3, Model 5). Threshold models of the number of hot and cold days (Table

[9]As a robustness check, we also excluded the first and last three years of the time-series from the analysis, and were able to reproduce results very similar to those presented here.

[10]Occupational groups in the HSN were coded using the HISCO classification (van Leeuwen, Maas & Miles 2002). Urban locations are defined as towns with over 10,000 inhabitants and with less than 2.5 percent of the population employed in the agricultural sector in 1899 (Kooij 1985).

3, Model 4) indicate that long-distance moves are negatively associated with the number of hot days and international moves are positively associated with the number of cold days, although the sizes of both effects are small. Both coastal and riverine flooding are not significantly associated with migration (Table 3, Models 1, 2) and riverine flooding remains non-significant with nonlinear and multiple lag specifications (not shown). When controls for agricultural variables (rye price and agricultural GDP) are included in the model, the effect of temperature on short moves is no longer significant, but the effects of rainfall and temperature on international moves remain negative and significant (Table 4, Model 7). When the price of rye is high, both short- and long-distance moves increase, but international moves decrease. Agricultural GDP is positively associated with long-distance moves.

Examining various subpopulations separately reveals that temperature has stronger influence on the long-distance and international migration of rural dwellers than urban dwellers, rainfall is a significant predictor of short moves among rural dwellers but not urban dwellers, and rainfall is a stronger predictor of international moves among urban dwellers (Table 3, Models 16, 17). There are also differences in the effects of temperature and rainfall in two periods, 1865–1900 and 1901–1937 (Table 3, Models 20, 21). The effect of temperature on long-distance moves changes direction between the two periods, with long moves increasing with temperature in the early period, but decreasing with temperature in the later period. High temperatures reduce short-distance migration in the later period. Rainfall is a negative predictor of long and international moves in the early period and only international moves in the later period. Age groups and place of residence also have an effect on the relationship between climate variables and migration. Climate has a stronger influence on the migration of individuals over age 25 (Table 3, Models 10, 11). Individuals who still reside in the municipality of their birth respond more to climate fluctuations (Table 3, Models 12, 13). Residents of the non-Western portion of the country respond more strongly to temperature and rainfall than residents of the Western, coastal part of the country.

Attrition is associated with some climate variables in the alternate model specifications (Table 3). While some attrition is attributable to changes in record keeping, which is used as a right-censoring event in the person-year dataset, the other causes of attrition are unknown. The similarities between attrition and migration are a limitation of this study, but attrition is not associated with climate variables in our main specification (Table 2, Model 1).

With respect to the control variables (Table 2, Model 1), women are more likely than men to become short-distance movers, but are less likely to undertake long-distance or international moves. Age and marital status are important predictors of migration. The young and unmarried are more likely to make all types of moves, with the exception of international moves, which are more likely among young-middle aged adults (ages 20–39). Individuals in households headed by professional and white-collar workers are more likely to migrate over long distances than blue-collar and farm workers. Urban dwellers make more long-distance and international moves than rural dwellers, but fewer short-distance moves, although it should be noted that the most likely type of urban short-distance moves, moves within the same city, are not addressed in this study.

Discussion

Predictions derived from a Malthusian point of view posit that unfavorable climate variation affects migration by placing downward stress on living standards, which induces migration. These moves are likely to be of both long distance and duration, as “climate refugees” move in times of distress to seek improved environmental and economic conditions. Competing predictions, drawn from the climate and migration literature, suggest that resource-poor individuals may be stuck in place during unfavorable climate conditions, as they are unable to afford a move or lack the capital, both social and economic, to achieve their migration goals. In these cases, adaptations to climate conditions will occur *in situ*. Individuals with access to more resources may be better able to realize their migration preferences, whatever they might be.

This study provides partial support to both explanations of climate-related migration. In the case of short moves, the weak negative effect of temperature on migration is stronger for urban dwellers, older individuals (ages 25 and up), blue collar workers, and in the later (1901–1937) period. This effect disappears when controlling for rye price and agricultural GDP. Rye price is a positive, significant predictor of short moves, and in this cool climate, cold temperatures may affect yields (Maracchi et al. 2005; Supit et al. 2010) and therefore prices. Perhaps during times of high temperatures, high yields, and low prices, which are favorable economic conditions for those not participating in the agricultural sector such as urban dwellers, people are more likely to stay in place.

For longer, within-country moves, there are no overall effects of climate, but comparing alternative model specifications reveals important differences. In the earlier period (1865–1900), high temperature and low rainfall increased long-distance moves, while in the later period (1901–1937), the direction of these effects reverses. For rural dwellers, high temperatures decrease migration. These results are consistent with a migration transition (Zelinsky 1971) in which the constraints on long-distance migration declined over time. In the earlier period, migration increased with positive conditions (high temperature and low rainfall in this wet and cool climate) which may have enabled individuals to overcome steep barriers to long-distance moves. In the later period, long-distance migration declined with positive conditions (high temperature), suggesting that individuals were now more free to move and did so when conditions were poor. Thus, contrary to expectations, it appears that in some respects the long-distance migration system became “more Malthusian” over time, in that migration began to increase with negative conditions. The stronger negative effect of temperature for rural populations is consistent with their more direct dependence on agricultural production, and the existence of distress migration during periods of low temperature.

In the case of international migration, there is a strong, negative effect of extreme rainfall that is consistent across time, space, and social groups. There is a weaker negative effect of temperature that is less consistent across comparison groups. Unlike the case of short- and long-distance migration, neither of these effects appears to be mediated by agricultural conditions. We speculate that extreme rainfall is capturing the effects of local areal flooding, as distinct from riverine flooding driven by upstream rainfall or coastal flooding generated by coastal storms. Potentially, areal flooding disrupted both agricultural and non-agricultural livelihoods and transportation networks, leaving individuals stuck in place and unable to make international moves. The strength of this effect appears to weaken over time (odds ratio of 0.73 vs. 0.84), suggesting that people were increasingly able to overcome the negative effects of extreme rainfall. This distinct pattern for international moves likely reflects their high costs relative to internal moves.

The results on both coastal and riverine flooding suggest that these events do not have lasting effects on migration. Maximum river water level and the presence of coastal flooding in the province over the previous three years are not associated with migration. This is consistent with studies from other flood-prone regions, such as Bangladesh (Gray & Mueller 2012b) and Pakistan (Mueller et al. 2014). It may be that these local flooding events led to very short moves that could not be detected with this dataset, or that we are unable to measure flooding accurately using river water levels and coastal flooding events. Local areal flooding, caused by extreme rainfall, may be more disruptive than riverine and coastal flooding in this context. Perhaps individuals did not migrate, but rather adapted to coastal and riverine flooding *in situ*, rendering these events temporary and routine, while extreme rain and temperature events were more harmful to livelihoods, as we argue in the case of the effects of rainfall on international moves. The Dutch government’s commitment to building and improving flood control measures in response to flood events may have encouraged people to remain in place, despite experiencing a negative environmental shock. In addition, these events were rare (only two coastal flooding events occurred during the study period, in 1906 and 1916), so individuals may perceive the risk of future flooding as relatively low, which would contribute to the decision to remain in place.

While it is counter-intuitive that migrants responded to moderate variation in rainfall and temperature but not to disasters such as flooding, recent work with contemporary populations in Bangladesh, Pakistan and Indonesia finds similar results (Gray & Mueller 2012a & 2012b; Bohra-Mishra, Oppenheimer, & Hsiang 2014). A potential explanation is that disasters represent a short-term disruption that can be managed through temporary migration and/or short-distance moves, but that climatic variability represents a longer-term threat to livelihoods, thus leading to permanent and long-distance moves of the sort described here and in the studies cited above.

This study is consistent with prior work on predictors of migration in the HSN. The results for the control variables make sense in this social and historical context. For instance, we find that young, unmarried people are more likely to move than entire families or households and professionals and white collar workers are more likely to make long-distance moves than lower status workers are (Adams, Kasakoff, & Kok 2002; Bras 2003; Kok 1997; Kok 2004). The small effect sizes observed between climate measures and migration are consistent with other studies of climate and demographic or economic indicators in the past (Le Roy Ladurie 1988, de Vries 1980). Indeed, these authors suggest that the apparent scarcity of examples of large or long-term effects of climate on historical demographic events or economic time series speak to the ability of individuals and economies to adapt to climate conditions, even in the past, a view consistent with our results and the predictions drawn from the perspective of adaptive capacity. In addition, the small effect sizes observed in this study may be related to the agricultural context of the Low Countries, where harvest timing can vary by local context and is weakly correlated with temperature data (de Kraker & Ferandes 2013).

Limitations of this work include the significant association between climate variables and attrition in some alternate model specifications. The cause of this association is uncertain. This study also does not consider local, within-municipality moves, which are difficult to detect with the available data. These very short moves were common, especially among the poor in urban areas (Kok, Mandemakers, & Wals 2005). Therefore, our focus on moves between municipalities overlooks short, within-municipality moves, which may also respond to climate variability. Finally, despite the availability of a large amount of historical environmental data for our study period, we are nonetheless limited to the use of (1) a small number of weather stations, (2) a crude measure of coastal flooding, and (3) lack of riverine flooding data for most of our sample.

In the times of population growth, agricultural crisis, and modernization that characterize the Netherlands in the study period, not all migration types are associated with unfavorable climate conditions; only internal moves for certain social groups and in the later period appear to include distress migration. In fact, the ability of households to send international migrants seems to be constrained by resources, as extreme rainfall robustly and uniformly decreases international migration. These constraints are relaxed in times of more favorable climate. Thus the conventional narrative that negative climate shocks induce migration receives only partial support.

Instead, the results are more congruent with the concepts of migration transition, migration streams, and climate vulnerability. Consistent with a migration transition, as freedom of movement increased over time the ability of negative climate conditions to trap migrants in place appears to have declined, and migrants began to move more often during negative conditions. Despite the increasing ease of moves, important distinctions remained among migration streams, with internal moves more likely to be stimulated by low temperatures and international moves more likely to be disrupted by extreme rainfall, likely reflecting differences in the costs of the moves and the different populations at risk of each form of movement. The results also support the concept of climate vulnerability, with clear differences across demographic and regional groups in their response to climate variation. In conclusion, this study adds to the growing literature in historical demography that emphasizes variation and complexity in demographic responses to economic stress, especially when comparing population sub-groups and considering change in responses over time. These results are congruent with recent studies of contemporary populations, which have also found complex and counterintuitive effects of climate on migration (Dillon et al. 2011; Gray & Mueller 2012a & 2012b), and indicate that these patterns extend further into the past than has previously been documented.

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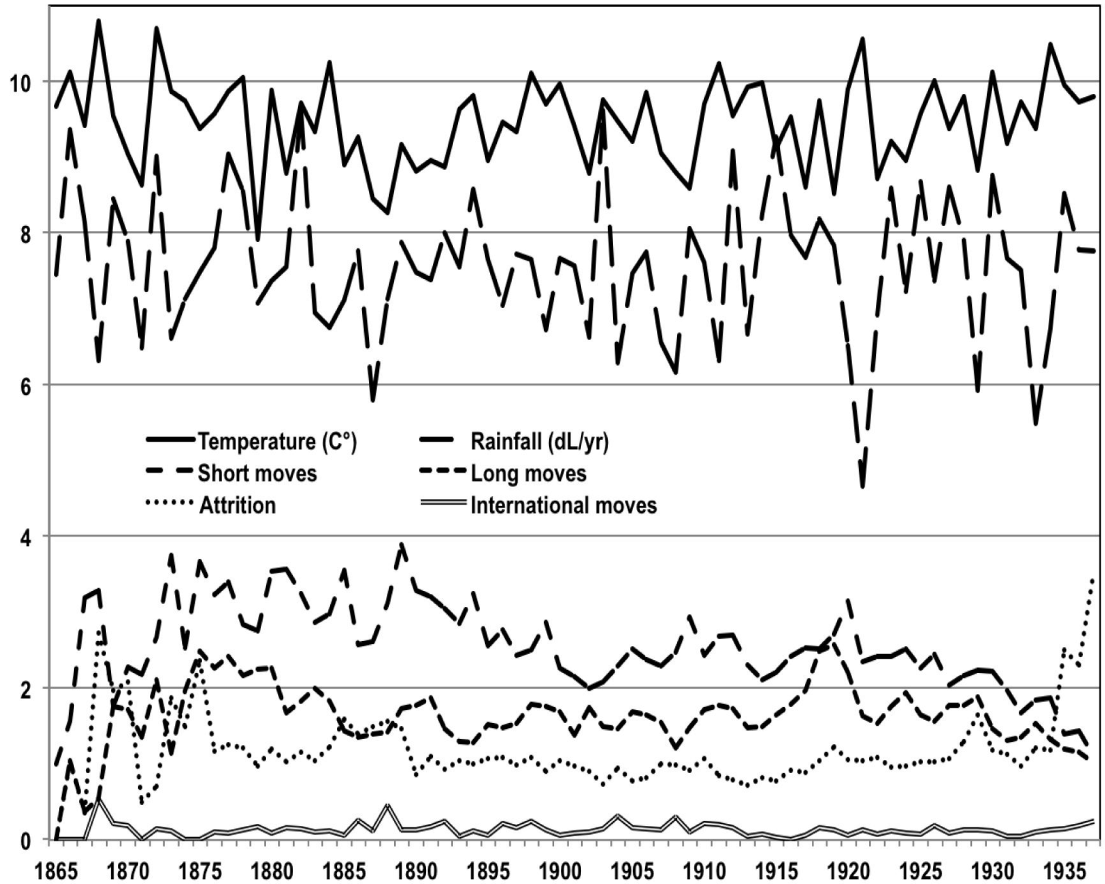

Figure 1.

Migration, temperature and rainfall in the Netherlands, 1865–1937.

Note: See Table 1 for definitions and text for data sources.

Table 1

Descriptive statistics for the person-year dataset.

Variable	Unit	Level	Time- varying	Mean	SD	Min	Max	Notes
Outcome								
Short move	0/1	Indiv	Yes	0.024	0.153	0	1	Different municipality but within 25 km in year t+1
Long move	0/1	Indiv	Yes	0.016	0.127	0	1	Different municipality and not within 25 km in year t+1
International move	0/1	Indiv	Yes	0.001	0.036	0	1	Outside of the Netherlands in year t+1
Attrition	0/1	Indiv	Yes	0.012	0.107	0	1	Missing location in year t+1
Climate variables								
Temperature	C°	Station	Yes	9.2	0.5	7.6	10.9	Mean daily temperature over previous 3 years
Hot days	#	Station	Yes	10.6	5.1	0.3	40.0	Days with mean temperature >20 C° over previous 3 years
Cold days	#	Station	Yes	25.6	8.0	5.7	52.7	Days with mean temperature <0 C° over previous 3 years
Rainfall	dm	Station	Yes	7.6	0.7	5.4	9.3	Mean annual rainfall over previous 3 years
Coastal flooding	0/1	Province	Yes	0.06	0.2	0.0	1.0	Presence of coastal flooding in previous 3 years
Riverine flooding	m	Muni	Yes	13.7	14.1	0.6	52.6	Maximum flood height over previous 3 years
Control variables								
Female	0/1	Indiv	No	0.50	0.50	0	1	Reference is male
Age 20–24	0/1	Indiv	Yes	0.19	0.39	0	1	Reference is age 15–19
Age 25–29	0/1	Indiv	Yes	0.16	0.37	0	1	Reference is age 15–19
Age 30–34	0/1	Indiv	Yes	0.14	0.35	0	1	Reference is age 15–19
Age 35–39	0/1	Indiv	Yes	0.12	0.32	0	1	Reference is age 15–19
Age 40–44	0/1	Indiv	Yes	0.10	0.29	0	1	Reference is age 15–19
Age 45–49	0/1	Indiv	Yes	0.07	0.26	0	1	Reference is age 15–19
Married	0/1	Indiv	Yes	0.33	0.47	0	1	Reference is not currently married (including widowed)
Marital status DK	0/1	Indiv	Yes	0.08	0.27	0	1	Reference is not currently married (including widowed)
Child of head	0/1	Indiv	Yes	0.39	0.49	0	1	Reference is household head or spouse
Other relation	0/1	Indiv	Yes	0.05	0.22	0	1	Reference is household head or spouse
Relation to head DK	0/1	Indiv	Yes	0.03	0.17	0	1	Reference is household head or spouse
Child present	0/1	Indiv	Yes	0.38	0.49	0	1	Biological child of this person is present in household
Place of birth	0/1	Indiv	Yes	0.60	0.49	0	1	Resident in municipality of birth
Catholic	0/1	Indiv	Yes	0.33	0.47	0	1	Reference is Protestant
Other religion	0/1	Indiv	Yes	0.07	0.25	0	1	Reference is Protestant

Variable	Unit	Level	Time- varying	Mean	SD	Min	Max	Notes
Religion DK	0/1	Indiv	Yes	0.02	0.15	0	1	Reference is Protestant
Female head	0/1	HH	Yes	0.13	0.33	0	1	Reference is male head
Gender of head DK	0/1	HH	Yes	0.00	0.03	0	1	Reference is male head
Age of head	years	HH	Yes	45.1	13.3	1	100	
Age of head DK	0/1	HH	Yes	0.00	0.03	0	1	
Adult males	#	HH	Yes	1.91	1.37	0	21	Males age 15+ in houshold
Adult females	#	HH	Yes	1.87	1.27	0	21	Females ages 15+ in household
Minors	#	HH	Yes	1.67	1.91	0	13	Males and females ages 0–14 in household
Professional	0/1	HH	Yes	0.06	0.24	0	1	Occupation of head, reference is blue collar
White collar	0/1	HH	Yes	0.17	0.38	0	1	Occupation of head, reference is blue collar
Farm	0/1	HH	Yes	0.18	0.38	0	1	Occupation of head, reference is blue collar
Occupation DK	0/1	HH	Yes	0.06	0.23	0	1	Occupation of head, reference is blue collar
Urban	0/1	Muni	Yes	0.42	0.49	0	1	Reference is rural
Rye price	fl./hl	Nation	Yes	8.8	4.2	4.8	26.4	Mean December price of rye over previous 3 years
Agricultural GDP	100 mill. fl.	Nation	Yes	4.2	1.0	2.7	6.3	Mean agricultural GDP over previous 3 years
Year	NA	Nation	Yes	1913	16	1865	1937	

N = 511,211 person-years (2,7215 for riverine flooding)

1/0 indicates a dichotomous variable; # indicates a count variable.

DK=Don’t know/missing value, Indiv = Individual, HH = Household, Muni=Municipality, Nation=National

Control variables also include indicators for the province of residence, not shown.

Table 2

Results from the multinomial event history model of migration (odds ratios and significance tests).

	Model 1				Model 2		
Predictor	Short move	Long move	Internationa	Attrition	Short move	Long move	Other
Temperature	0.93 *	0.97	0.82 *	1.04	-	-	-
Rainfall	1.00	1.01	0.82 ***	0.97	-	-	-
Coastal flooding	0.96	1.09	0.81	1.05	-	-	-
Riverine flooding	-	-	-	-	1.04	1.05	0.99
Female	1.11 ***	0.86 ***	0.69 *	1.00	1.23+	0.85	1.08
Age 20–24	0.94 +	1.12 ***	2.07 ***	1.37***	1.11	0.87	1.25
Age 25–29	0.74 ***	0.77 ***	2.10 ***	1.25***	0.89	0.46***	1.16
Age 30–34	0.42 ***	0.44 ***	1.41	0.91	0.48***	0.24***	0.92
Age 35–39	0.25 ***	0.25 ***	1.89 **	0.66***	0.30***	0.16***	0.71+
Age 40–44	0.17 ***	0.19 ***	0.90	0.54***	0.10***	0.08***	0.41*
Age 45–49	0.15 ***	0.12 ***	0.90	0.50***	0.12***	0.08***	0.27
Married	0.91	0.89	0.79 *	0.70***	0.66*	1.02	0.49
Marital status DK	1.09	1.18	1.01	1.25***	0.67	1.39*	1.21
Child of head	0.17 ***	0.15 ***	1.09	0.50***	0.12***	0.11***	0.47
Other relation	0.42 ***	0.36 ***	1.02	0.95	0.62*	0.31***	0.92
Relation to head DK	0.34 ***	0.30 ***	0.55 *	1.20	0.33***	0.26***	0.63
Child present	0.54 ***	0.46 ***	0.64 **	0.38***	0.56**	0.52***	0.44
Place of birth	0.42 ***	0.36 ***	0.85 **	0.69***	0.42***	0.32***	0.65
Catholic	0.94 *	0.92	1.20	0.95	1.03	0.99	0.99
Other religion	0.86 **	1.12	1.43 +	0.95	0.41**	1.58+	0.85
Religion DK	0.86 **	1.08	1.18	1.13	1.12	0.75	0.87
Female head	0.91 ***	0.95	1.25 *	1.07	0.86	0.90	0.90
Gender of head DK	0.46	0.26 *	1.34	1.26	0.00***	0.00***	1.48

	Model 1				Model 2		
Predictor	**Short move**	**Long move**	**Internationa**	**Attrition**	**Short move**	**Long move**	**Other**
Age of head	1.06 ***	1.08 ***	1.02	1.00	1.09**	1.07**	0.99
(Age of head)^2	1.00 ***	1.00 ***	1.00	1.00	1.00*	1.00	1.00
Age of head DK	2.56 ***	2.08 *	0.00 ***	1.87*	6.33***	2.28	3.01
Adult males	0.95 ***	0.92 ***	1.04	0.99	0.93	0.97	0.98
Adult females	0.94 ***	0.97 +	0.90 ***	0.94***	0.93	0.93*	1.06
Minors	0.98 *	0.96 **	1.00	1.01	0.97	0.93*	0.98
Professional	0.91	1.84 ***	2.15 ***	1.21***	1.13	1.64**	1.36
White collar	1.01	1.32 ***	0.98	1.00	1.17	1.22**	1.10
Farm	1.01	0.56 ***	0.89	0.85***	1.46	0.62*	0.74
Occupation DK	0.88 ***	1.23 ***	1.56 ***	1.06	0.88	1.36	1.19
Urban	0.43 ***	1.27 **	1.29 *	0.78**	0.48***	0.78+	1.16
Year	2.17 *	2.73 ***	1.05	0.04***	4.47	2.01	0.12*
(Year)^2	1.00 *	1.00 ***	1.00	1.00***	1.00	1.00	1.00*
Joint test	1140.4***				0.4		
Person-years	5,11,211				27,215		

Province indicators included but not shown.

The joint test is a Wald test of the three migration coefficients, excluding attrition, for the climate variables.

+ $p < 0.10$,

* $p < 0.05$,

** $p < 0.01$,

*** $p < 0.001$

Table 3

Results from the multinomial model with alternative specifications (odds ratios and significance tests).

Model	Predictor	Short move	Long move	International	Attrition	Joint test
3	Temperature	0.93^{+}	0.96	0.83^{*}	1.04	233.4^{***}
	Rainfall	1.00	1.01	0.81^{***}	0.97	
4	Hot days (>20 C°)	1.00	0.98^{***}	1.01	1.00	345.2^{***}
	Cold days (<0 C°)	1.00^{+}	1.00	1.01^{*}	1.00	
	Rainfall	1.00	1.00	0.82^{***}	0.97	
5	Temperature, second quartile	1.01	1.05	0.89	0.94^{*}	113.8^{***}
	Temperature, third quartile	0.96	0.94	0.73^{**}	0.96	
	Temperature, fourth quartile	0.91^{**}	1.02	0.87	1.16^{***}	
	Rainfall, second quartile	0.98	0.95	1.08	1.14^{+}	
	Rainfall, third quartile	0.97	0.99	0.81^{*}	0.98	
	Rainfall, fourth quartile	1.00	1.00	0.67^{***}	0.93	
6	Temperature, t	1.01	0.98	1.04	0.95^{**}	92.2^{***}
	Temperature, t-1	0.97^{+}	0.97	0.88^{+}	1.05^{+}	
	Temperature, t-2	0.96^{**}	1.00	0.93	1.04	
	Temperature, t-3	0.97	1.02	0.90	1.08^{**}	
	Temperature, t-4	1.00	1.07^{*}	1.01	0.98	
	Rainfall, t	1.00	0.98	0.89^{**}	0.99	
	Rainfall, t-1	1.00	1.02	0.95^{+}	1.00	
	Rainfall, t-2	1.00	1.00	0.95^{**}	1.00	
	Rainfall, t-3	1.02^{+}	1.01	0.98	0.98^{+}	
	Rainfall, t-4	1.02	1.00	0.90^{***}	0.97	
7	Temperature	0.97	1.06	0.78^{**}	0.99	179.7^{***}

Model	Predictor	Short move	Long move	International	Attrition	Joint test
	Rainfall	1.00	0.98	0.83***	1.00	
	Rye price	1.02 **	1.02***	0.98+	1.00	
	Agricultural GDP	1.05	1.33***	0.81	0.76**	
8	Temperature, women only	0.94 +	0.93	0.83	1.12*	153.6***
	Rainfall, women only	1.01	0.98	0.77***	1.00	
9	Temperature, men only	0.92	0.99	0.82+	0.96	39.9***
	Rainfall, men only	0.99	1.05	0.84***	0.95+	
10	Temperature, age<25 only	0.99	1.01	0.80	1.11*	22.8***
	Rainfall, age<25 only	1.00	1.05	0.75**	0.93**	
11	Temperature, age>=25 only	0.88 **	0.91	0.87	0.98	224.5***
	Rainfall, age>=25 only	1.00	0.97	0.87**	1.02	
12	Temperature, in birthplace	0.92 *	1.03	0.83	0.99	184.3***
	Rainfall, in birthplace	0.99	1.03	0.75***	0.97	
13	Temperature, out of birthplace	0.94	0.93	0.82	1.10+	25.5***
	Rainfall, out of birthplace	1.01	1.01	0.90+	0.98	
14	Temperature, blue collar only	0.93 *	1.01	0.81	1.06	64.8***
	Rainfall, blue collar only	1.00	1.00	0.75***	0.96*	
15	Temperature, other occupations	0.93	0.91	0.82	1.02	79.9***
	Rainfall, other occupations	1.00	1.02	0.87*	0.98	
16	Temperature, urban only	0.87 *	1.02	0.93	1.08	78.9***
	Rainfall, urban only	0.95	0.97	0.77***	0.98	
17	Temperature, rural only	0.94	0.89*	0.79+	1.05	72.2***

Model	Predictor	Short move	Long move	International	Attrition	Joint test
	Rainfall, rural only	1.03 +	1.05	0.86**	0.96	
18	Temperature, western region	0.93	1.03	0.77	1.08	2.6
	Rainfall, western region	0.97	0.95	0.84***	0.97	
19	Temperature, rest of country	0.89 **	0.89	0.92	1.03	47114.5***
	Rainfall, rest of country	1.01	1.08**	0.82**	0.98	
20	Temperature, 1865–1900	0.95	1.14*	0.85	1.13	64.2***
	Rainfall, 1865–1900	0.95	0.89***	0.73*	0.83***	
21	Temperature, 1901–1937	0.87 ***	0.88*	0.92	1.13*	308.0***
	Rainfall, 1901–1937	0.99	1.02	0.84***	0.99	

Models also includes control variables, not shown.

The joint test is a Wald test of the three migration coefficients, excluding attrition, for the climate variables. In quartile specifications, the first quartile is the reference category.

+ $p < 0.10$,

* $p < 0.05$,

** $p < 0.01$,

*** $p < 0.001$