Is internal migration a way to cope with weather extremes? Evidence from Egypt

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Abstract

Purpose – In this study, the authors examine the push and pull effects of extreme weather events on migration among governorates in Egypt.

Design/methodology/approach – To estimate the effect of extreme weather events on internal migration, the authors use migration gravity models and data from the 1996 and 2006 Population and Housing Censuses. The authors measure weather extremes by the number of months in the past 36 months with temperatures or precipitation of a governorate below the 5th percentile and above the 95th percentile of the distribution of monthly temperatures or precipitation of the corresponding governorate during the period 1900–2006.

Findings – This study's results suggest that high temperatures in the origin area act as a push factor. High-temperature extremes have a positive effect on out-migration. A 1% increase in the number of months with high-temperature extremes in the original governorate results in a 0.1% increase in the number of out-migrants.

Practical implications – The study suggests that people may respond to weather extremes through migration. However, climate migrants in Egypt may encounter several significant risks that authorities must address.

Originality/value – This study is one of the first attempts to measure the push and pull effect of weather extremes on migration in Egypt.

Keywords Climate change, Migration, Households, Population census, Egypt

Paper type Research paper

1. Introduction

There is a broad consensus that climate change has been and will be the biggest challenge for humankind. Both natural and human factors cause climate change, but it seems that human factors are becoming dominant (Stern, 2008). The increasing accumulation of carbon dioxide and other greenhouse gases leads to predictions of a rise in the mean global temperature between 2.3 and 4.1 °C over the next 100 years (Khandekar, 2010). The connection between extreme weather events and climate change is well documented (Hulme, 2014).

An important issue is whether migration constitutes a way to cope with extreme weather events. Human history suggests that climate change historically was associated with the

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JEL Classification — O15, Q54, R23

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massive displacement of populations. Several empirical studies find that drought and heat waves can increase out-migration from rural areas (e.g. Call and Gray, 2020; Nepal *et al.*, 2021; Epstein *et al.*, 2022), while Groger and Zylberberg (2015) find a positive effect of typhoons on labor migration. Understanding whether weather extremes push or pull migrants is vital for economic development. It provides informative insights for both policymakers and researchers regarding the role of migration in coping with climate change.

This study uses a gravity model to examine weather extremes' push and pull effects on inter-governorate migration in Egypt. The availability of data from the 1996 and 2006 Population and Housing Census allows us to estimate the extent to which extremes in temperature and precipitation impact migration between Egyptian governorates. We focus on inter-governorate migration in this study, since the censuses do not provide data on internal migration at a level smaller than governorates. Additionally, we assess whether these weather events impact different types of migration, such as work- and non-work related, as well as migration among individuals of different ages and education levels.

Our study contributes several aspects of environmental and development economics to the literature. Firstly, it provides empirical findings on the effect of climate change on migration in Egypt, which is an interesting case. Egypt is the largest country in the Arab world and has a high migration rate. In 2009, there were 6.5mn out-migrants from Egypt (Migration Policy Centre, 2013), and in 2010 the internal migration rate was around 6.5% (Herrera and Badr, 2012). Also, Egypt is vulnerable to global warming (World Bank, 2010). Hassan (2013) predicts that the Egyptian economy, especially the agricultural sector, will be more affected by climate change. Although there are several studies on migration in Egypt (e.g. Wodon *et al.*, 2014; Wahba, 2015), none of them investigate the impact of weather extremes on migration. Secondly, using a gravity model, this study examines both climate change's push and pull effects on migration. While most studies focus on the effect of extreme weather events on rural out-migration, we examine whether people consider weather when choosing a destination area. Thirdly, this study compares the effects of temperature and precipitation variation on different types of migration, including overall migration and migration of different population subgroups. Although the empirical analysis focuses on Egypt, the results are expected to be essential for a wider group of emerging and developing economies in the Arab world.

The paper is organized into six sections. Section 2 presents the theoretical framework and reviews the migration and climate change literature. Section 3 describes the data set and the descriptive analysis of migration and climate variations in Egypt. Sections 4 and 5 present the estimation method and the empirical results, respectively. Finally, Section 6 concludes the paper.

2. Theoretical framework and literature review

There are numerous studies of the impact of climate change on household welfare and the strategies employed by households to cope with climate change and extreme weather (Calzadilla *et al.*, 2013; Ngigi *et al.*, 2017; Issa *et al.*, 2023 and references therein). Relevant climate events include more frequent periods of extreme heat, more frequent periods of reduced precipitation and drought, floods and storms, and long-term changes in mean temperatures. Common strategies households employ to cope with climate change and weather extremes include using savings, selling assets or livestock, or asking for loans. Migration can also be used to address the problems of climate change and weather extremes and can be seen as an efficient way to diversify income and improve resilience.

Weather extreme events such as extreme heat, reduced precipitation, storms and long-term increases in mean temperature can deteriorate people's health and living standards (Barreca *et al.*, 2016; Karlsson and Ziebarth, 2018; Mullins and White, 2020; Zhao *et al.*, 2021). Migration can be considered a form of adaptation or failure to adapt to climate change. However, climate change's push and pull effects on migration are *a priori* unknown. There are several channels through which climate change might affect migration and labor mobility. Firstly, climate change results in weather shocks that can directly affect health. High temperatures cause discomfort and tiredness, reducing productivity and labor supply, especially among outdoor workers (e.g. Deryugina and Hsiang, 2014; Somanathan *et al.*, 2021). Hot temperatures are associated with cardiovascular, respiratory, cerebrovascular and blood cholesterol problems (Barreca *et al.*, 2016; Karlsson and Ziebarth, 2018; Mullins and White, 2020). Exposure to low temperatures also causes health problems (e.g. Deschenes and Moretti, 2009). Health problems can reduce or increase the probability of migration. The impact of climate change on migration depends on the intensity and vulnerability of the person exposed to the change.

Secondly, weather extremes can affect migration through the income effect. Extreme weather conditions can affect economic growth and reduce labor demand, causing high unemployment levels and pushing people to migrate. Agriculture workers are expected to be the most affected by climate change and extreme weather. Burgess *et al.* (2014) showed that excessive heat reduced agricultural income and increased mortality among the rural population in India. In contrast, they found that the income effect of climate change is weaker among people employed in the non-agricultural sector. Heal and Park (2013) suggest that excessive heat could reduce physical and cognitive abilities and labor productivity, especially in the agricultural sector. Mueller *et al.* (2014) found that high temperatures reduce labor productivity in the agricultural and other sectors by causing thermal stress on humans, and as a result, high temperatures push migration in Pakistan. Deryugina and Hsiang's (2014) study of the US case provides similar findings: the reduction in non-farm income caused by excessive temperatures equals one-fifth of the reduction caused to farm incomes. The negative effect of climate change on income and labor productivity can motivate both internal and international migration. For instance, Barrios *et al.* (2006), for Sub-Saharan African countries, find that a decline in rainfall leads to increased rural-to-urban migration.

Regarding the rainfall extremes, Sharon and Yang (2009) estimated the effect of high levels of rainfall in early life on Indonesian adults' health, education and socioeconomic outcomes. Human capital factors can influence how climate change affects the propensity for migration. Black *et al.* (2011) show that the migration from rural to urban areas is a popular strategy to cope with flooding in Bangladesh. Groger and Zylberberg (2015) found a positive effect of typhoons on labor migration in Vietnam.

Climate change and extreme weather are significant concerns, particularly for Middle East and North Africa (MENA) countries, vulnerable to environmental threats (Wodon *et al.*, 2014). Environmental hazards in the MENA region include seasonal temperature variability, lack of rainfall and water stress, deforestation and rising sea levels. In 50 years, the region is projected to experience a 2–3° temperature increase and a 10–30% decrease in precipitation (IPCC, 2014). Those climate threats affect agricultural activities in particular. Agriculture employs a large percentage of the labor force in some MENA countries such as Egypt. Reducing agricultural income and labor productivity can be a push factor for migration. Climate change and extreme weather can also act as pull factors: people migrate to urban areas where they are less vulnerable and less exposed to the impacts of climate change and where they will have more economic opportunities and better living standards. For instance, Wodon *et al.* (2014) studied the effects of climate change, extreme weather and environmental degradation in some MENA countries, including Egypt, and showed that they positively influence temporary and permanent migration.

3. Data sets and descriptive analysis

3.1 Data set

We exploit two main data sets. The first which is used to construct the migration variables is the Population and Housing Census of Egypt conducted by the Central Agency for Mobilization and Statistics (CAPMAS) in 1996 and 2006. The Egyptian Population and

Housing Censuses provide individual-level and household-level data. The individual-level section provides data on individual demography, education, employment, disability and migration. The household-level module provides data on housing conditions and facilities, and durables. In the present study, we focus on internal migration within Egypt.

For migrants, the censuses collected data on the previous governorate of residence before the move to the current governorate. The censuses also collected information on the year of the move. We do not consider international migration because we do not have information on the location of migrants in other countries. Using the information on the previous governorates of migrants, we compute the number of migrants from one governorate to another. We compute the flow of migrants for ten years before each census. With a total of 27 governorates in Egypt, each paired with 26 other governorates, and 20 years of data available from the two censuses, we obtained a total of 14,040 observations (governorate pairs) for this study.

The second source of data is information on climate change. Monthly temperature and precipitation data are available from Willmott and Matsuura (2015). This data set provides worldwide (terrestrial) monthly mean temperature and precipitation data at a relatively high resolution. We use geospatial software to compute governorate-level monthly temperatures and precipitation from 1900 to 2014.

3.2 Climate in Egypt

Egypt has a hot desert climate, where most areas are arid, except on the northern Mediterranean coast. Using climate data from Willmott and Matsuura (2015), we compute monthly precipitation and temperature at the Egyptian governorate level for the period 1900–2014. Panels A and B of Figure 1 depict the average monthly precipitation and temperatures from 1900 to 2014. The dots indicate the average monthly precipitation or temperature in a particular year. They are computed as the average across governorates and months (weighted by the surface area of the governorate). Figure 1 shows that temperatures were lowest in the 1970s and increased since then; in 2014, the average temperature was 23.6 ℃. Rainfall levels are low in Egypt and have tended to decrease in recent years.

Although average monthly temperature and precipitation are low, both show a high variation within a single year. Panels C and D of Figure 2 present the median monthly temperatures and precipitation over time. The estimates are averaged across years from 1900 to 2014 and across governorates. Temperatures are high, especially in July and August, and exceptionally high in the daytime in certain areas and can exceed 40 ℃ in cities and places located in the deserts of Egypt.

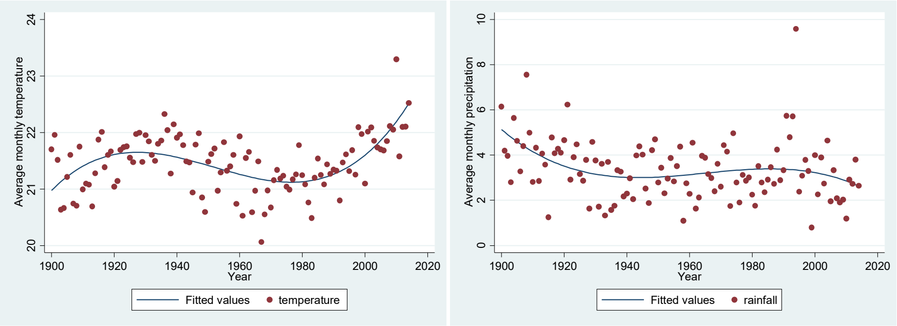
Figure 2 depicts the geographic variations in average monthly precipitation and temperatures computed from 1900 to 2014. Figure 3 shows a relatively large variation in monthly precipitation and temperature in Egypt. Northern governorates experience relatively lower temperatures and higher precipitation than southern governorates.

3.3 Internal migration in Egypt

This study uses the Egypt Population and Housing Censuses to estimate governorate migration flows. The 1996 and 2006 Egypt Population and Housing Censuses ask about individuals' migration status and current and previous governorates. Figure 3 shows that the percentages of internal migrants in 1996 and 2006 were 8.9 and 5.9, respectively. The rate of migrants across governorates was lower at 6.3% in 1996 and 5.4% in 2006. In this study, we measure migration flows in the past ten years before the census year so that migration rate estimates do not overlap between the 1996 and 2006 Egypt Population and Housing Censuses. The percentage of migrants during the past ten years (before the survey time) was lower than that of all the migrants. In the 2006 Egypt Population and Housing Census, 2.1% of the population had migrated across governorates during the previous ten years.

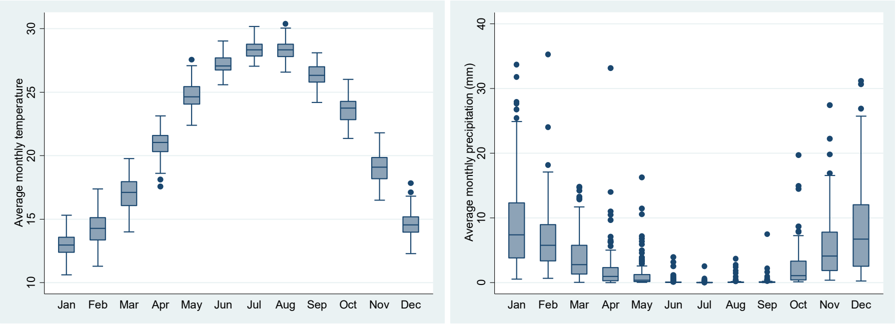
Panel A. Average monthly temperatures

Panel B. Average monthly precipitation



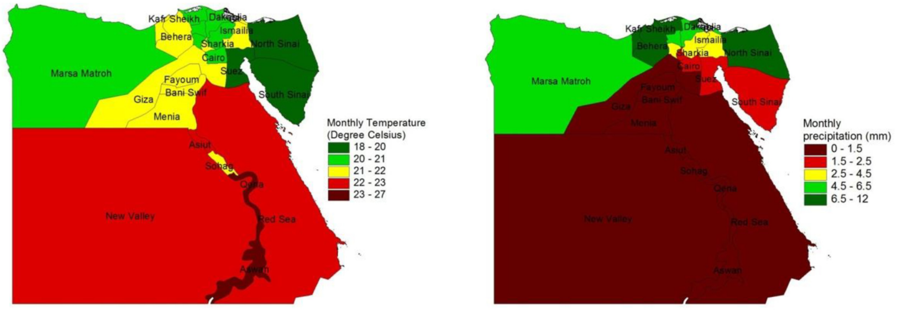
Panel C. Monthly temperatures

Panel D. Monthly precipitation



Source(s): Author’s estimation using climate data from Willmott and Matsuura (2015)

Figure 1.
Average monthly temperatures and precipitation over time



Average monthly temperatures

Average monthly precipitation

Source(s): Author’s estimation using climate data from Willmott and Matsuura (2015)

Figure 2.
Temperature and rainfall by governorates

Panels A and B of Figure 4 provide a mapping of the percentage of inter-governorate out-migration and in-migration in the ten years previous to 2006, taken from the 2006 Population and Housing Census. Cairo has the highest out-migration rate at 5.82%, and Marsa Matruh

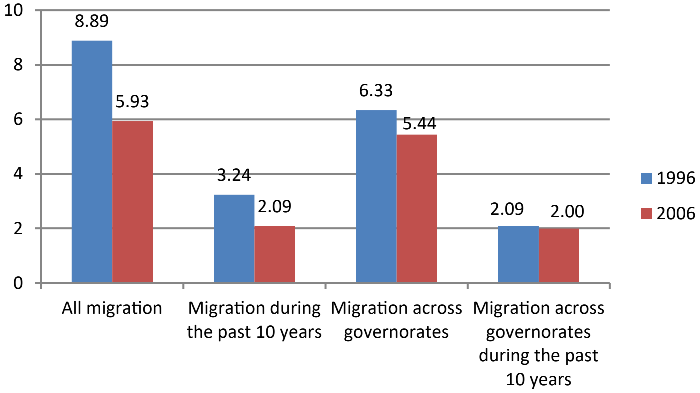
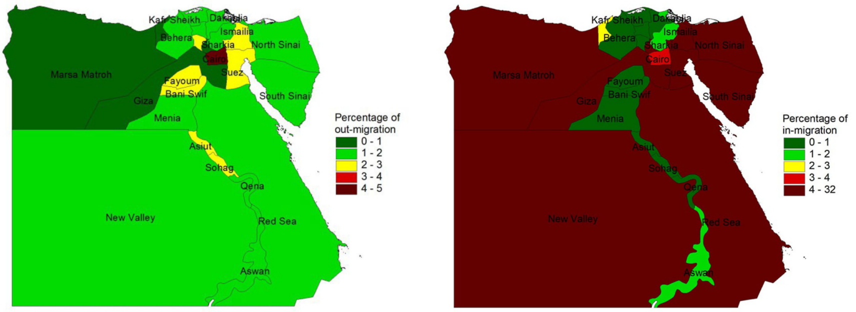
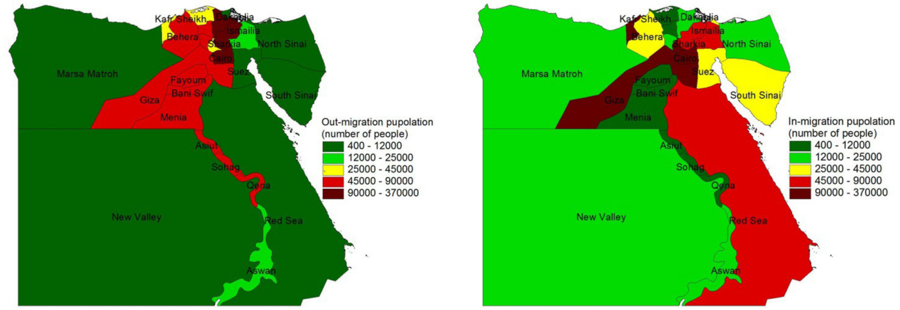


Figure 3.
Migration rates in Egypt

Source(s): Authors' estimation based on the 1996 and 2006 Egypt Population and Housing Censuses


Panel A. Percentage of out-migration population

Panel B. Percentage of in-migration population


Panel C. The numbers out-migrant population

Panel D. The numbers of the in-migrants population

Figure 4.
Out-migration and in-migration during the past ten years (1996–2006) across governorates in the 2006 population census

Source(s): Authors' estimate based on the 2006 Egypt Population and Housing Census has the lowest out-migration rate at 0.89%. The governorates with the highest in-migration rates are South Sinai, Suez and Port Said. Detailed estimates of migration rates and number of migrants are provided in Appendix Tables A1 and A2.

Although some governorates, such as Cairo, show low migration rates, they receive many migrants since their population is large. Panels C and D of Figure 4 present the numbers of out-migrants and in-migrants during the ten years previous to 2006 across governorates (estimated from the 2006 Population and Housing Census). It shows that Cairo had the highest number of both in-migrants and out-migrants.

4. Econometric method

A large number of economic and econometric models have been developed to examine the factors determining migration. Gravity migration models are widely used to model migration flow between geographic areas (Grogger and Hanson, 2011; Kim and Cohen, 2010; Nguyen, 2021). The initial gravity model was inspired by Newton's law of universal gravitation which states that any two objects attract each other with force proportional to their masses and inversely proportional to the squared distance between them. By extension, the migration gravity model posits that the migration flow between two distinct geographic locations is positively associated with their population size, geographic area and GDP and negatively associated with the distance between them. The basic gravity model can be expressed as follows:

$$M_{ij} = g\frac{P_{it}^{\alpha}P_{jt}^{\beta}}{D_{ij}^{\gamma}} \tag{1}$$

where M_{ijt} is the out-migration flow from governorate i to governorate j in year t (i and j could be any two geographic areas, but in our study, they are governorates). It is measured by the number of migrants from governorate i to governorate j in year t. P_{it} and P_{jt} are the respective population sizes in governorates i and j in year t; D_{ij} is the distance between the two governorates. Taking the log of both sides of Equation (1), we get:

$$\log\ (M_{ijt}) = \log(g) + \alpha\log(P_{it}) + \beta\log(P_{jt}) - \gamma\log(D_{ij}) \tag{2}$$

The censuses do not include information on districts or smaller administrative units than governorates. As a result, we are unable to analyze migration patterns between districts. We model the effect of weather extremes on migration across governorates. One empirical problem, which is expected, is that the dependent variable could be zero if there are no instances of migration between governorate pairs which does not allow logarithms. To address this problem, we use the log transformation (x+1).

In this study, we extend the basic model to include variables of weather extremes in governorates i and j. We also include time and pairwise governorate dummies. The full econometric model can be written as follows:

$$\log\ (M_{ijt}) = \alpha + \beta_1 C_{it} + \beta_2 C_{jt} + \gamma\log(D_{ij}) + X_{it}'\theta_1 + X_{jt}'\theta_2 + T_t\delta + u_{ij} + \varepsilon_{ijt}, \tag{3}$$

where C_{it} and C_{jt} are the variables measuring weather extremes of governorates i and j in year t, respectively; X is a vector of the control variables such as the logarithms of population size and other exogenous variables; T_t is the time dummies corresponding to the year of migration flow from governorate i to governorates j; errors include time-invariant, u_{ij}, and time-variant, ε_{ijt}. The time-invariant error term includes dummies for home and destination governorates.

Climate change's push and pull effects are measured by the coefficients β_1 and β_2. We expect that people will tend to move from governorates with extreme weather events to those without, so we expect $\beta_1 > 0$ that $\beta_2 < 0$ $\beta_2 > 0$.

In this study, we focus on assessing the impact of weather extremes on migration in general and different types of migration. We employ various measures for our dependent variable, including the overall outflow of migrants, the outflow of migrants for other reasons, the outflow of highly-educated and lowly-educated migrants, and the outflow of migrants categorized by age and gender. We classify highly-educated migrants as individuals who have completed a tertiary education degree, while lowly-educated migrants refer to those without such a degree. Table A3 in the Appendix presents summary statistics of dependent and independent variables in regressions.

The yearly climate variables can be endogenous. For example, people in hot or cold areas can adopt different livelihood strategies to adapt to the temperature. Thus, we focus on the effect of weather shocks or extremes, which are more exogenous. This captures unusually high or low levels of precipitation and temperature in the district-year-month (e.g. Deschenes *et al.*, 2009; Deschenes and Greenstone, 2011). More specifically, we measure climate shocks as the number of months in the past 36 months with temperatures or precipitation of a governorate below the 5th percentile and above the 95th percentile of the distribution of monthly temperatures or precipitation of the corresponding governorate during the period 1900–2006. We assess weather extremes by examining the frequency of months with extreme temperatures and precipitation over a 36-month period. This approach allows us to capture both these extremes' short-term and medium-term effects. Additionally, to verify the reliability of our findings and evaluate the short-term impact of weather extremes, we also analyze the occurrences over the past 12 months. Detailed results can be found in Tables A4 and A5, which are included in the Online Appendix.

We estimate model (3) using a pairwise governorate fixed effects regression. Time-invariant unobserved variables, u_{ij}, are controlled by governorate-fixed effects. Thus, we should be able to estimate the impact of weather events on inter-governorate migration without incurring bias.

5. Empirical results

Tables 1 and 2 present the regressions for the migration flow between governorates on weather extremes. In addition to climate variables, the explanatory variables include the basic gravity model variables, including the log of the distance between governorates, the log of governorate population and year dummies. Since we use the pairwise governorate fixed effects, the log of the distance between governorates is dropped. It should be noted that endogenous variables caused by treatment variables are not controlled for in impact evaluations (e.g. Angrist and Pischke, 2008). For example, although pre-migration income might substantially affect the migration decision, it should not be controlled since climate events can also affect it. Since most variables that can be affected by weather events should not be used, we employ very few control variables.

Table 1 presents the regression results for inter-governorate migration of all individuals. The signs of the population in both the origin and destination governorates are positive. However, the origin governorate population size is not statistically significant. The destination governorate population size is statistically significant at the 1% level. This means that people move to governorates with a large population. A 1% increase in the population of the destination governorate is associated with a 1.38% increase in the number of in-migrants (column 1 in Table 1).

Our main variables of interest are the extremes in temperature and precipitation of the original and destination governorates. We observe that only the high-temperature extreme of

Explanatory variables	Dependent variables Log of migration flow (1)	Log of migration flow of children (aged 0–15) (2)	Log of migration flow of young people (aged 16–30) (3)	Log of migration flow of middle-aged people (aged 31–60) (4)	Log of migration flow of older people (aged 60+) (5)	Log of migration flow of males (6)	Log of migration flow of females (7)
Log of population of origin governorates	0.0267 (0.1197)	−0.0085 (0.1041)	0.0394 (0.0904)	−0.0906 (0.0835)	−0.1330** (0.0454)	−0.1126 (0.1141)	0.0846 (0.0929)
Log of population of destination governorates	1.3826** (0.1497)	1.0434** (0.1822)	1.3853** (0.1521)	0.9262** (0.1449)	0.1276** (0.0448)	1.3099** (0.1496)	1.1856** (0.1556)
Origin: Number of months with low temperature	0.0002 (0.0168)	0.0090 (0.0157)	0.0024 (0.0161)	0.0067 (0.0160)	0.0014 (0.0088)	−0.0088 (0.0166)	0.0041 (0.0159)
Origin: Number of months with high temperature	0.0582** (0.0103)	0.0548** (0.0104)	0.0609** (0.0102)	0.0157 (0.0087)	0.0063 (0.0061)	0.0522** (0.0103)	0.0478** (0.0096)
Origin: Number of months with low precipitation	0.0035 (0.0048)	0.0014 (0.0049)	0.0089 (0.0048)	−0.0016 (0.0047)	−0.0037 (0.0028)	−0.0017 (0.0051)	0.0071 (0.0046)
Origin: Number of months with high precipitation	−0.0044 (0.0093)	−0.0265** (0.0101)	−0.0025 (0.0083)	−0.0090 (0.0086)	−0.0215** (0.0052)	−0.0057 (0.0097)	−0.0075 (0.0084)
Destination: Number of months with low temperature	−0.0162 (0.0173)	−0.0211 (0.0171)	−0.0223 (0.0158)	0.0194 (0.0146)	0.0126 (0.0087)	−0.0067 (0.0173)	−0.0102 (0.0157)
Destination: Number of months with high temperature	0.0157 (0.0100)	0.0067 (0.0109)	0.0227* (0.0093)	0.0190* (0.0090)	0.0065 (0.0055)	0.0293** (0.0099)	0.0032 (0.0096)
Destination: Number of months with low precipitation	−0.0020 (0.0049)	0.0036 (0.0045)	−0.0010 (0.0048)	0.0004 (0.0041)	0.0031 (0.0024)	−0.0018 (0.0048)	0.0038 (0.0044)
Destination: Number of months with high precipitation	0.0162 (0.0086)	0.0140 (0.0087)	0.0206* (0.0081)	−0.0015 (0.0080)	0.0071 (0.0049)	0.0189* (0.0088)	0.0110 (0.0082)
Pairwise governorate fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes

(*continued*)

Table 1. Regression of migration flows by age and gender

Table 1.

	Dependent variables						
Explanatory variables	Log of migration flow (1)	Log of migration flow of children (aged 0–15) (2)	Log of migration flow of young people (aged 16–30) (3)	Log of migration flow of middle-aged people (aged 31–60) (4)	Log of migration flow of older people (aged 60+) (5)	Log of migration flow of males (6)	Log of migration flow of females (7)
Constant	−17.5108**	−13.3961**	−18.3178**	−10.4448**	0.3688	−15.0555**	−16.1460**
	(2.8013)	(3.1158)	(2.5749)	(2.4724)	(1.0113)	(2.7994)	(2.6272)
Observations	14,040	14,040	14,040	14,040	14,040	14,040	14,040
R-squared	0.796	0.702	0.784	0.733	0.545	0.764	0.789

Note(s): Weather extremes are measured by the number of months with low or high temperatures/precipitation during the past 36 months. A temperature (and precipitation) value is defined as low if it is below the 5th percentile of the governorate-specific distribution over the 1900–2006 period. A temperature (and precipitation) value is defined as high if it is above the 95th percentile of the governorate-specific distribution over the 1900–2006 period

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

Robust standard errors in parentheses

Source(s): Authors' estimation based on the 1996 and 2006 Egypt Population and Housing Censuses and climate data

the original governorates affects migration between governorates. Other climate variables of the original and destination governorates have a minimal and insignificant effect on the probability of out-migration. An increase of one month of temperatures above the 95th percentile of the temperature distribution increases the number of out-migrants by 5.8%. Our finding is consistent with recent studies such as Call and Gray (2020), Epstein *et al.* (2022), and Issa *et al.* (2023), which also find that very high temperatures can push people to migrate to other areas.

It is important to note that we can calculate the elasticity of the migration flow with respect to the number of months with high-temperature extremes. The average number of months with high-temperature extremes over the past 36 months was 1.67. A one-month increase equals 59.7% of the average number of months with high-temperature extremes. Using this value, we can compute the elasticity of the migration flow concerning the number of months featuring high-temperature extremes, which is equal to 0.1, obtained by dividing 5.8 by 59.7. A 1% rise in the number of months with high-temperature extremes in the original governorate results in a 0.1% increase in the number of out-migrants.

Columns 2 to 5 of Table 2 present the regressions of the migration flow for different age groups: children (under 16 years), young people (aged 16 to 30), middle-aged people (31–60 years) and the elderly (over 60 years). The propensity for migration varies across age groups. The migration literature shows migration is more prevalent among younger individuals compared to older ones since the latter have a shorter period to obtain returns or benefit from migration. The shorter payoff period decreases the net gains to migration, reducing the migration probability (Borjas, 2005). The regression results show that high-temperature extremes positively and significantly affect the out-migration flow of children and young people. The effect estimates of high-temperature extremes on out-migrants older than 30 years are not statistically significant at the 5% level. Notably, individuals aged 16 to 30 displayed a higher propensity to move to governorates with high temperature and precipitation extremes. Probably, there is an out-migration flow from governorates experiencing high temperatures, leading to a shortage of laborers in those areas. Consequently, this labor shortage increases the in-migration of young workers to those areas.

The above finding for young people is similar to the finding for the migration of males. High-temperature extremes push both males and females to migrate to another area (columns 6 and 7 of Table 1). However, males are also likely to move to governorates with high

Table 2. Regression of migration flows by education and migration purpose

Explanatory variables	Dependent variables Log of the flow of lowly educated migrants (1)	Log of the flow of highly educated migrants (2)	Log of the flow of work migrants (3)	Log of the flow of family migrants (4)	Log of the flow of marriage migrants (5)	Log of the flow of migrants of other purposes (6)
Log of population of origin governorates	0.2542* (0.1139)	−0.4476** (0.0822)	−0.1767 (0.0919)	0.0160 (0.1014)	0.1365 (0.0791)	−0.4003** (0.0840)
Log of population of destination governorates	1.0740** (0.1700)	1.3013** (0.1855)	1.2193** (0.1586)	0.9595** (0.1646)	1.1032** (0.1563)	1.1694** (0.1974)
Origin: Number of months with low temperature	−0.0192 (0.0170)	0.0562** (0.0151)	0.0463** (0.0158)	0.0017 (0.0175)	0.0141 (0.0142)	−0.0216 (0.0140)
Origin: Number of months with high temperature	0.0615** (0.0109)	0.0325** (0.0091)	0.0483** (0.0093)	0.0501** (0.0103)	0.0345** (0.0085)	0.0333** (0.0090)
Origin: Number of months with low precipitation	0.0016 (0.0050)	0.0134** (0.0046)	0.0012 (0.0046)	−0.0056 (0.0051)	0.0091* (0.0040)	0.0103* (0.0046)
Origin: Number of months with high precipitation	−0.0042 (0.0097)	−0.0029 (0.0076)	−0.0138 (0.0088)	−0.0163 (0.0102)	−0.0075 (0.0074)	−0.0077 (0.0079)
Destination: Number of months with low temperature	−0.0323 (0.0178)	0.0259 (0.0139)	−0.0129 (0.0149)	−0.0219 (0.0181)	−0.0051 (0.0140)	0.0321* (0.0149)
Destination: Number of months with high temperature	0.0227* (0.0093)	0.0071 (0.0104)	0.0196* (0.0094)	0.0025 (0.0109)	0.0115 (0.0081)	0.0193 (0.0098)
Destination: Number of months with low precipitation	−0.0013 (0.0049)	0.0054 (0.0043)	0.0008 (0.0041)	0.0007 (0.0048)	0.0050 (0.0037)	0.0026 (0.0043)
Destination: Number of months with high precipitation	0.0240** (0.0090)	0.0018 (0.0079)	0.0165* (0.0073)	0.0076 (0.0093)	0.0152 (0.0081)	0.0152 (0.0082)
Pairwise governorate fixed effects	Yes	Yes	Yes	Yes	Yes	Yes

(*continued*)

	Dependent variables					
Explanatory variables	Log of the flow of lowly educated migrants (1)	Log of the flow of highly educated migrants (2)	Log of the flow of work migrants (3)	Log of the flow of family migrants (4)	Log of the flow of marriage migrants (5)	Log of the flow of migrants of other purposes (6)
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Constant	−16.5540**	−11.1808**	−13.4439**	−12.1007**	−16.4049**	−10.2201**
	(3.0542)	(2.8673)	(2.6718)	(2.8869)	(2.5096)	(2.9991)
Observations	14,040	14,040	14,040	14,040	14,040	14,040
R-squared	0.773	0.724	0.754	0.735	0.779	0.667

Note(s): Weather extremes are measured by the number of months with low or high temperatures/precipitation during the past 36 months. A temperature (and precipitation) value is defined as low if it is below the 5th percentile of the governorate-specific distribution over the 1900–2006 period. A temperature (and precipitation) value is defined as high if it is above the 95th percentile of the governorate-specific distribution over the 1900–2006 period

$^{**}p < 0.01$, $^{*}p < 0.05$

Robust standard errors in parentheses

Source(s): Authors' estimation based on the 1996 and 2006 Egypt Population and Housing Censuses and climate data

Table 2.

temperatures and precipitation. An increase of one month with the average temperature above the 95th percentile of the temperature distribution increases the number of male migrants by 2.9% (column 6). Similarly, high precipitation extremes yield a corresponding estimate of 1.9% (column 7).

In Table 2, we examine the effect of weather extremes on the log of lowly- and highly-educated migrants and the log of migration flows for different purposes. The migration literature suggests that more highly educated individuals have better information and employment opportunities and are more likely to migrate than less educated people (e.g. Faggian *et al.*, 2007; Herrera and Badr, 2012). In the case of Egypt, Herrera and Badr (2012) show that people with high secondary education are the most likely to migrate, followed by those with post-secondary education. Column 1 of Table 2 shows that the effect of weather extremes on lowly-educated people is similar to that of weather extremes on young people. High-temperature extremes of the original governorates increase the out-migration of lowly-educated people, but high temperature and precipitation extremes also induce in-migration of lowly-educated people. This pattern is similar to the effect of weather extremes on work migration (column 3 of Table 2). The impact of climate events on better-educated individuals is similar to the effect on the overall population. People tend to move from governorates with high temperatures. However, we also find that low temperature and precipitation extremes also cause out-migration of highly-educated people.

Table 2 reports the estimates for the effect of weather events on migration for different reasons. There were no significant differences in the effect of weather events on different types of migration. Very high temperatures cause more migration for work, family and marriage reasons.

6. Conclusion

There is growing concern about climate change and extreme weather events, and how people are coping with these phenomena is attracting the attention of both researchers and policymakers. The present study used migration gravity models to examine the effect of extreme weather events on migration in Egypt. We find that high-temperature extremes cause people to migrate. An additional month of high-temperature extremes during the past 36 months increases the number of out-migrants by 5.8%. The elasticity of out-migration concerning the number of months with high-temperature extremes is estimated at 0.1. It means that a 1% increase in the number of months with high-temperature extremes in the original governorates leads to a 0.1% increase in the number of out-migrants. We also find that high temperature and precipitation extremes increase the in-migration of young and low-educated people.

Our study suggests that people may respond to weather extremes through migration. However, climate migrants in Egypt may encounter several significant risks that authorities must address. Firstly, the costs associated with migration, such as travel, food and housing, can be exorbitant. Since migrants often leave rural areas, this can result in their families facing a worsened financial situation. Secondly, we have observed that young and less educated individuals tend to relocate to areas characterized by high temperatures and precipitation extremes. Consequently, the working and housing conditions for these migrants can be inferior to those of non-migrants. Addressing this issue requires the government's support in facilitating access to public services. Thirdly, migration due to climate-related reasons might have a detrimental social impact on the family members left behind. Consequently, they risk being trapped in adverse circumstances with limited coping strategies.

References

Angrist, J.D. and Pischke, J.S. (2008), *Mostly Harmless Econometrics: An Empiricist's Companion*, Princeton University Press, Princeton, New Jersey.

Barreca, A., Clay, K., Deschenes, O., Greenstone, M. and Shapiro, J.S. (2016), "Adapting to climate change: the remarkable decline in the US temperature-mortality relationship over the twentieth century", *Journal of Political Economy*, Vol. 124 No. 1, pp. 105-159, doi: 10.1086/684582.

Barrios, S., Bertinelli, L. and Strobl, E. (2006), "Climatic change and rural-urban migration: the case of Sub-Saharan Africa", *Journal of Urban Economics*, Vol. 60 No. 3, pp. 357-371, doi: 10.1016/j.jue.2006.04.005.

Black, R., Bennett, S.R., Thomas, S.M. and Beddington, J.R. (2011), "Climate change: migration as adaptation", *Nature*, Vol. 478 No. 7370, pp. 447-449, doi: 10.1038/478477a.

Borjas, G.J. (2005), *Labor Economics*, 3rd ed., McGraw Hill/Irwin, New York.

Burgess, R., Deschenes, O., Donaldson, D. and Greenstone, M. (2014), *The Unequal Effects of Weather and Climate Change: Evidence from Mortality in India*, Massachusetts Institute of Technology, Department of Economics, Cambridge. Manuscript.

Call, M. and Gray, C. (2020), "Climate anomalies, land degradation, and rural out-migration in Uganda", *Population and Environment*, Vol. 41 No. 4, pp. 507-528, doi: 10.1007/s11111-020-00349-3.

Calzadilla, A., Zhu, T., Rehdanz, K., Tol, R. and Ringler, C. (2013), "Economywide impacts of climate change on agriculture in Sub-Saharan Africa", *Ecological Economics*, Vol. 93, pp. 150-165, doi: 10.1016/j.ecolecon.2013.05.006.

Deryugina, T. and Hsiang, S. (2014), "Does the environment still matter? Daily temperature and income in the United States", NBER Working Paper No. 20750, NBER.

Deschenes, O. and Greenstone, M. (2011), "Climate change, mortality, and adaptation: evidence from annual fluctuations in weather in the US", *American Economic Journal: Applied Economics*, Vol. 3 No. 4, pp. 152-185, doi: 10.1257/app.3.4.152.

Deschenes, O., Greenstone, M. and Guryan, J. (2009), "Climate change and birth weight", *American Economic Review*, Vol. 99 No. 2, pp. 211-217.

Deschenes, O. and Moretti, E. (2009), “Extreme weather events, mortality and migration”, *Review of Economics and Statistics*, Vol. 91 No. 4, pp. 659-681, doi: 10.1162/rest.91.4.659.

Epstein, A., Treleaven, E., Ghimire, D.J. and Diamond-Smith, N. (2022), “Drought and migration: an analysis of the effects of drought on temporary labor and return migration from a migrant-sending area in Nepal”, *Population and Environment*, Vol. 44 Nos 3-4, pp. 145-167, doi: 10.1007/s11111-022-00406-z.

Faggian, A., McCann, P. and Sheppard, S. (2007), “Human capital, higher education and graduate migration: an analysis of Scottish and Welsh students”, *Urban Studies*, Vol. 44 No. 13, pp. 2511-2528, 10.1080/00420980701667177.

Groger, A. and Zylberberg, Y. (2015), “Internal labor migration as a shock coping strategy: evidence from a typhoon”, *American Economic Journal: Applied Economics*, Vol. 8 No. 2, pp. 123-153, doi: 10.1257/app.20140362.

Grogger, J. and Hanson, G.H. (2011), “Income maximization and the selection and sorting of international migrants”, *Journal of Development Economics*, Vol. 95 No. 1, pp. 42-57, doi: 10.1016/j.jdeveco.2010.06.003.

Hassan, K.E. (2013), “Impacts of future climate change on Egyptian population”, *Proceedings of the XXVII IUSSP International Population Conference*, Busan, pp. 26-31.

Heal, G. and Park, J. (2013), “Feeling the heat: temperature, physiology & the wealth of nations”, NBER Working Paper No. 19725, NBER.

Herrera, S. and Badr, K. (2012), “Internal migration in Egypt levels, determinants, wages, and likelihood of employment”, Policy Research Working Paper No. 6166, The World Bank.

Hulme, M. (2014), “Attributing weather extremes to ‘climate change’ a review”, *Progress in Physical Geography*, Vol. 38 No. 4, pp. 499-511, doi: 10.1177/0309133314538644.

IPCC (2014), “Fifth assessment report of intergovernmental panel on climate change”, available at: https://www.ipcc.ch/report/ar5/ (accessed 15 August 2015).

Karlsson, M. and Ziebarth, N.R. (2018), “Population health effects and health-related costs of extreme temperatures: comprehensive evidence from Germany”, *Journal of Environmental Economics and Management*, Vol. 91, pp. 93-117, doi: 10.1016/j.jeem.2018.06.004.

Khandekar, M. (2010), “Global warming, glacier melt and sea level rise: new perspectives”, in Harris, S.A. (Ed.), *Global Warming*, available at: http://www.intechopen.com/books/global-warming/global-warming-glacier-melt-sea-level-rise-new-perspectives

Kim, K. and Cohen, J.E. (2010), “Determinants of international migration flows to and from industrialized countries: a panel data approach beyond gravity”, *International Migration Review*, Vol. 44 No. 4, pp. 899-932, doi: 10.1111/j.1747-7379.2010.00830.x.

Migration Policy Centre (2013), “Migartion profile: Egypt”, Migration Policy Centre, available at: http://www.migrationpolicycentre.eu/docs/migration_profiles/Egypt.pdf

Mueller, V., Gray, C. and Kosec, K. (2014), “Heat stress increases long-term human migration in rural Pakistan”, *Nature Climate Change*, Vol. 4 No. 4, pp. 182-185, doi: 10.1038/nclimate2103.

Mullins, J.T. and White, C. (2020), “Can access to health care mitigate the effects of temperature on mortality?”, *Journal of Public Economics*, Vol. 191, 104259, doi: 10.1016/j.jpubeco.2020.104259.

Nepal, S., Tripathi, S. and Adhikari, H. (2021), “Geospatial approach to the risk assessment of climate-induced disasters (drought and erosion) and impacts on out-migration in Nepal”, *International Journal of Disaster Risk Reduction*, Vol. 59, 102241, doi: 10.1016/j.ijdrr.2021.102241.

Ngigi, M., Mueller, U. and Birner, R. (2017), “Adaptation strategies and participation in group-based approaches: an intra-household analysis from rural Kenya”, *Ecological Economics*, Vol. 138, pp. 99-108, doi: 10.1016/j.ecolecon.2017.03.019.

Nguyen, C.V. (2021), “Do weather extremes induce people to move? Evidence from Vietnam”, *Economic Analysis and Policy*, Vol. 69, pp. 118-141, doi: 10.1016/j.eap.2020.11.009.

Sharon, M. and Yang, D. (2009), “Under the weather: health, schooling, and economic consequences of early-life rainfall”, *American Economic Review*, Vol. 99 No. 3, pp. 1006-1026, doi: 10.1257/aer.99.3.1006.

Somanathan, E., Somanathan, R., Sudarshan, A. and Tewari, M. (2021), “The impact of temperature on productivity and labor supply: evidence from Indian manufacturing”, *Journal of Political Economy*, Vol. 129 No. 6, pp. 1797-1827, doi: 10.1086/713733.

Stern, N. (2008), “The economics of climate change”, *American Economic Review*, Vol. 98 No. 2, pp. 1-37, doi: 10.1257/aer.98.2.1.

Wahba, J. (2015), “Selection, selection, selection: the impact of return migration”, *Journal of Population Economics*, Vol. 28 No. 3, pp. 535-563, doi: 10.1007/s00148-015-0541-4.

Willmott, C.J. and Matsuura, K. (2015), “Terrestrial air temperature and precipitation: monthly and annual time series (1950-2014)”, available at: http://climate.geog.udel.edu

Wodon, Q., Burger, N., Grant, A. and Liverani, A. (2014), “Climate change, migration, and adaptation in the MENA region”, in Wodon, Q., Liverani, A., Joseph, G. and Bougnoux, N. (Eds), *Climate Change and Migration: Evidence from the Middle East and North Africa*, World Bank, Washington, DC.

World Bank (2010), *World Development Report 2010: development and climate change*, The World Bank, Washington, DC.

Zhao, Q., Guo, Y., Ye, T., Gasparrini, A., Tong, S., Overcenco, A., Urban, A., Schneider, A., Entezari, A., Vicedo-Cabrera, A.M., Zanobetti, A., Analitis, A., Zeka, A., Tobias, A., Nunes, B., Alahmad, B., Armstrong, B., Forsberg, B., Pan, S.C., Íñiguez, C., Ameling, C., De la Cruz Valencia, C., Åström, C., Houthuijs, D., Dung, D.V., Royé, D., Indermitte, E., Lavigne, E., Mayvaneh, F., Acquaotta, F., de’Donato, F., Di Ruscio, F., Sera, F., Carrasco-Escobar, G., Kan, H., Orru, H., Kim, H., Holobaca, I.H., Kyselý, J., Madureira, J., Schwartz, J., Jaakkola, J.J.K., Katsouyanni, K., Hurtado Diaz, M., Ragettli, M.S., Hashizume, M., Pascal, M., de Sousa Zanotti Stagliorio Coélho, M., Valdés Ortega, N., Ryti, N., Scovronick, N., Michelozzi, P., Matus Correa, P., Goodman, P., Nascimento Saldiva, P.H., Abrutzky, R., Osorio, S., Rao, S., Fratianni, S., Dang, T.N., Colistro, V., Huber, V., Lee, W., Seposo, X., Honda, Y., Bell, M.L. and Li, S. (2021), “Global, regional, and national burden of mortality associated with non-optimal ambient temperatures from 2000 to 2019: a three-stage modelling study”, *The Lancet Planetary Health*, Vol. 5 No. 7, pp. e415-e425, doi: 10.1016/s2542-5196(21)00081-4.

Online appendix

The supplementary material for this article can be found online.

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