Environmental Shocks and the Decision to Migrate

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Abstract

Climate change will affect many aspects of societies and economic production. Some places will become less productive and attractive places to live, while others will become more attractive. Using microlevel census data for three countries in West Africa, Burkina Faso, Ghana, and Senegal, I estimate the change in migration patterns in response to climatic shocks. In addition to focusing only on the two most commonly used climate variables, temperature and precipitation, I also consider the effects of dust exposure on relocation decisions. In order to address measurement concerns that can introduce endogeneity to the dust response, I instrument dust exposure using long-range transported dust from a major source in the Sahara Desert. The use of individual-level data allows for the inclusion of a rich set of fixed effects and individual characteristics, as well as precisely localized climate shocks. Exposure to higher temperatures decreases emigration from the poorest countries, while also decreasing the rates of regional migration within these countries. This suggests that households desiring to migrate face moving costs that they are unable to overcome when agricultural production declines. Precipitation has small effects compared to temperature, with increases in precipitation decreasing emigration rates across countries. Dust exposure appears to have little influence on migration rates, contrasting with previous literature documenting migration responses to particulate matter concentrations in other contexts. Taken together, the results indicate that migration responses in low-income places may not be available to alleviate climate-induced strains.

1 Introduction

Humans are constantly looking for ways to adapt to their environment. While societies tend to be resilient to environmental shocks, over time, people will tend to leave the place experiencing negative shocks to seek opportunities elsewhere. Societies dependent on subsistence agriculture are particularly likely to see strong reactions, as in this case, there may be little that can be done other than to move to another location.

Dust storms are an important source of shocks to agricultural and total economic production in West Africa, and therefore they may be expected to lead to changes in decisions of where people locate. This is in addition to other shocks that will be affected by climate change, namely changes in temperature and precipitation. Previous work has established that temperature has important consequences for economic growth (Dell et al., 2009), as well as implications for other social outcomes, such as civil conflict (Miguel et al., 2004).

This study utilizes long-range transported dust to identify the effect that dust storms have on human migration across West Africa. Reanalysis dust data is combined with microlevel census data to provide accurate estimates of household dust exposure, as well as follow these households when they migrate to shed light on their decision-making in response to environmental shocks.

There is recent evidence that dust storms have been a driving force for migration in the past. In the Dust Bowl in the United States, migrants stopped looking to the plains as an attractive destination (Long and Siu, 2016). The government incentivized farmers to use more sustainable farming practices that protected land against erosion. Trees were also planted in order to prevent further erosion. These policies, combined with the end of extreme drought, decreased the frequency and intensity of dust storms, as well as reduced the potential damage that could be done. However, regions bordering on the world's largest deserts cannot necessarily adapt in the same way. Intense dust storms will continue regardless of mitigation efforts, but given that there are significant human consequences of these storms, these societies potentially have incentives make costly investments to reduce the damage. This could take the form of migration, moving to areas less affected by dust storms.

Adaptation to environmental threats has received greater attention recently, but is still not well understood. It is clear that individuals and countries with higher levels of income have more adaptation possibilities and show reduced effects from environmental risks, but the mechanisms by which this occurs have not been well explored. There is also evidence that urbanization is helping to mitigate damages from climate change, but it is often hard to differentiate between adaptation resulting from urbanization and adaptation resulting from income increases, as urban areas are often places with higher incomes. (Kahn, 2016)

Human migration is one adaptation mechanism that has the potential to completely cancel out the negative effects on economic production. If everyone could move to a location with a climate similar to the one they experienced prior to climate change, there is little reason to believe economic opportunity would be harmed. Hsiang and Sobel (2016) estimate that in order to achieve this, many people in the tropics will need to move very long distances, and that population densities in the subtropics would steeply increase. This work begins to indicate that these population movements will be difficult to achieve, but it also ignores the fact that the people who may want to move the most in response to a changing climate, may in fact be restricted from doing so by the changing climate itself.

This paper closely relates to the literature on migration responses to climate shocks, and this work is summarized in a review by Klaiber (2014). The studies in this field typically consider the income effect from a climate shock and its effects on the decision to migrate (Feng et al., 2012; Saldaña-Zorrilla and Sandberg, 2009). More recent studies have shed light on the types of people who are induced to migrate in response to a shock, finding that middle income countries are more likely to see emigration due to a negative shock than either low or high income countries (Cattaneo and Peri, 2016). This suggests that the decision to migrate could be a combination of expected or actual productivity associated with the climate of a location, as well as the means of people to actually migrate.

Millock (2015) reviews the broader literature around the environment and migration, considering both climate shocks as well as responses to natural disasters. Hornbeck (2012) and Long and Siu (2016) consider migration to the Dust Bowl in the United States. These papers find that families' locational choices responded to the damage caused by the Dust Bowl. However, even in this case, the environmental shock was mostly in refraining from relocating to impacted areas, rather than leading to a mass exodus of these places. Chen et al. (2017) finds that exposure to particulate matter increases out-migration from provinces in China using thermal inversions to construct plausibly exogenous changes in air pollution. The current study sheds light on this question using a similar strategy in a different context, and finds that air pollution due to dust storms does not strongly affect migration patterns.

The issue of environmental migration is also highly relevant to policy debates around the world. The concept of environmental refugees has been recently active in both policy and academic debates. Asylum claims in Europe have been shown to be responsive to climate shocks that affect crop yields (Missirian and Schlenker, 2017). Beine and Parsons (2017) argue that natural disasters have differing effects across different income levels, by largely deterring emigration, but encouraging emigration from middle-income countries to former colonial powers. The complex interactions between the climate and social factors makes this a particularly important topic in the climate impact space.

Dust storms can have meaningful income shocks and can also affect crop yields (Birjandi-Feriz and Yousefi, 2018). Given this income shock, it could be expected that increased dust exposure could lead to similar effects as increased exposure to higher temperatures. Prior analyses have also concentrated on country-level data, which could be masking both the influence that the environment has on within-country migration, and subnational differences in how populations respond to shocks. Using census data from West African countries allows a deeper study of the environmental factors that affect individual migration decisions.

I find that dust exposure does not affect the decision to migrate, either within-country or across countries. Higher temperatures are associated with increased within-country migration, at least in a middle-income context. Higher temperatures and higher levels of precipitation are associated with lower levels of cross-country migration. This result is driven by the lowest-income countries, where there is also some evidence that dust shocks can reduce emigration. This is broadly consistent with other evidence, however also presents a puzzle. I present more evidence that increased precipitation can decrease emigration rates from low-income places. This would seem to contradict the hypothesis that negative income shocks decrease emigration from low-income places. However, this depends on the effects that precipitation has on income. While generally more precipitation is associated with higher incomes, the results here could potentially be driven by extremes or correlations with other weather events. More work would need to be done to disentangle these different possible explanations.

2 Data

The dust data comes from the Modern-Era Retrospective Reanalysis for Research and Applications, Version 2. (Randles et al., 2017) The advantage is that the data covers 1980-present every day for a $0.5° \times 0.625°$ grid. This allows for fine-scale analysis of whether dust storms are migration at a regional scale, and can provide data on days with extreme dust events. This data can be matched up to regions and countries by using all pixels for which the center of the pixel is part of the region or country. At the country level, the dust values are population-weighted using the Gridded Population of the World, version 4. The regional dust values are simply area-weighted, since most of the regions are relatively small. Temperature data also comes from MERRA-2. Precipitation comes from the Climatic Research Unit at the University of East Anglia. (Climatic Research Unit, 2013)

Data on migration comes from the Integrated Public Use Microdata Series-International (IPUMS-International) at the Minnesota Population Center. This data combines records from the public use subsamples from national censuses. The data consists of between 1 and 10 percent of the national population for each country. An important note about the census data is that the collection intends to count everyone in the country at a particular point in time. This means that not everyone counted will be a permanent resident in the place they are counted. This means that workers who spend e.g. a season in one place for work could be classified as a migrant for the purpose of this study. While this could lead to over-estimation of the number of migrants, it can be thought of as capturing both temporary and permanent migrants. To the extent that the timing of the census is effectively random within the year, this data will be capturing all types of population flows between different places, and the results can be thought of in that context. However, for my purposes here, I will refer to someone who reports being in a location different than their residence at some past point in time as being a “migrant.”

The IPUMS census data is available for seven West African countries. While it is fairly comprehensive, the data are not always collected at even intervals, for example Ghana has census data for 1984, 2000, and 2010. However, the dates of collection are not influenced by climate variables, so this should not impact the results of the analysis. This data includes number of years residing in the current location, as well as data on region of previous residence for those that have moved in the past 1 or 5 years.

For the country-level analysis, I focus on migrants to Mali and Senegal, as these countries record the year that the migrant into these countries entered. This allows me to create a panel of emigration from 20 West African countries from 1980-2009.

To explore within-country migration patterns, I focus on Burkina Faso, Ghana, and Senegal. These countries ask as part of their censuses about the region of residence within the country either one or five years ago. This analysis will inherently be limited to migrants from these countries who remained in these countries. I will not be able to estimate a total emigration rate from these regions, as some migrants will undoubtedly move to a different country. Missing these emigrants will likely lead to an underestimation of the environmental effects on migration decisions. However, to the extent that destinations do not vary over time in response to environmental shocks, this should not significantly impact the results.

3 Empirical Results

3.1 International Migration

The approach largely follows that of Cattaneo and Peri (2016), who develop a model of workers of different skills who choose to migrate across country categories of low-, middle-, and high-income. The main implication of the model is that middle-income countries will see an increase in emigration in response to higher temperatures, whereas low-income countries will see a decrease. This is due to emigration becoming infeasible for people in the poorest countries when they experience a negative productivity shock. Since an increase in dust exposure generally mirrors that of a temperature shock, we could expect to see the same general patterns.

The regression specification is adapted from Cattaneo and Peri (2016) Equation 10, with slight modification. Namely, temperature and precipitation enter linearly, rather than logarithmically to be consistent with other work considering weather effects on output. In addition, I also consider the effects of climate variables in the destination, as this could also affect an individual's decision to relocate.

I first consider cross-country migration. Compared to within-country regional migration, this is on average a more extreme form of adaptation to local conditions, as it requires leaving one's home country to seek out better opportunities. It likely has larger costs, meaning that the barriers to international migration will be more often prohibitively costly to low-income households. This is where the Cattaneo and Peri (2016) model is particularly relevant. The regression takes the following form:

$$Y_{ijt} = \beta_O D_{it} + \psi_O T_{it} + \eta_O P_{it} + \beta_D D_{jt} + \psi_D T_{jt} + \eta_D P_{jt} + \phi_{ij} + \alpha_t + \epsilon_{ijt} \tag{1}$$

where Y_{ijt} is the migration rate from country i to country j in year t. D_{it} and D_{jt} are the population-weighted mean dust exposure in year t in origin countries i and j. These values will be instrumented for using predicted dust transport from the Bodele Depression. The ϕ_{ij} are country pair fixed effects which capture time-invariant characteristics that affect the overall emigration rate from one country to another. These are allowed to be asymmetric, i.e. in general $\phi_{ij} \neq \phi_{ji}$. The T_{it}, T_{jt}, P_{it}, and P_{jt} are the population-weighted temperature and precipitation at the origin and destination countries. The α_t are year fixed effects to account for common time-varying shocks.

One important modeling decision is whether to include either dust exposure or weather variables from the destination country. One could expect that if a person or household decides to migrate away from a location due to a fluctuation in dust exposure, that person may be interested in knowing that where they move to will not be subject to the same fluctuations. However, the feasibility of making decisions with this information is dependent upon the existence of communication networks. While these effects have not been extensively modeled in the literature, they may be an important part of the migration decisions.

The results of equation 1 are shown in Table 1. Precipitation at the origin country decreases the probability of migrating to a given country, while an increase in dust exposure and temperature in the destination country also decreases the migration probability. Also interesting is that an increase in temperature in the origin country seems to have some small effects in increasing migration, but they are not statistically significant. Dust exposure at the origin is also estimated to decrease migration, but the effects are very imprecisely estimated. It is possible that since the dust shocks across countries will be correlated, the estimates in this context are somewhat less precise.

These results are broadly consistent with the idea that a negative shock in a country will induce migration to other countries, and does not support the liquidity constraint story. While these countries are relatively poor compared to the rest of the world, it may be that the liquidity constraint story has become less important in recent years as these countries have increased their incomes. It is also apparent that conditions in the destination country matter nearly as much as at the origin. This is likely because of communication networks transmitting information about conditions in different places.

VARIABLES	(1) Migration rate	(2) Migration rate	(3) Migration rate
Dust exposure, Origin	-96.316	9.767	-419.850***
	(539.966)	(587.125)	(85.662)
Dust exposure, Destination	-87.727	-114.318	-13.407
	(190.967)	(196.306)	(18.301)
Precipitation, Destination	-455.731***	-729.985***	-701.113***
	(159.651)	(159.506)	(99.865)
Temperature, Destination	27.125	-49.782	-221.110***
	(303.868)	(303.894)	(72.475)
Precipitation, Origin	-760.803***	-370.494***	-997.206
	(6.459)	(94.523)	(944.957)
Temperature, Origin	-959.162	-970.627	-608.589
	(1,534.384)	(1,576.651)	(974.434)
Observations	34	34	34
R-squared	0.807	0.814	0.844
Origin FE	X	X	X
Destination FE	X	X	X
First stage F-stat	49.13	61.93	1398
Year trend		X	
Country-year trend			X

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 1: Change in number of migrants per million population at the country level.

To investigate the timing of the effects, I also include leads and lags of the variables of interest as follows:

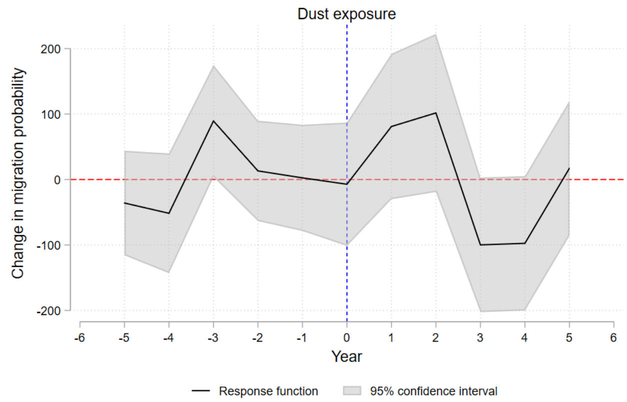

Figure 1: Migration response to a 1 standard deviation increase in dust over the dry season in year 0.

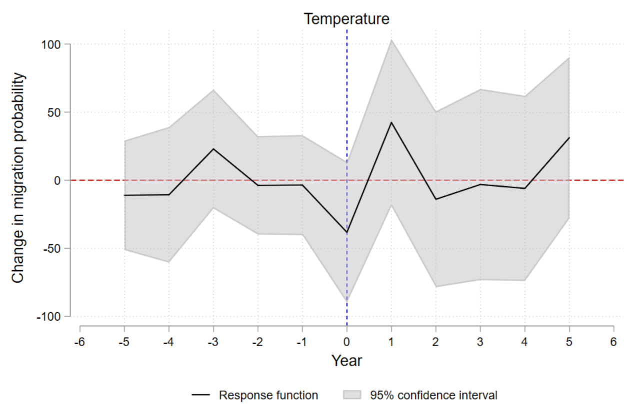

Figure 2: Migration response to a 1 standard deviation increase in temperature in year 0.

$$Y_{ijt} = \sum_{l=-5}^{5} [\beta_l D_{it-l} + \psi_l T_{it-l} + \eta_l P_{it-l}] + \phi_{ij} + \alpha_t + \epsilon_{ijt} \tag{2}$$

The results of equation 2 are shown in Figures 1-3. Consistent with the estimation of the contemporary effect, dust seems to have no effect, while both temperature and precipitation have an immediate negative effect on migration rates. The coefficients on the lagged climate variables tend to be positive, indicating that migration again increases afterwards, although for precipitation these effects are smaller than the contemporaneous effect and not statistically significant, which means that migration in total is likely to be affected by climate shocks.

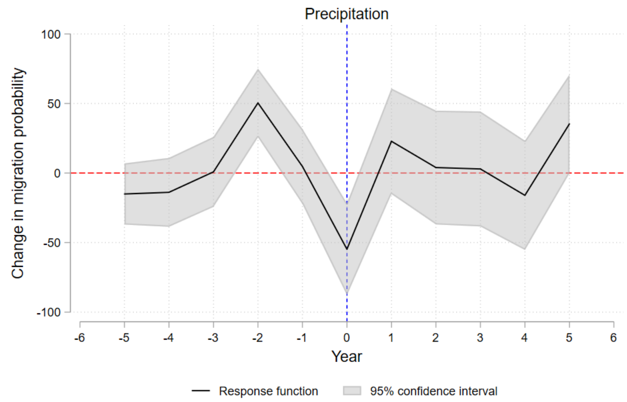

Figure 3: Migration response to a 1 standard deviation increase in precipitation in year 0.

3.2 Regional Migration

While international migration is clearly important, both because it signals a high level of desire to move and because it has potentially large social implications, regional migration within countries is the dominant form of population movements. The Roy-Borjas model employed in Cattaneo and Peri (2016) cannot resolve whether the anticipated sign of a negative shock will be the same or different for regional migration as for international migration (Roy, 1951; Borjas, 1987). Because the cost of movement will be lower, local migration could substitute for international migration when income is low. However, if incomes are low enough, any migration may be infeasible.

To determine the effect that environmental shocks have on regional migration, regressions take the following form:

$$Y_{it} = \psi T_{r(i)t} + \eta P_{r(i)t} + \alpha_t + \epsilon_{it} \tag{3}$$

where Y_{it} is an indicator for whether individual i moved across a region boundary in time period t. The temperature and precipitation values are all defined for $r(i)$, the origin region. Precipitation is measured as the average 6-month Standardized Precipitation Index (SPI). I also include origin region fixed effects, $\phi_{r(i)}$. The effect of a dust shock was also attempted to be included in this analysis, however the first stage regression is too weak to implement the two stage procedure. Given that dust shocks were not found to significantly influence international migration, it is also unlikely that dust exposure will have a significant effect on regional migration. I run this regression separately for the three countries where I have data. This allows for differential responses across countries, which can be expected, given the earlier discussion of income effects. The main specification does not include either destination or origin region fixed effects, as this absorbs nearly all of the variation.

	(1)	(2)	(3)
VARIABLES	Ghana	Senegal	Burkina Faso
Temperature	-0.002	0.041	0.000
	(0.005)	(0.024)	(0.003)
SPI	-0.088***	-0.139	-0.005
	(0.023)	(0.233)	(0.010)
Observations	1,612,174	1,272,466	3,123,562
R-squared	0.001	0.011	0.001
Year FE	X	X	X

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 2: Change in migration probability for migration across regions within the country. Columns are for Ghana, Senegal, and Burkina Faso. Standard errors are clustered at the region level.

The results of the main specification are shown in Table 2. Across all 3 countries, the effect of SPI is negative, meaning that an increase in precipitation reduces the propensity to migrate across regions within each country, though the effect is only statistically significant in the case of Ghana. The temperature effects are mixed and quite small, indicating that these effects are less important. Rainfall is likely the main driver of agricultural productivity in this region, and so as incomes increase, the need to move across regions decreases.

One limitation of this analysis is that if an individual decides to migrate across country borders, they will not be counted in this analysis, since in order to be included, you must be in the country at time of survey and at the previous time (1 or 5 years prior to the survey). Because Senegal and Burkina Faso are geographically small, it may be that the returns to crossing a country border are higher than crossing only a regional border, and the costs may be similar. These regressions also do not account for the conditions at the destination, which are likely to be even more important in this context, as the origin and destinations

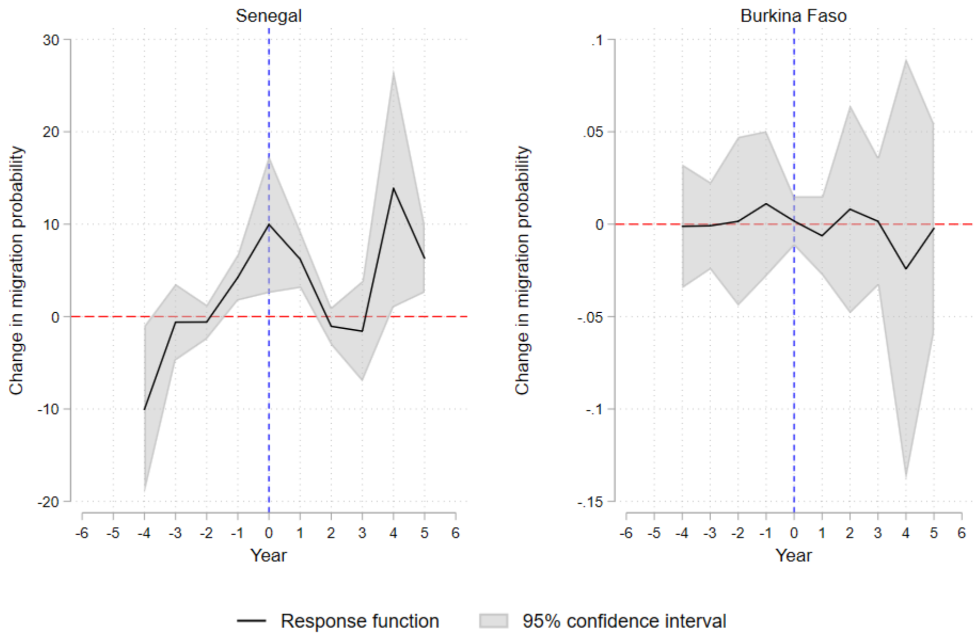

Figure 4: Migration response to a 1 standard deviation increase in temperature in year 0.

are closer together, meaning information flows are expected to be even better than for the international migration analysis.

The timing of the effects are again explored, estimated using the following regression:

$$Y_{it} = \sum_{l=-5}^{5} [\psi_l T_{r(i)t-l} + \eta_l P_{r(i)t-l}] + \epsilon_{it} \tag{4}$$

This equation can only be estimated for Senegal and Burkina Faso, as there is not enough variation in Ghana to estimate the number of parameters required. The results are shown in Figures 4 and 5.

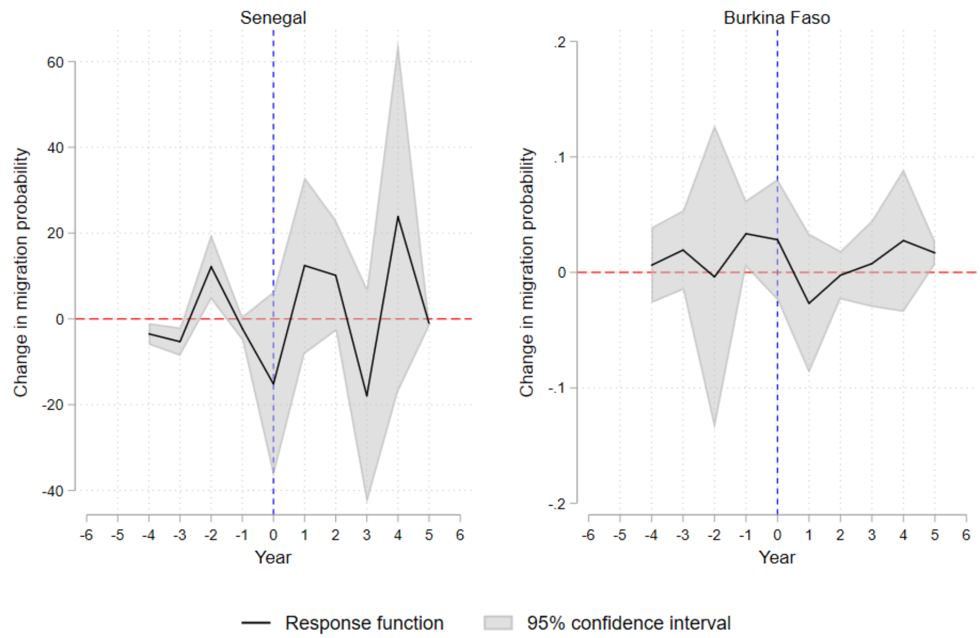

Figure 5: Migration response to a 1 standard deviation increase in precipitation in year 0.

4 Conclusion

I have shown that dust storms have little influence on either international or regional migration in West Africa, despite their negative impact on economic activity. There is some evidence that increased dust exposure reduces migration in some of the lowest-income situations. Consistent with previous findings, increased temperatures can decrease emigration rates from low-income countries. I provide new evidence in the context of West Africa that higher temperatures can also depress rates of regional migration, though this result is not shown to be consistent across countries. The effects of precipitation are somewhat mixed, with increased precipitation decreasing rates of emigration in low-income countries, but increasing rates of within-country migration.

One possible explanation is that increased rainfall could open up opportunities within the country that could facilitate within-country movements, while decreasing the desire to cross international borders. Although this may be an appealing explanation, it contrasts with the results for temperature, where a reduction in opportunity decreases both types of migration. It is also possible that the relationship between precipitation and local economic opportunity is non-linear. Modest increases in precipitation may be beneficial, but large increases damaging.

The findings inform estimates of the individuals' capacity to adapt to the effects of climate change. Migration is just one tool that individuals have for adapting to a change in their environment. The results here provide evidence that this may not be feasible in low-income contexts. A negative income shock can make adaptation more challenging, implying that income effects estimated from short-run fluctuations in weather are not as biased as could be expected to estimate the long-run impacts of a permanent change in climate. In fact, the damages could be even larger considering the normal rates of migration are impaired by climate change, as those who would otherwise seek opportunities in wealthier locations may no longer able to do so.

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A Additional Tables and Figures

VARIABLES	(1) Ghana	(2) Senegal	(3) Burkina Faso
Transported Dust (5 year mean)	-23.284	5.590	
	(17.326)	(6.103)	
Transported Dust			54.911***
			(9.361)
Observations	1,612,174	1,272,466	3,123,562
R-squared	0.858	0.397	0.721
Year FE	X	X	X

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 3: First stage regression for regional migration results. Columns are for Ghana, Senegal, and Burkina Faso.

VARIABLES	(1) Dust exposure	(2) Dust exposure	(3) Dust exposure	(4) Dust exposure
Transported Dust	62.974***	64.158***	40.464***	62.473***
	(4.679)	(4.592)	(5.167)	(3.944)
Observations	509	509	509	509
R-squared	0.970	0.971	0.980	0.980
Origin FE	X	X	X	X
Destination FE	X	X	X	X
Year trend		X		
Country-year trend				X
Year FE			X	

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 4: First-stage regressions at the country level.

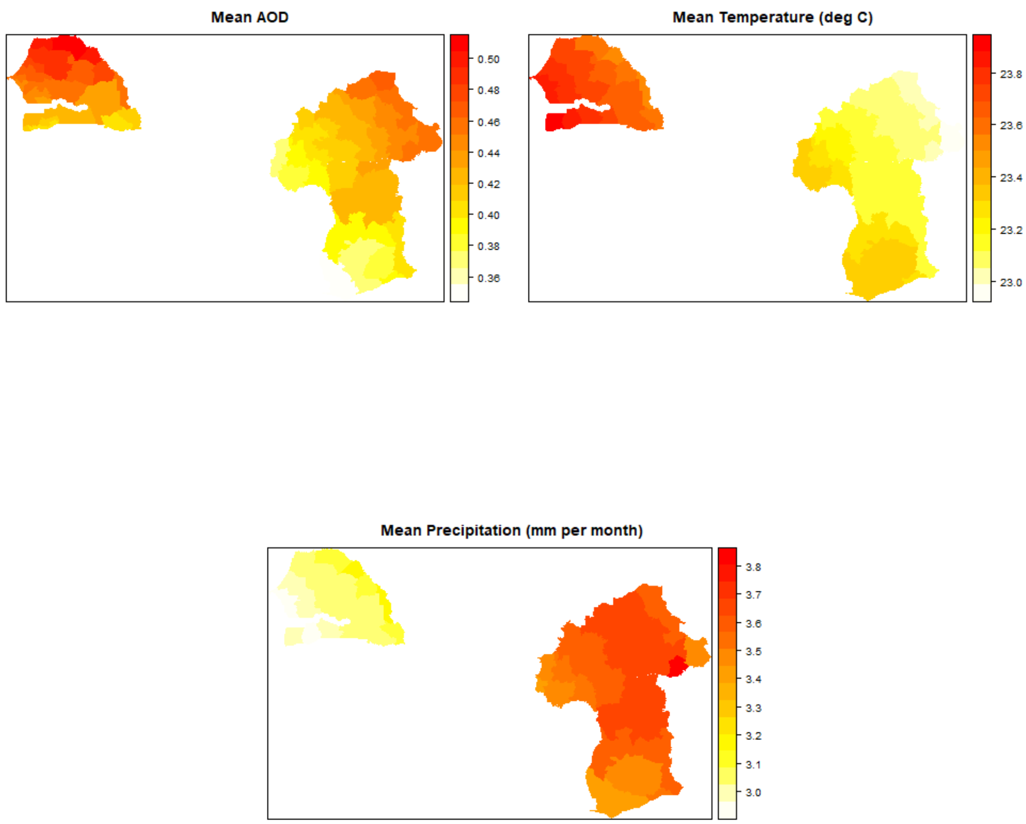

Figure 6: Mean dust, temperature, and precipitation by region in Senegal, Burkina Faso, and Ghana.

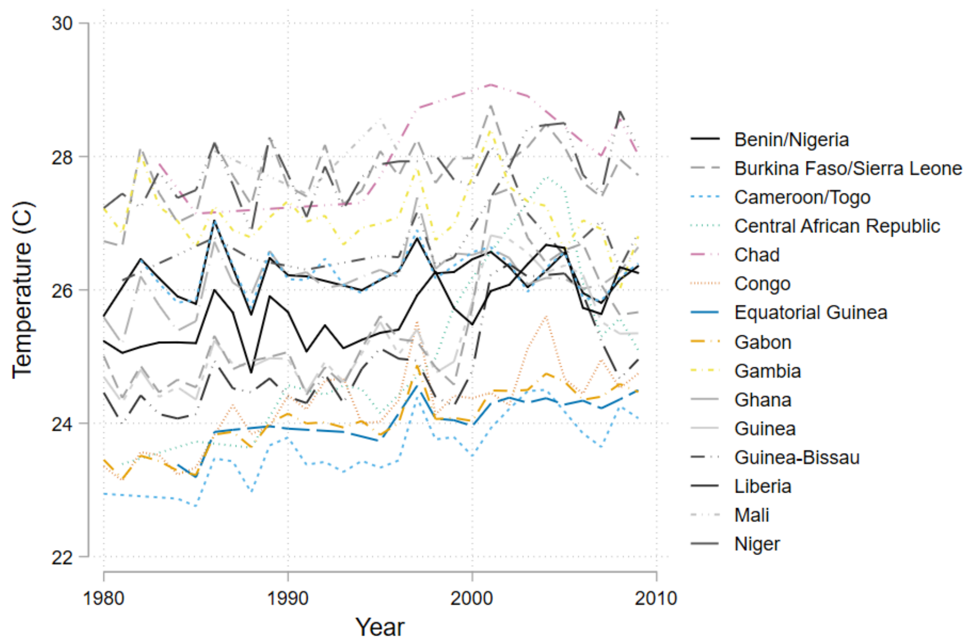

Figure 7: Population-weighted mean temperature by year.

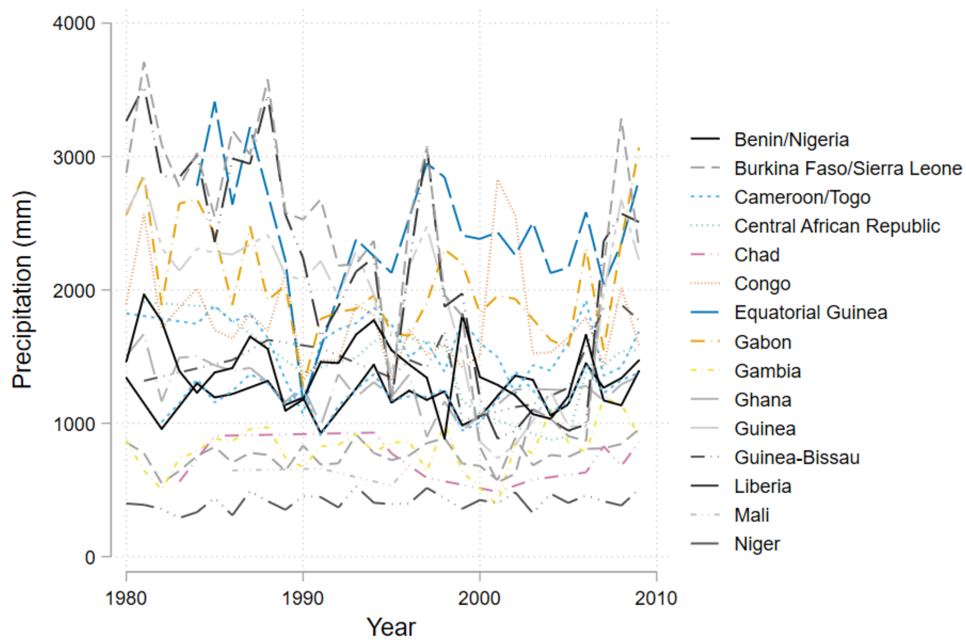

Figure 8: Population-weighted mean precipitation by year.

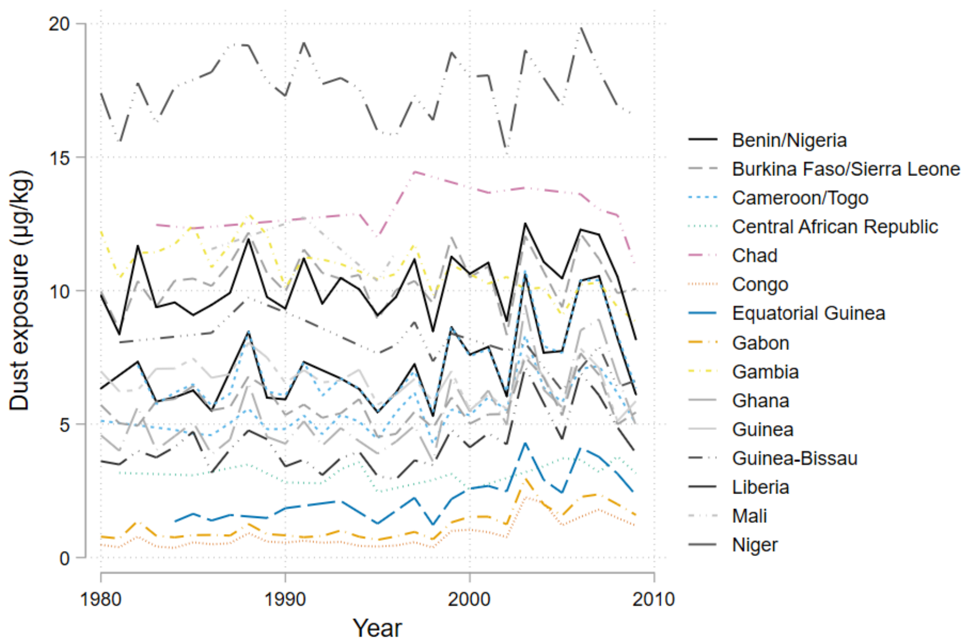

Figure 9: Population-weighted mean dust exposure during the dry season by year.

VARIABLES	(1) Migration rate	(2) Migration rate
Benin x Dust	-2.014	-32.941
	(28.230)	(38.749)
Burkina Faso x Dust	1.198	-46.840
	(33.872)	(48.769)
Cameroon x Dust	0.498	-69.474
	(119.038)	(144.575)
Central African Republic x Dust	-0.394	34.139
	(353.982)	(400.811)
Chad x Dust	2.267	-3.473
	(72.099)	(78.482)
Congo x Dust	4.642	-333.305
	(699.348)	(868.099)
Equatorial Guinea x Dust	-12.079	-42.130
	(257.908)	(302.846)
Gabon x Dust	-0.961	-212.739
	(393.166)	(505.069)
Gambia x Dust	-0.622	-44.603
	(54.574)	(65.833)
Ghana x Dust	4.137	-38.445
	(54.539)	(67.574)
Guinea x Dust	-1.880	-58.229
	(57.370)	(80.460)
Guinea-Bissau x Dust	13.165	-17.050
	(50.447)	(59.907)
Liberia x Dust	-316.867***	-373.699***
	(70.600)	(85.689)
Mauritania x Dust	1.463	-15.838
	(27.695)	(29.642)
Morocco x Dust	1.192	-125.524
	(123.112)	(165.352)
Niger x Dust	-7.969	-46.368
	(25.663)	(40.275)
Nigeria x Dust	-6.888	-45.575
	(24.698)	(39.588)
Sierra Leone x Dust	-126.582*	-171.110**
	(69.180)	(84.917)
Togo x Dust	-3.368	-38.600
	(38.466)	(49.464)
Mali x Dust	166.278	230.492
	(927.833)	(980.864)
Observations	498	498
R-squared	0.315	0.291
Origin FE	X	X
Destination FE	X	X
Year trend	X	
First stage F-stat	0.182	0.118
Year FE		X

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 5: Change in emigration rate by country in response to 1 standard deviation increase in dust exposure.

VARIABLES	(1) Ghana	(2) Senegal	(3) Burkina Faso
Dust Exposure	0.011	0.169	-0.000
	(0.012)	(0.265)	(0.001)
Temperature	0.008	0.072	-0.000
	(0.014)	(0.065)	(0.003)
SPI	-0.128**	-0.362	-0.005
	(0.048)	(0.546)	(0.010)
Observations	1,612,174	1,272,466	3,123,562
R-squared	-0.001	-0.071	0.001
Year FE	X	X	X
First stage F-stat	1.801	2.496	37.70

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 6: Change in migration probability across regions within each country. Columns are for Ghana, Senegal, and Burkina Faso.

VARIABLES	(1) 0 Lag	(2) 1 Lag	(3) 2 Lag	(4) 3 Lag	(5) 4 Lag	(6) 5 Lag
Dust Exposure	0.015	0.014	0.970	-0.285	-0.027	0.013
	(0.017)	(0.013)	(93.099)	(1.590)	(0.053)	(0.012)
Temperature	0.108	-0.057	-1.720	-1.475	-0.155	0.027
	(0.103)	(0.037)	(164.317)	(8.312)	(0.343)	(0.037)
Precipitation	-0.036	-0.571	-41.646	-2.246	0.227	-0.196
	(0.050)	(0.398)	(3,987.163)	(12.803)	(0.377)	(0.121)
Observations	1,612,174	1,612,174	1,612,174	1,612,174	1,612,174	1,612,174
R-squared	-0.004	-0.005	-52.832	-0.868	-0.013	0.001
Year FE	X	X	X	X	X	X
First stage F-stat	1.846	2.081	0.000110	0.0308	0.487	3.747

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 7: Ghana- Change in migration probability for various lags.

VARIABLES	(1) 0 Lag	(2) 1 Lag	(3) 2 Lag	(4) 3 Lag	(5) 4 Lag	(6) 5 Lag
Dust Exposure	-0.026	-0.091	0.104	0.044	0.016	-0.072
	(0.133)	(0.171)	(0.211)	(0.079)	(0.029)	(0.090)
Temperature	0.044*	0.066	0.077	0.054	0.037**	-0.017
	(0.022)	(0.090)	(0.092)	(0.034)	(0.016)	(0.066)
Precipitation	0.496*	-0.305	0.162	-0.249*	0.563*	0.014
	(0.282)	(0.954)	(0.259)	(0.142)	(0.297)	(0.027)
Observations	1,272,466	1,272,466	1,272,466	1,272,466	1,272,466	1,272,466
R-squared	0.016	-0.024	-0.037	0.011	0.012	-0.007
Year FE	X	X	X	X	X	X
First stage F-stat	1.779	2.889	2.564	6.878	11.36	42.43

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 8: Senegal- Change in migration probability for various lags.

VARIABLES	(1) 0 Lag	(2) 1 Lag	(3) 2 Lag	(4) 3 Lag	(5) 4 Lag	(6) 5 Lag
Dust Exposure	-0.012	-0.001	0.002	-0.001	-0.001	0.001
	(0.045)	(0.001)	(0.008)	(0.001)	(0.003)	(0.003)
Temperature	0.004	0.002	0.007	-0.000	0.001	0.005
	(0.007)	(0.002)	(0.022)	(0.003)	(0.005)	(0.003)
Precipitation	0.018	0.007	-0.002	-0.001	-0.002	0.001
	(0.062)	(0.006)	(0.008)	(0.001)	(0.002)	(0.003)
Observations	3,123,562	3,123,562	3,123,562	3,123,562	3,123,562	2,348,499
R-squared	-0.019	0.001	0.000	0.001	0.001	-0.000
Year FE	X	X	X	X	X	X
First stage F-stat	0.0423	6.532	1.467	4.448	0.442	1.303

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 9: Burkina Faso- Change in migration probability for various lags.

VARIABLES	(1) Ghana	(2) Senegal	(3) Burkina Faso
Dust Exposure	0.001	-0.027	-0.001**
	(0.003)	(0.020)	(0.000)
Temperature	-0.001	0.036	-0.001
	(0.005)	(0.022)	(0.003)
SPI	-0.091***	-0.102	-0.005
	(0.027)	(0.212)	(0.010)
Observations	1,612,174	1,272,466	3,123,562
R-squared	0.001	0.013	0.001
Year FE	X	X	X

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 10: Change in migration probability, OLS results.