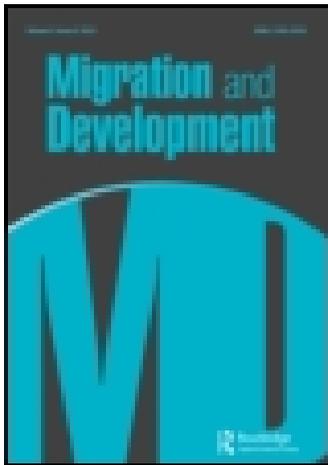


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Is environmentally induced income variability a driver of human migration?

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Is environmentally induced income variability a driver of human migration?

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The role of environmentally induced income variability as a determinant of migration has been studied little to none. We provide a theoretical discussion based on a ‘risk aversion channel’ and an overview of the empirical literature on this. We also extend a previous empirical study on 39 sub-Saharan African countries with yearly data from 1960 to 2000 by including income variability and its weather determinants. Our findings lead us to acknowledge that, based on our dataset and methodology, income variability is a negligible driver of migration decisions at the macroeconomic level.

Keywords: income variability; international migration; rural–urban migration; weather anomalies; sub-Saharan Africa

JEL Classifications: F22; Q54; R13

1. Introduction

The widely known predictions for environmental migration¹ in Black (2001) or the Stern review (Stern et al., 2006) have attracted a growing number of academic studies that more closely investigate the determinants of environmental migration.² Among socio-demographic determinants, these studies have mainly found a role for environmentally induced income differences between urban or rural regions or receiving and sending countries as drivers of migration decisions. One of the main questions that came out of the readings of the literature was whether only income differences play a role in determining migration, or whether there is also a role for income variability. In this article, we investigate whether environmental conditions drive migration through their impact on income variability. We do this in three steps.

In Section 2, we describe a theoretical model that we introduced in Marchiori, Maystadt, and Schumacher (2012) and that captures the primary links between weather variability, rural–urban migration, and international migration. The two channels through which the environment may drive migration are the ‘amenity channel,’ which impacts migration decisions directly through non-market costs, and the ‘economic geography channel,’ which works through wage and agglomeration effects. Based on this model and a further extension which we call the ‘risk aversion channel,’ we find reason to believe that income variability may play a role for environmental-induced migration

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decisions. However, the theoretical discussion does not allow us to quantify the importance of the risk aversion channel, and thus, only an empirical investigation will be able to clarify its role.

In Section 3, we go through a close to exhaustive list of the migration literature and investigate in which ways income variability has been shown to play a significant role for environmentally induced migration. In our reading of the literature, we find that income variability has only been emphasized in one microeconomic study and only in a rather specific setting. We find income variability to be missing from all macroeconomic studies.

As a result, in Section 4, we extend a previous macroeconomic study (Marchiori et al., 2012) on 39 sub-Saharan African countries between 1960 and 2000 to include income variability as an additional explanatory variable. We argue for different ways in which income variability should be modeled in a macroeconomic setting and test several different specifications.

Though our empirical results suggest that there is no significant role for environmentally induced income variability as a driver of migration decisions, we would like to emphasize to the reader that our approach should be understood as a preliminary step in the analysis of the role of income variability. We conclude with some further remarks in Section 5 on why income variability could nevertheless play a role and how future studies could try addressing vital links.

2. A theoretical discussion

In a recent article (Marchiori et al., 2012), we analyze the effects of weather anomalies³ on migration in sub-Saharan Africa. We propose a two-country, two-sector model, where the motivation to migrate depends on the difference in standards of livings (i.e. indirect utility) between rural and urban areas (internal migration), as well as between urban sectors of domestic and foreign countries (international migration). The model predicts that (i) weather anomalies have a direct effect on migration via amenities; (ii) weather anomalies have indirect effects on migration through changes in income and urbanization; (iii) the environmental impact is stronger in economies that depend heavily on the agricultural sector; (iv) the weather-induced change in income is endogenous to migration; and (v) the weather-induced change in urbanization is endogenous to migration. Compared to the conceptual framework provided by Black et al. (2011), we mathematically formalize the direct and indirect effects of environmental change on migration drivers. Exceptions are the theoretical possibility that environmental change affects migration through the political (e.g. conflict) and social channels (e.g. family obligations). The empirical analysis will control for the former channel, while political refugees are excluded from the dependent variable.⁴ For the later channel, there is no obvious reason to believe that environmental change will affect that migration channel in a systematic way.

The mechanism of the model is as follows. Assume we are in an equilibrium where nobody wants to migrate. Further, assume migration decisions are taken based on indirect utility comparisons, where indirect utility is depending on wages and amenity conditions. Finally, assume climatic conditions worsen in one country. Since it is well-known that worsening of climatic conditions has the strongest impact on the rural sector, then this reduces wages in the rural sector, leading to a gap between rural and urban wages. As a consequence, rural workers have now an incentive to migrate to the urban sector. Consequently, a worsening of climatic conditions in one country leads to a rural–urban migration.

In the urban sector, there are now two opposing forces at play. One is that an increase in the urban population has a so-called agglomeration effect. It is a kind of Marshallian externality that increases local wages due to, for example, labor sharing. Since this agglomeration effect has a positive impact on wages, it is expected to further attract migrants from the rural sector, but also now from abroad, since there are higher wages in the urban sector compared to other countries. However, decreasing returns to labor in the production function reduce wages in the urban sector. As a result, if decreasing returns to scale outweigh the agglomeration effect, then the worsening of the climatic condition leads first to rural–urban migration, and then, to international migration. We dubbed this channel the *economic geography channel*. To be precise, it is comprised of an income channel and an agglomeration channel, both working in opposite directions.

Finally, there is the *amenity channel*. It is, for example, well-known that illnesses like malaria or dengue increase substantially in some countries with worsening climatic conditions. In this case, migratory decisions might not be based on income differentials but simply be due to quality of life considerations.⁵

This is the starting point, and we now have to figure out how environmentally induced income variability influences the mechanisms introduced above. Our assumption is that income variability is disliked by agents because of risk aversion. Leaving the amenity channel aside and assuming we are in a two-country setting, it is clear that environmental variables affect both income levels and income variability at the same time. Assume we start from a situation where weather variability is driving income to a significant extent, and assume that there was no important weather variability during the past years in both countries. If country A has the more favorable weather conditions, then it will have a higher income level and there will be migration from country B to country A based on the economic geography channel. Thus, if weather variability is sufficiently low, then environmentally induced income differences are the drivers of migration.

Assume now that income variability increases in country A. We assume that this increase in income variability arises due to a mean preserving increase in weather volatility, where for some years, the weather improves, and for other years, it worsens, while on average, income stays the same. This is basically referring to variability around a given level.⁶

Let us, for simplicity, only look at two periods, as depicted in Figure 1.

We assume that welfare is given by function $W = u(w_L) + u(w_H)$, where weather conditions drive period 1 income w_L to be less than average income \bar{w} , which itself is lower than period 2 income w_H , such that, $w_L < \bar{w} < w_H$. Utility is a concave and increasing function. The higher the risk aversion, the more concave the utility function. Since we, for simplicity, assumed weather variability to come in form of a mean preserving spread, we know that $1/2w_L + 1/2w_H = \bar{w}$. From a standard mathematical property (called Jensen's equality), we can obtain that for any utility function with risk aversion, the following property has to hold: $u(w_L) + u(w_H) \leq 2u(\bar{w})$. This result means that for anyone who is risk averse, the changing income w_L and w_H will provide less utility than the constant stream \bar{w} . An implication of this is that risk averse agents subjected to a fluctuating income should be more willing to migrate than those with a constant income. It is then important to know how relevant such a risk aversion channel is likely to be. Having identified the qualitative direction that the risk aversion channel will lead us, we now turn to some points that are more quantitative in nature.

For example, it should be expected that the risk aversion channel is mediated by savings in good years which may be used to compensate income reductions in bad

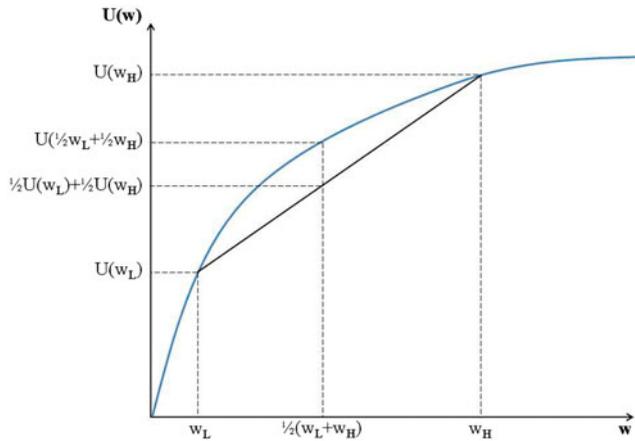


Figure 1. Average welfare versus welfare under variability.

years. Remittances can also be used as an insurance mechanism against weather shocks (Combes & Ebeke, 2011). Also, it is well-known that weather conditions play the largest role in the agricultural sector of the developing countries. However, weather variability is the rule rather than the exception, and consequently income variability is well-known to agricultural workers. This could potentially imply that a farmer who spent years and years cultivating his land may be less likely to migrate somewhere else because of a smaller increase in weather variability. Instead, migration will be considered a necessary option in case income levels have reduced to below subsistence levels or to levels that are far worse than in other countries.

Also, discount rates in less-developed countries are very high such that current living conditions tend to matter more than potential future ones. Finally, recent contributions by Barro (2009) suggest that the welfare costs of smaller income variability are rather low, while larger income variability may strongly impact welfare. If that is the case, then it is reasonable to believe that this point also extends to migration decisions.

Based on the framework above, it is difficult to predict the quantitative importance of income variability as a driver of migration decisions, at least from a theoretical perspective. However, a potential risk aversion channel exists; the importance of which relies on the level of risk aversion of the agents and the ability to compensate for this variability by relying on savings from good times or on remittances.

3. Empirical evidence on income variability and environmental migration

To see whether income variability is really an important driver of environmentally induced migration decisions, we revisit the empirical evidence on the effects of income variability on environmental migration.

In effect, we only know about two microeconomic studies that investigate the impact of income variability as a driver of migration decisions (cf. Lilleør & Van den Broeck, 2011), namely Rosenzweig and Stark (1989) as well as Yang and Choi (2007). Rosenzweig and Stark (1989) investigate how marriage is used as a risk-mitigating device by Indian households and find that profit variability has an impact on marriage-related migration of household members. Yang and Choi (2007) use household data

from the Philippines and find that the change in household income (as a share of initial household income) increases the likelihood of a household having a migrant, but only for non-migrant households. Thus, both articles predict that household migration is used to smooth consumption expenditure.

In the macroeconomic literature, we have not come across a single article that studied the role of income variability for migration decisions. Our subsequent discussion is partly based on the review in Lilleør and Van den Broeck (2011), and also extends this to new articles. Even assuming that climate variability drives income variability to a substantive extent, the evidence is not supportive of the assertion that environmentally induced income variability is a major determinant of migration. As far as we know (see Table 1), the only other articles that directly investigate the role of climate variability as a factor of migration – but not referenced in the review of Lilleør and Van den Broeck (2011) – are Mueller and Osgood (2009), Dillon, Mueller, and Salau (2011), Lewin, Fisher, and Weber (2012), and Kumar and Viswanathan (2012). Mueller and Osgood (2009) observe greater migration rates in Brazil from areas with lower precipitation variance. The same authors indicate that such a variance has a detrimental impact on household income. As acknowledged by the authors, that result is not robust to the inclusion of household characteristics (number of household members in a given age category, or the household head educational attainment), while the authors do not assess the impact on income variability. The most robust finding in their income equation relates to their measure of precipitation shocks, proxied as the difference between the precipitation mean and the level of precipitation the year the household migrated. Dillon et al. (2011) use climate variability to measure agricultural income variability and assess its importance in determining migration in Nigeria. However, these authors rightly suggest that, based on their econometric method, their results rather imply that climate variability is associated with low income *levels*, but not necessarily income variability. If one were to extrapolate this result, then we should conclude that climatic shocks should increase migration, at the household level, for reasons of consumption smoothing. Lewin et al. (2012) also introduce a measure of climate variability, defined as the average for the last 10 rainy seasons of the coefficient of variations of daily rainfall. Contrary to Mueller and Osgood (2009) and Dillon et al. (2011), the authors find that such a proxy is negatively associated with the fact to have migrated. That result seems to be in contradiction with the risk aversion channel that we described above. However, the fact that they use the mean (and not the change) of the standard deviation in a cross-sectional setting limits their ability to draw causal inference. Finally, a recent study by Kumar and Viswanathan (2012) directly introduce the standard deviation of annual rainfall over the past 20 years to explain migration between Indian districts. Such variable has a significant impact on short-term migration (defined as within 6 months) and no impact on long-term migration (larger than 6 months). The same authors then identify the link between weather variability and migration, through changes in crop yields levels (in particular of wheat) but not on crop yields (or income) variability. The study applies the method proposed by Feng, Krueger, and Oppenheimer (2010), who only investigate the role of changes (not variability) in annual precipitation and temperature. So even extending the literature review of Lilleør and Van den Broeck (2011), we find very little support, with the exception of the special case of marriage-related female migration in India (Rosenzweig & Stark, 1989), for a role of income variability.⁷ Furthermore, the additional studies that we considered relied on a reduced form regression that does not study whether weather variability impacts income variability and thereby affects migration.

Table 1. Updated table of Lilljeor and Van den Broeck (2011).

	Authors	Country (datasets)	Finding	Migration type	Origin	Environmental measure	CC ^a
A	Studies describing empirical evidence of climate effects on <i>income</i>						
1	Ahmed et al. (2011)	Tanzania (Ministry of Agriculture/Agro MAPS/CRU TS3.0)	Temperature has a significant negative effect on yields, while precipitation has a significant positive effect			Precipitation and temperature levels (not panel data)	Yes
2	Barrios, Bertinelli, and Strobl (2010)	Developing countries (IPCC/World Penn Tables)	Rainfall is a significant positive determinant of poor economic growth in African developing countries, but not in others			Rainfall anomalies ^b	Yes
3	Blanc (2012)	FAO data on area harvested and yields, CRU TS 2.1 weather dataset and other data (CO ₂ , crop growing areas) available for the period 1961–2002 for 37 SSA countries	Temperature and precipitation do not affect cassava yields, but floods are detrimental to cassava yields; Excessive precipitation negatively affects maize yields (concave relationship between precipitation and maize yield); temperature is detrimental to millet and sorghum yields, while precipitation shows a concave relationship to yields of these two crops		Rural	Temperature and precipitation (with quadratic terms and interactions terms with a dummy for less favorable agricultural conditions) as well as measures of evapotranspiration and the standardized precipitation index	Yes
4	Dell, Jones, and Olken (2009)	Americas – 12 countries (household surveys)	Negative relationship between income and temperature, both between and within countries, (taking country fixed effect into account). Suggest that half of the strong negative short-term effects are offset in the long run through adaptation			Mean temperature and precipitation (artificial panel data)	Yes

5	Dell, Jones, and Olken (2012)	World (Penn World Tables/WDI)	Higher temperatures reduce economic growth (levels and rates) in poor, but not in rich, countries through reductions in both agricultural and industrial output, aggregate investment, and political stability Negative and persistent effects of rainfall shocks on consumption growth at household level	Variations in rainfall and temperature levels over 50 years	Yes
6	Dercon (2004)	Rural Ethiopia (household survey)	The effect of climate change on agricultural profits in the USA may prove to be much smaller than that found in other studies, when the adaptive responses of farmers are taken into account	Rainfall shocks defined as change in the log(rainfall) at t relative to $t-1$	No
7	Deschênes and Greenstone (2007)	USA (Census of Agriculture)	Replicating and correcting Deschênes and Greenstone (2007) empirical analysis	Variations in rainfall and temperature levels (degree days)	Yes
8	Fisher, Hanemann, Roberts, and Schlenker (2012)	USA (Census of Agriculture)	adverse potential impact on USA agriculture (corn and soybeans yields and profits) by the end of the century	Variations in rainfall and temperature levels (degree-days)	Yes
9	Jayachandran (2006)	India (WB India Agriculture Climate Dataset)	Rainfall shock is used in the first stage as an instrument for agricultural productivity. A positive rainfall shock increases crop yields by 7%	Rainfall shock (= level \leq 80th percentile of a district's normal rainfall)	No
10	Kazianga and Udry (2006)	Rural Burkina Faso (ICRISAT)	Short-term negative rainfall deviations result in negative income shocks, which translate into negative consumption shocks with little evidence of smoothing or insurance	Rainfall deviations from long-run mean at village level	No

(Continued)

Table 1. (Continued).

	Authors	Country (datasets)	Finding	Migration type	Origin	Environmental measure	CC ^a
11	Kumar and Viswanathan (2012)		See Panel D below				
12	Lewin et al. (2012)		See Panel C below				
13	Marchiori et al. (2012)		See Panel D below				
14	Rowhani, Lobell, Linderman, and Navin (2011)	Tanzania (national crop climate data)	Both inter- and intra-seasonal changes in precipitation and temperature are associated with changes in crop yields. Increased precipitation variability reduces yields			Temperature and precipitation levels, and variability (not panel data)	Yes
15	Schlenker and Roberts (2009)	USA (Census of Agriculture)	Based on an hedonic approach, adverse impact (in a nonlinear way) on corn soybeans, and cotton yields in the USA			Variations in rainfall and temperature levels (degree-days)	Yes
16	Schlenker, Hanemann, and Fisher (2006)	USA (Census of Agriculture)	Based on an hedonic approach, adverse impact on USA agriculture (farm land value per acre) and potential detrimental impact by the end of the century			Variations in rainfall and temperature levels (degree-days)	Yes
17	Schlenker and Lobell (2010)	FAO dataset on crop yields from 1961 to 2006	Detrimental impact on crop yields for maize, sorghum, millet, groundnut, and cassava			Variations in rainfall and temperature levels (degree-days)	Yes
18	Yang and Choi (2007)		See Panel D below				
B	Studies describing empirical evidence of climate effects on <i>income variability</i>						
19	Rosenzweig and Stark (1989)		See Panel E below				

C	Studies describing empirical evidence of climate effects on <i>migration</i> , but not tested through an explicit driver (reduced form)						
20	Barrios et al. (2006)	SSA and non-SSA (78 countries 1960–1990)	Climate change (proxied by rainfall) was a significant determinant of urbanization in sub-Saharan Africa but not in other developing countries	Internal	Rural	Rainfall (level, normalized by LT mean)	Yes
21	Beegle, De Weerd, and Dercon (2011)	Tanzania (KHDS)	In an auxiliary regression, the authors find a positive effect of rainfall shock when a child on migrating as adult	Internal	Rural	Rainfall shock ^c	No
22	Beine and Parsons (in press)		See Panel D below				
23	Bettin and Niccoli (2012)	Bilateral panel migration data for 231 origin and 231 destination countries between 1960 and 2000	Significant direct impact of different climate change proxies on international migration. In particular, disasters on outmigration flows are statistically significant in Asian countries.	International		Rainfall and temperature deviations from the long-run average (Dummy taking value 1 if above the 90th percentile); Natural disasters	Yes
24	Bohra-Mishra and Massey (2011)	Chitwan Valley Family Study (CVFS) for Nepal from February 1997 to January 2006	Using a (pooled) multinomial logit, local migration is associated with increase in the time to collect fodder, time required to collect firewood, a perceived decrease in crop production, and an increase in population density, but not with a change in water quality. Only time to collect fodder is associated with long-distance migration	Internal and international	Rural	Indirect measurements: Change in time to collect animal fodder, change in time to collect firewood for fuel, change in agricultural productivity, change in the quality of drinking water, and population density	Yes

(Continued)

Table 1. (*Continued*).

	Authors	Country (datasets)	Finding	Migration type	Origin	Environmental measure	CC ^a
25	Bohra-Mishra, Oppenheimer, and Hsiang (2014)	Data on 7185 households followed over 15 years in Indonesia	Climatic variations impact permanent migration (in a non-linear way), while natural disasters tend to have a much smaller or no impact on migration.	Province-to-province migration		Natural disasters (flood, earthquake, volcanic eruptions, landslides)	Yes
26	Carvajal and Pereira (2009)	Nicaragua (LSMS)	Wealth, and whether the sector of origin is rural or urban, is correlated with the likelihood of migration.	Internal and international	Rural Urban	Hurricane Mitch (1998)	Yes
27	Deschênes and Moretti (2009)	2002 US Census	Evidence on detrimental impact on mortality but also decreasing impact of the number of extreme cold days on the probability to move to another (warmer) US state than the one the individual is born in			Differences in cold days between locations for the migration models	
28	Dillon et al. (2011)	Household survey in Northern Nigeria	Suggestive evidence of household response to ex-ante risk (unfortunately cannot be tested with household fixed effect, see text) and robust findings that male migrate in response to ex-post risk		Rural	Ex-ante risks proxied by the coefficient of variation of temperature degree days over the growing period, interacted with land holding and ex-post risk proxied by the lagged number of standard deviations of temperature degree days interacted by land holding	Yes
29	Drabo and Mbaye (in press)	Bilateral migration from 88 developing countries to 6 OECD countries, 1950–2010	Disasters drive international migration of highly educated	International		no. of disasters (meteorological, hydrological, drought, wildfire, and climatological disasters)	Yes

30	Ezra and Kiros (2001)	Ethiopia, 1984–1994	fertility of land and vulnerability to food crisis affects out-migration	International	Rural	community vulnerability to food crisis	Yes
31	Findley (1994)	Mali (CERPOD)	There is a positive correlation between drought and internal migration and a negative correlation between drought years and international migration, but without controlling for individual or household characteristics	Internal and international	Rural	Drought ^d	Yes
32	Gray (2009)	Ecuador (own data)	Less precipitation is associated with more internal and international rural out-migration, while an unusual harvest in period $t - 1$ is associated with more local and internal migration	Local Internal International	Rural	Mean annual community precipitation	Yes
33	Halliday (2006)	El Salvador (BASIS)	agricultural loss leads to international migration, while earthquakes reduce out-migration	International (to US)	Rural	Earthquake and agricultural loss	Yes
34	Henry, Paul, and Lambin (2003)	Burkina Faso (Population Census Survey)	Environmental variables are significant in explaining inter-provincial migration, but their contribution was slightly lower than that of the socio-demographic variables	Internal, mainly R-R	Rural	Drought frequency, decade-to-decade rainfall variability	Yes
35	Henry, Schoumaker, and Beauchemin (2004)	Burkina Faso (EMTUB)	People from drier regions are generally more likely to migrate. Short-term rainfall deficits increase long-term rural-urban migration, but decrease short-term international migration	Internal, mainly R-R	Rural	Rainfall from global monthly precipitation data (annual mean and short-term deviations)	Yes

(Continued)

Table 1. (*Continued*).

	Authors	Country (datasets)	Finding	Migration type	Origin	Environmental measure	CC ^a
36	Kumar and Viswanathan (2012)		See Panel D below	International			
37	Lewin et al. (2012)	Malawi's 2004/05 Integrated Household Survey (IHS2)	Rainfall shocks have a negative association with rural out-migration, and migrants choose to move to communities where rainfall variability and drought probability are lower	Internal	Rural	Rainfall variability measured by reported damages due to a drought or a flood, similar shocks reported at the community level, average for the last 10 rainy seasons of the coefficient of variation of daily rainfall, and ratio of the average annual rainfall for the last 10 years rainy seasons over a 30-year period (not panel data)	Yes
38	Massey, Axinn, and Ghimire (2010)	Chitwan Valley Family Study (CVFS) for Nepal in 1996	Short-distance mobility affected by perceived declines in productivity, declining land cover, and increasing time required to collect firewood. Long-distance mobility is predicted by perceived declines in productivity	Internal	Rural	Indirect measurements (declining land cover, times to gather organic inputs, increasing population density, and perceived declines in agricultural productivity)	Yes
39	Meze-Hausken (2004)	Ethiopia	Droughts lead to migration, but adaptation reduces migration	both	Rural	drought	Yes
40	Mueller, Gray, and Kosec (2014)	21-year longitudinal survey (4428 individuals from 583 households) conducted in rural Pakistan (1991–2012)	Flooding has modest to insignificant impacts on migration, while heat stress increases permanent migration of men (the study gives indirect evidence that shocks on agricultural income is a possible channel)			Cumulative rainfall over the monsoon period (June–September), average temperature over the Rabi season (November–April), the annual number of deaths caused by flooding, and the SPEI (moisture index)	Yes

41	Munshi (2003)	Mexico-US (MMP)	Uses rainfall history in origin community to instrument US destination network size. The auxiliary regression shows a negative effect of past rainfall on the number of migrants in the destination network, implying that lower-than-average rainfall induces more out-migration	International	Rural	Community rainfall levels with up to six-year lags	No
42	Naude (2010)	45 Sub-Saharan African (SSA) countries over the period 1965–2005	Environmental pressures are found to have a less important direct impact (compared to conflict and income differential), although they may have an indirect impact on migration through conflict and job opportunities	International	Rural	Water scarcity proxied by the percentage of land under irrigation and natural hazard disasters	Yes
43	Paul (2005)	Bangladesh (own data)	No evidence of out-migration in the aftermath of a tornado	Internal	Rural	Tornado (not panel data)	Yes
44	Rappaport (2007)	US (Census Bureau and Bureau of Economic Analysis) countries from 1970 to 2000	Association between increased variation of nice weather (as a consumption amenity) and changes in population density, interpreted as weather-related internal migration	Internal	Both rural urban	January average maximum temperature, July daily maximum heat index, July average mean relative humidity, and average number of rainy days	Yes
45	Reuveny and Moore (2009)	OECD dyadic migration flows to 14 developed countries and migration to the USA (Statistical Yearbooks) Mexico, 1990–2000	Environmental decline plays a significant role in out-migration, pushing people to leave their homes toward OECD countries	International		Indirect measurements (land farmed with permanent crops, arable land) and weather-related natural disasters	Yes
46	Saldaña-Zorrilla and Sandberg (2009)		household study where higher disaster frequency increases migration rates	unknown	Rural	disaster frequency	Yes

(Continued)

Table 1. (Continued).

	Authors	Country (datasets)	Finding	Migration type	Origin	Environmental measure	CC ^a
47	Strobl and Valfort (in press)	Uganda (2002 Uganda census and IPCC datasets)	Weather-induced internal migrants have a negative impact on the probability for non-migrants living in destination regions to be employed.			Standardized Precipitation Index	No
48	Warner (2010)	Mozambique, Vietnam, Egypt (EACH-FOR)	Environmental factors (flooding in Mozambique and Vietnam, desertification, and sea-level rise in Egypt) contribute to migration, especially via their effect on livelihoods			Flooding, desertification, sea-level rise (not panel data)	Yes
D	Studies describing empirical evidence of climate effects on migration through the income differential driver						
49	Beine and Parsons (in press)	Bilateral panel migration data for 137 origin and 166 destination countries between 1960 and 2000	Little direct impact of climate change on international migration. Indirect impact of natural disasters through wage differentials in LDC countries only	Internal and international	Rural	Natural disasters, rainfall, and temperature deviations from the long-run average	Yes
50	Feng et al. (2010)	Census data from Mexico between 1995 and 2005	Significant effect of climate-driven changes in crop yields on the rate of emigration to the United States	International	Rural	Annual precipitation, annual average temperature and summer temperature	Yes
51	Marchiori et al. (2012)	43 SSA countries	Climate variations increase the incentives to migrate internationally via changes in the wage ratio, but urbanization mitigates the effect on international migration	International (+R+U)	Rural	Precipitation and temperature anomalies	Yes

52	Yang and Choi (2007)	Philippines (LFS, SOF, FIES, APIS)	Rainfall deviations are used to instrument income changes. Positive income shocks increase international migration, while negative shocks increase receipts of remittances	International	Both rural urban	Rainfall shocks (season specific) ^e	No
E	Studies describing empirical evidence of climate effects on migration through the income variability driver						
53	Rosenzweig and Stark (1989)	India (ICRISAT)	Rainfall means and variances are used to instrument agricultural profit means and variances, which in turn are used to explain household consumption smoothing and migration	Internal (R-R)	Rural	Rainfall means and variances	No

Note: Studies describing empirical evidence of climate effects on (A) income, (B) income variability, (C) migration, but not tested through an explicit driver (reduced form), (D) migration through the income differential driver, and (E) migration through the income variability driver.

^aIs climate change or environmental migration a focus of the study?

^bRainfall anomalies = deviations from the country's long-term mean divided by its long-run standard deviation.

^cRainfall shock: largest deviation of rainfall from 25-year average annual rainfall.

^dDrought: % rain below long-term 50-year average in 1983–1985.

^eRainfall shock: changes in local rainfall constructed as rainfall in year t in that season minus rainfall in the same season in year $t - 1$.

Naturally, the fact that neither of the articles (apart from microeconomic study mentioned above) in our review of articles in Table 1 include income variability as a driver of migration does not preclude the possibility that it may, nevertheless, be a driver of migration decisions. This holds especially true since most of the articles only investigate a reduced-form relationship between migration and climate variables, without studying further through which channels these climate variables drive migration. Indeed, the microeconomic study of Rosenzweig and Stark (1989) suggests that income variability plays a role at the micro level. However, it is not clear a priori whether the result of Rosenzweig and Stark (1989) really applies further than simply to a couple of villages in rural India and beyond a particular institutional setting, namely marriage arrangements in South Asia. The question, thus, is whether their result is sufficiently important also at the macroeconomic level. We thus go back to our original empirical study and add income variability in order to know whether this variable turns out to be an important driver of migration or not.

4. Empirical study

The empirical model adopted by Marchiori et al. (2012) is based on the theoretical framework that we described above. Such a framework has been equally adopted by related studies on the issue of environmental migration such as Barrios, Bertinelli, and Strobl (2006), Naude (2010), or Beine and Parsons (in press). We adapt this basic framework in order to understand how weather variations may affect the internal and international migration and also shed light on the sources of multiple endogeneities. We investigate the following econometric model.

$$\begin{aligned} MIGR_{r,t} = & \beta_0 + \beta_1 Weather_{r,t} + \beta_2 (Weather_{r,t} * AGRI_{r,t}) + \beta_3 \log \left(\frac{GDP_{pc_{r,t}}}{GDP_{pc_{-r,t}}} \right) \\ & + \beta_4 \log(URB_{r,t}) + \beta_5 \log(GDP_{pc}Variability_{r,t}) + \beta_6 \log X_{r,t} \\ & + \alpha_{r,t} + \alpha_r + \alpha_t + \varepsilon_{r,t}. \end{aligned}$$

Based on a dataset of 39 sub-Saharan African countries with yearly data from 1960 to 2000, the empirical model seeks to explain the average net migration rates ($MIGR_{r,t}$), excluding net refugee flows, defined for each country r at year t by variables describing the weather characteristics ($Weather_{r,t}$), the economic and demographic situations, for example, the income differential $GDP_{pc_{r,t}}/GDP_{pc_{-r,t}}$, or the level of urbanization ($URB_{r,t}$), as well as several country-specific variables, denoted by vector $X_{r,t}$. To proxy for weather, we follow the standard literature and rely on two variables, namely rainfall ($RAIN_{r,t}$) and temperature ($TEMP_{r,t}$). In order to meaningfully compare these across time and other countries, we rely on the so-called rain and temperature anomalies. Anomalies are calculated as the deviations from a country's long-term mean, divided by its long-run standard deviation.

Guided by the above theoretical model, we follow Marchiori et al. (2012) in distinguishing the direct effects of weather variations (*amenity channel*) on international migration from the indirect channels (weather-induced changes in GDP ratio and the weather-induced changes in urbanization or agglomeration). While changes in income differences are expected to increase the incentives to move to another country, an increase in urbanization is expected to mitigate the impact of weather variations on international migration. Since the theoretical model points to a stronger environmental impact in economies heavily dependent on the agricultural sector, we introduce an

interaction term between the weather variables and a dummy variable, defined as in Dell et al. (2009), as being equal to one for an above-median agricultural GDP share in 1995. The nature of the *economic geography* channel underlined in the above theoretical model poses additional econometric challenges. To reduce the threat of endogeneity biases (due to simultaneity, omitted variable, measurement errors, or spurious trends), we also control for any time-constant source of country heterogeneity by the use of a country fixed effect, α_r , for phenomena common to all countries across time through the introduction of time dummies, α_t , and for changes in the regional patterns of migration with time-region fixed effect, $\alpha_{r,t}$. We also adopt an instrumental variables approach to induce some exogenous variations in our variables of interest and be able to draw causal inference. More explanations are given in Marchiori et al. (2012).

The main change compared to Marchiori et al. (2012) is the addition of a proxy for income variability ($GDPpcVariability_{r,t}$). Like Rosenzweig and Stark (1989), we use the standard deviation of income as a measure of the intertemporal variability in income (per capita). The average income per capita over a certain period N is

$$\bar{y}_t^N = \frac{1}{N} \sum_{k=t-n+1}^N y_k. \quad (1)$$

where $n \geq 1$. The intertemporal variance of income $(s_t^N)^2$, over N periods, is given by

$$(s_t^N)^2 = \frac{1}{N} \sum_{k=t-n+1}^N (y_k - \hat{y}_t^N)^2 \quad (2)$$

where the standard deviation of income (s_t^N) is simply the square root of the variance. It is denoted by s_{it}^N , and it varies across countries i and over time t , where again N denotes the number of periods over which the standard deviation is defined.

The coefficient of variation is then defined as

$$cv_t^N = \frac{s_t^N}{\bar{y}_t^N}.$$

One comment that we have for future works investigating the role of climate variability is that similar concerns should apply to income variability as to income differences. It would not make sense for a migrant to move from an origin country because of high income variability to another country with even higher income variability. As a consequence, any study should take the income variability differences between origin and destination country into account. However, simply considering income variability at the origin and destination country is also not enough. Imagine a country with low income compared to one with high income. Even though the income variability in the low income country is high, it may be that a lower income variability in the high income country has a higher relative value. This arises because income levels are having a scale effect on the standard deviation. To properly take this scale effect into account, one would have to use the coefficient of variation, which adjusts the standard deviation by the mean. Finally, it goes without saying that if one believes income levels to be endogenous like we showed it to be the case in Marchiori et al. (2012), then one will directly accept that also income variability is endogenous. As a consequence, one has to control for this endogeneity.

Table 2 offers a short description of the main variables used, where the reference to the data sources can be found in Marchiori et al. (2012). Table 3 presents, in columns 1

Table 2. Short description of main variables.

CODE	Definition/description
MIGR	Net migration rate: Difference between numbers of immigrants and emigrants per thousands of population, corrected by the refugee movement
Weather	
RAIN	Rain Anomalies: deviations from the country's long-term mean divided by its long-run standard deviation
TEMP	Temperature Anomalies: deviations from the country's long-term mean divided by its long-run standard deviation
y/y^F	GDP per capita over GDP per capita in other African countries weighted by distance.
WAR	War onset, value 1 for civil war onset
WAR^F	War onsets in other countries weighted by distance
URB	Share of urban population in total population
AGRI	Whether a country has an agricultural value added above the median in 1995 (similar to Dell et al., 2009)
Δ Money	Money plus Quasi-Money: Absolute growth in money supply
New State	Independence: value 1 if country is in the two first years of independence
NetREF	Net refugee movement per thousands of population
Variability variables	
$(s/s^F)^N$	Intertemporal standard deviation of GDP per capita over intertemporal standard deviation of GDP per capita in other African countries weighted by distance. The number of periods to calculate the standard deviation were 3 (i.e. $N = 3$)
$(cv/cv^F)^N$	Intertemporal coefficient of variation in GDP per capita over intertemporal coefficient of variation in GDP per capita in other African countries weighted by distance. The number of periods to calculate the coefficient of variation were 3 (i.e. $N = 3$)

Notes: A more detailed description of variables containing the different sources for the data is provided in Marchiori, Maystadt, and Schumacher (2011) or in the supplementary material of Marchiori et al. (2012).

to 3, the results of our preferred specification (i.e. columns 3–5 of Table 6 in Marchiori et al., 2012). The other columns show how these results change when income variability (s^M) is introduced. Similar results are obtained for $N=2,3,4,5$. We present the results for $N=3$. As a quick reminder, our theoretical framework predicts that wages and the level of urbanization should be treated as endogenous variables in any empirical framework. Thus, regressions (1) and (2) give the first-stage regressions, where both the income differential and the level of urbanization are treated endogenously, with the instruments being the change in money supply (Δ Money), and whether the country has recently become independent ('New State' as well as 'New State UK' from British colonial rule). For the sake of identification, these instruments are used, as they can be reasonably assumed to affect the income differential and the level of urbanization, without affecting migration through another channel. Regression (3) then presents the results with migration as the dependent variable, the two instrumented variables and the climate controls. We find that both the income differential and the level of urbanization are affected by the climate variables, and both are also explaining migration. Furthermore, we have a direct effect from the climate variables on migration, which we – based on the theoretical model – can ascribe to the amenity affect.

We now include income variability into our specification. To minimize potential future criticism we do this in three steps. Firstly, we include income variability as an exogenous variable, which we suggested above should be problematic due to its potential

Table 3. Two-stage regressions.

Regression	(1)	(2)	(3)	(4)	(5)	(6)
Models	FE2SLS	FE2SLS	FE2SLS	FE2SLS	FE2SLS	FE2SLS
SE	robust	robust	robust	robust	robust	robust
Stage	1st	1st	2nd	1st	1st	2nd
Dependent	$\log(y/y^F)$	$\log(\text{URB})$	MIGR	$\log(y/y^F)$	$\log(\text{URB})$	MIGR
<i>Variable</i>						
RAIN	-0.023 [0.0140]	-0.00332 [0.00832]	0.843 [0.832]	-0.0229 [0.0140]	-0.00336 [0.00831]	0.834 [0.872]
TEMP	-0.0432*** [0.0153]	-0.0204** [0.00876]	2.841** [1.239]	-0.0433*** [0.0153]	-0.0203** [0.00880]	3.040** [1.305]
RAIN*AGRI	0.0494*** [0.0187]	0.00162 [0.00997]	-1.258 [0.936]	0.0494*** [0.0187]	0.00169 [0.00996]	-1.227 [0.980]
TEMP*AGRI	0.00811 [0.0218]	0.0455*** [0.00980]	-4.253** [1.693]	0.00836 [0.0222]	0.0452*** [0.0101]	-4.869*** [1.816]
WAR	-0.0738 [0.0877]	0.0104 [0.0259]	2.997 [5.709]	-0.0739 [0.0876]	0.0105 [0.0259]	3.186 [5.823]
WAR ^F	-0.182 [0.150]	0.02 [0.0850]	0.86 [7.194]	-0.182 [0.151]	0.0198 [0.0855]	0.74 [7.437]
$\log(y/y^F)$			21.58*** [7.216]			22.36*** [7.647]
$\log(\text{URB})$			67.51*** [24.14]			73.25*** [25.75]
(s) ³				0.00000848 [9.87e-05]	-0.0000103 [5.15e-05]	-0.0118* [0.00638]
<i>Instruments</i>						
ΔMoney	0.131** [0.0557]	0.0596* [0.0350]		0.130** [0.0558]	0.0600* [0.0351]	
New State UK	-0.641*** [0.0892]	0.230*** [0.0484]		-0.641*** [0.0897]	0.230*** [0.0485]	
New State	-0.0297 [0.0504]	-0.0362 [0.0338]		-0.0307 [0.0520]	-0.035 [0.0345]	
HW-Dum	Incl.	Incl.	Incl.	Incl.	Incl.	Incl.
Region-Dum	Incl.	Incl.	Incl.	Incl.	Incl.	Incl.
Time-Dum	Incl.	Incl.	Incl.	Incl.	Incl.	Incl.
Region-Time	Incl.	Incl.	Incl.	Incl.	Incl.	Incl.
Observations	750	750	750	749	749	749
Number of countries	39	39	39	39	39	39
F-test	88.87***	65.79***	22.17***	54.17***	56.06***	29.19***
F-test on excl. IV	30.84***	12.99***		30.99***	13.02***	
Underid test p-value			7.595*** 0.871			7.668** 0.5766
Hansen Endo stat			14.53***			12.296***
Root MSE	0.2283	0.09746	10.82	0.2285	0.09754	11.19

Notes: Robust standard errors are in square brackets. y stands for domestic GDP per capita; y^F stands for foreign GDP per capita. 'HW-Dum' stands for the 4 dummies of Hatton and Williamson (2003) for Ghana and Nigeria for the years 1983 and 1985, 'Region-Dum' includes region dummies, 'Time-Dum' time dummies, and 'Region-Time' time-region dummies. $t-1$ indicates a one-period lagged variable. R-squared is not shown, because, in the case of 2SLS/IV, it is not an appropriate measure of the goodness of fit and has no statistical meaning (see www.stata.com).

*** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$.

endogeneity, and also because it should be measured relative to the income variability in the foreign countries. In any case, including income variability (s^3) into the model gives regressions (4) to (6). We see that income variability has no effect on income or urbanization, and that it has a marginally negative effect on migration. Looking at the coefficients, we find no differences that are worth mentioning. Consequently, we could stop here and dismiss income variability as the omitted variable that might be responsible for what we called the amenity effect.

However, in order to do things properly, we suggested that we would have to treat income variability as being endogenous. Not only that, but it must also be viewed relative to income variability in the country where the migrants might want to move to. Clearly, what use would there be migrating into a country with a higher income variability, when the reason for migrating is the income variability in the origin country in the first place. Thus, in Table 4, we include the relative income variability $(s/s^F)^3$ and the relative coefficient of variation $(cv/cv^F)^3$ as endogenous regressors. As a first remark, we find that they pass the instrument validity tests. Thus, based on the standard overidentification and weakness tests, we have some confidence about the validity of the instruments for these variables. First-stage regressions for the income differential (y/y^F) and for urbanization (URB) stay the same. Regression (4) shows the model (1) to (3) with the income variability differential $(s/s^F)^3$ as being treated as an additional endogenous variable. We see that this has no impact on the results, which are now presented in regression (5). In regression (6), we use the measure that we view as more appropriate, namely the coefficient of variation differential $(cv/cv^F)^3$. The new regression results for migration are presented in regression (7). Again, we find no changes to the previous results.

We conclude that our previous results are robust to the inclusion of income variability in different ways. Specifically, measuring it by the standard deviation or by the coefficient of variation of income over time, treating it as being exogenous or endogenous, and using its level or its difference with respect to other countries do not impact the results. Conclusively, we do not find sufficient evidence to be able to conclude that income variability has an impact on migration, be it rural to urban or international migration.

5. Some further comments

In several empirical studies, it has been suggested to discriminate between the effects of ‘climate change,’ which is a shift in the average climate, and the effects of ‘climate variability,’ which is a change in the variance of the climate. Given the time scale that we have, it is impossible to know whether changes in temperature or rainfall are actual level changes or simply changes in variability. For example, climatologists work with climate data extending over thousands of years, whereas economists tend to look at data from 30 to at maximum 50 years back. Obviously, at this range, we can never know whether the data that we have is due to climate change or due to a short-run climate variability. Consequently, it is impossible to discriminate between the two since we can actually only observe climate variability on this short time scale.

As another concern, and this is also a problem in our robustness study, one problem with income variability at the macro level is clearly that a lot of micro-variability is simply washed out. For example, assume a country is consisting of two individuals. During the past three years, individual A had an income of 1, 2, and 3, whereas individual B had an income of 3, 2, and 1. Total income at the country level was 4 in each

Table 4. Two-stage regressions.

Regression	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Models	FE2SLS	FE2SLS	FE2SLS	FE2SLS	FE2SLS	FE2SLS	FE2SLS
SE	robust	robust	robust	robust	robust	robust	robust
Stage	1st	1st	2nd	1st	2nd	1st	2nd
Dependent	$\log(v/y^F)$	$\log(\text{URB})$	MIGR	$\log((s/s^F)^3)$	MIGR	$\log((cv/cv^F)^3)$	MIGR
<i>Variable</i>							
RAIN	-0.023 [0.0140]	-0.00332 [0.00832]	0.843 [0.832]	-0.0602 [0.0517]	0.842 [0.817]	-0.0372 [0.0532]	0.841 [0.818]
TEMP	-0.0432*** [0.0153]	-0.0204** [0.00876]	2.841** [1.239]	0.0334 [0.0625]	2.758** [1.229]	0.0747 [0.0634]	2.758** [1.228]
RAIN*AGRI	0.0494*** [0.0187]	0.00162 [0.00997]	-1.258 [0.936]	0.0972 [0.0693]	-1.259 [0.915]	0.0455 [0.0711]	-1.256 [0.916]
TEMP*AGRI	0.00811 [0.0218]	0.0455*** [0.00980]	-4.253*** [1.693]	-0.0214 [0.0768]	-4.127** [1.700]	-0.0374 [0.0804]	-4.127** [1.700]
WAR	-0.0738 [0.0877]	0.0104 [0.0259]	2.997 [5.709]	0.161 [0.232]	2.957 [5.670]	0.118 [0.210]	2.95 [5.670]
WAR ^F	-0.182 [0.150]	0.02 [0.0850]	0.86 [7.194]	-0.489 [0.750]	1.026 [7.115]	-0.631 [0.704]	1.023 [7.109]
$\log(v/y^F)$			21.58*** [7.216]		21.10*** [7.078]		21.38*** [6.921]
$\log(\text{URB})$			67.51*** [24.14]		64.96** [26.24]		65.03** [26.08]
$\log((s/s^F)^3)$							
$\log((cv/cv^F)^3)$							
<i>Instruments</i>							
ΔMoney	0.131** [0.0557]	0.0596* [0.0350]		0.735*** [0.203]		0.612*** [0.216]	0.315 [1.884]

(Continued)

Table 4. (Continued).

Regression	(1)	(2)	(3)	(4)	(5)	(6)	(7)
New State UK	-0.641*** [0.0892]	0.230*** [0.0484]		-0.534 [0.391]		-0.016 [0.400]	
New State	-0.0297 [0.0504]	-0.0362 [0.0338]		1.173*** [0.317]		1.219*** [0.317]	
HW-Dum	Incl.	Incl.	Incl.	Incl.	Incl.	Incl.	Incl.
Region-Dum	Incl.	Incl.	Incl.	Incl.	Incl.	Incl.	Incl.
Time-Dum	Incl.	Incl.	Incl.	Incl.	Incl.	Incl.	Incl.
Region-Time	Incl.	Incl.	Incl.	Incl.	Incl.	Incl.	Incl.
Observations	750	750	750	749	749	749	749
Number of countries	39	39	39	39	39	39	39
F-test	88.87***	65.79***	22.17***	79.27***	17.01***	42.92***	17.07***
F-test on excl. IV	30.84***	12.99***		13.19***		17.01***	
Underid test			7.595***		1.549		1.561
p-value Hansen			0.871				
Endo stat			14.53***		14.389***		14.301***
Root MSE	0.2283	0.09746	10.82	0.8	10.66	0.8233	10.67

Notes: Robust standard errors are in square brackets. y and y^F stand for domestic and foreign GDP per capita, respectively. s and s^F stand for domestic and foreign standard deviation in income, respectively. cv and cv^F stand for domestic and foreign coefficient of variability in income, respectively. 'HW-Dum' stands for the 4 dummies of Hatton and Williamson (2003) for Ghana and Nigeria for the years 1983 and 1985. 'Region-Dum' includes region dummies, 'Time-Dum' time dummies, and 'Region-Time,' time-region dummies. $t - 1$ indicates a one-period lagged variable. R -squared is not shown, because, in the case of 2SLS/IV, it is not an appropriate measure of the goodness of fit and has no statistical meaning (see www.stata.com).

*** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$.

period. Thus, at the macro level, we would believe there to be no income variability. In contrast, it is clear that there is income variability at the household level. If that variability is then the source of migration decisions at the household level, it would be impossible to find the same feedbacks at the macro level. As a consequence, it is more likely to find income variability as a driver of migration decisions at the micro level. However, and as we argued above, this income variability must be viewed relative to the variability in the destination region. This is certainly a problem for cross-individual datasets that very often do not observe the income variability, at the household level, of the destination region. It is clear that, to arrive at a good measure of income variability at the macro level, one would not want to start with aggregate income per se, but one would need to look at the income variability of individuals over time and then aggregate this over the region in question.

6. Conclusions

The results that we present in this article point more toward the importance of the level of income than income variability as a driver of migration at the macroeconomic level. Not only is this suggested through our theoretical model, but also based on our empirical results. However, we also believe that this should not necessarily be the final say yet on income variability versus income levels. As we suggested from the beginning, our approach should be understood as a preliminary step in the analysis of the role of income variability.

For example, one reason for which income variability may not show up as a significant explanatory variable in macroeconomic studies is simply because it is being washed out in the country aggregate measures. Based on the currently available datasets, it will be very difficult, if not impossible, to construct a better cross-country or within-country aggregate measure of income variability. One objective for future research should thus be to take the household-level result on income variability and aggregate this to the country level to see whether the effect is significant. Much more can also be done to better measure the impact of weather shocks on agricultural outputs. In that respect, the recent studies by Beine and Parsons (*in press*) or Schlenker and Lobell (2010) pave the way for key improvements in assessing the relationship between weather variations and migration in sub-Saharan Africa.

Most importantly, in future work, one has to dig a little deeper and really try to understand under which circumstances income variability may play a crucial role and why this role may not be captured by the level of income itself. For example, income variability itself may not be a problem, but the problem comes from negative income shocks. However, these shocks may be better captured via lags of income in the empirical studies.

Also, recent contributions by Barro (2009) suggest that rare disasters induce much larger welfare costs than smaller variability. This suggests that future work should take further moments of the climate or income distribution into account when studying migration decisions. Nevertheless, even small shocks can have large impacts when societies live close to thresholds like subsistence consumption levels. Thus, future works should investigate the role of non-linearities like thresholds.

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Notes

1. By environmentally induced migration decisions, we shall, henceforth, mean any impact from environmental conditions, such as weather variability or natural disasters, on migration decisions, either directly or indirectly through other variables.
2. A list of these studies with a description of their main results is given in Section 3 below.
3. Weather anomalies are calculated as the deviations from a country's long-run mean divided by its long-run standard deviation.
4. We cannot exclude that climatic variations affect conflict (Hsiang, Burke, & Miguel, 2013) and hence wipe out a potential channel to migration. Nonetheless, it does not jeopardize our identification strategy, as empirically, its omission increases the magnitude of the estimated effects of environmental change on migration.
5. The amenity channel has been shown to exist for the case of the USA by Rappaport (2007) and also discussed in the World Development Report (World Bank, 2010).
6. We do not discuss variability around a trend here since it should be obvious that the effect of the trend will be picked up by the income level itself in a regression analysis.
7. Reviewing the studies that have used climatic variations as an instrument for income is outside the scope of this review as it would touch upon a wide variety of fields such as issues related to democratization (Brückner & Ciccone, 2011; Burke & Leigh, 2010), conflict (Miguel, Satyanath, & Sergenti, 2004; Brückner, 2010; Miguel & Satyanath, 2011; or Ciccone, 2011), health (Burke, Gong, & Jones, *in press*; Hoddinott & Kinsey, 2001), financial flows (Arezki & Brückner, 2012; Yang & Choi, 2007), and labor (Rose, 2001). More fundamentally, the search for a source of exogenous variation (for the sake of finding a valid instrument for income shocks) in these related studies means that researchers legitimately only show the significant relationship between certain types of weather shocks and income, while a review should not exclude by construction studies that would not find any relationship between weather shocks and economic outcomes. We thus limit the review to quantitative studies that ensure some degrees of comparability.

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References

- Ahmed, S. A., Diffenbaugh, N. S., Hertel, T. W., Lobell, D. B., Navin, R., Rios, A. R., & Rowhani, P. (2011). Climate volatility and poverty vulnerability in Tanzania. *Global Environmental Change, 21*, 46–55.
- Arezki, R., & Brückner, M. (2012). Commodity windfalls, polarization, and net foreign assets: Panel data evidence on the voracity effect. *Journal of International Economics, 86*, 318–326.
- Barrios, S., Bertinelli, L., & Strobl, E. (2006). Climatic change and rural-urban migration: The case of sub-Saharan Africa. *Journal of Urban Economics, 60*, 357–371.
- Barrios, S., Bertinelli, L., & Strobl, E. (2010). Trends in rainfall and economic growth in Africa: A neglected cause of the African growth tragedy. *Review of Economics and Statistics, 92*, 350–366.
- Barro, R. J. (2009). Rare disasters, asset prices, and welfare costs. *American Economic Review, 99*, 243–264.
- Beegle, K., De Weerd, J., & Dercon, S. (2011). Migration and economic mobility in Tanzania: Evidence from a tracking survey. *Review of Economics and Statistics, 93*, 1010–1033.
- Beine, M., & Parsons, C. (in press). Climatic factors as determinants of international migration. *Scandinavian Journal of Economics*.
- Bettin, G., & Nicolli, F. (2012). *Does climate change foster emigration from less developed countries? Evidence from bilateral data* (Quaderno del Dipartimento di Economia Istituzioni Territorio n.10/2012). Ferrara: Università degli Studi di Ferrara.
- Black, R. (2001). *Environmental refugees: Myth or reality?* (UNHCR Working Paper 34). Geneva: United Nations High Commissioner for Refugees.
- Black, R., Adger, W. N., Arnell, N. W., Dercon, S., Geddes, A., & Thomas, D. (2011). The effect of environmental change on human migration. *Global Environmental Change, 21*, S3–S11.
- Blanc, E. (2012). The impact of climate change on crop yields in sub-Saharan Africa. *American Journal of Climate Change, 1*, 1–13.
- Bohra-Mishra, P., & Massey, D. (2011). Environmental degradation and out-migration: Evidence from Nepal. In E. Piguet, A. Picoud, & P. De Guchteneire (Eds.), *Migration and climate change* (Chap. 4, pp. 74–101). New York, NY: Cambridge University Press.
- Bohra-Mishra, P., Oppenheimer, M., & Hsiang, S. (2014). Nonlinear permanent migration response to climatic variations but minimal response to disasters. *Proceedings of the National Academy of Sciences, 111*, 9780–9785.
- Brückner, M. (2010). Population size and civil conflict risk: Is there a causal link? *The Economic Journal, 120*, 535–550.
- Bruckner, M., & Ciccone, A. (2011). Rain and the democratic window of opportunity. *Econometrica, 79*, 923–947.
- Burke, M., Gong, E., & Jones, K. (in press). Income shocks and HIV in Africa. *Economic Journal*.
- Burke, P., & Leigh, A. (2010). Do output contractions trigger democratic change? *American Economic Journal: Macroeconomics, 2*, 124–157.
- Carvajal, L., & Pereira, I. M. (2009). *Climate shocks and human mobility: Evidence from Nicaragua*. New York, NY: Human Development Report Office, UNDP.
- Ciccone, A. (2011). Economic shocks and civil conflict: A comment. *American Economic Journal: Applied Economics, 3*, 215–212.
- Combes, J.-L., & Ebeke, C. (2011). Remittances and household consumption instability in developing countries. *World Development, 39*, 1076–1089.
- Dell, M., Jones, B. F., & Olken, B. A. (2009). Temperature and income: Reconciling new cross-sectional and panel estimates. *American Economic Review, 99*, 198–204.
- Dell, M., Jones, B., & Olken, B. (2012). Temperature shocks and economic growth: Evidence from the last half century. *American Economic Journal: Macroeconomics, 4*, 66–95.
- Dercon, S. (2004). Growth and shocks: Evidence from rural Ethiopia. *Journal of Development Economics, 74*, 309–329.
- Deschênes, O., & Greenstone, M. (2007). The economic impacts of climate change: Evidence from agricultural output and random fluctuations in weather. *American Economic Review, 97*, 354–385.
- Deschênes, O., & Moretti, E. (2009). Extreme weather events, mortality, and migration. *Review of Economics and Statistics, 91*, 659–681.

- Dillon, A., Mueller, V., & Salau, S. (2011). Migratory responses to agricultural risk in Northern Nigeria. *American Journal of Agricultural Economics*, 93, 1048–1061.
- Drabo, A., & Mbaye, L. M. (in press). Climate change, natural disasters and migration: An empirical analysis in developing countries. *Environment and Development Economics*.
- Ezra, M., & Kiros, G.-E. (2001). Rural out-migration in the drought prone areas of Ethiopia: A multilevel analysis. *International Migration Review*, 35, 749–771.
- Feng, S., Krueger, A. B., & Oppenheimer, M. (2010). Linkages among climate change, crop yields and Mexico-US cross-border migration. *Proceedings of the National Academy of Sciences*, 107, 14257–14262.
- Findley, S. E. (1994). Does drought increase migration? A study of migration from rural Mali during the 1983–1985 drought. *International Migration Review*, 28, 539–553.
- Fisher, A. C., Hanemann, W. M., Roberts, M. J., & Schlenker, W. (2012). The economic impacts of climate change: Evidence from agricultural output and random fluctuations in weather: Comment. *American Economic Review*, 102, 3749–3760.
- Gray, C. L. (2009). Environment, Land, and rural out-migration in the Southern Ecuadorian Andes. *World Development*, 37, 457–468.
- Halliday, T. (2006). Migration, risk, and liquidity constraints in El Salvador. *Economic Development and Cultural Change*, 54, 893–925.
- Hatton, T. J., & Williamson, J. G. (2003). Demographic and economic pressure on emigration out of Africa. *Scandinavian Journal of Economics*, 105, 465–486.
- Henry, S., Paul, B., & Lambin, E. F. (2003). Modelling inter-provincial migration in Burkina Faso, West Africa: The role of socio-demographic and environmental factors. *Applied Geography*, 23, 115–136.
- Henry, S., Schoumaker, B., & Beauchemin, C. (2004). The impact of rainfall on first-out migration: A multi-level event-history analysis in Burkina Faso. *Population and Environment*, 25, 423–460.
- Hoddinott, J., & Kinsey, B. (2001). Child growth in the time of drought. *Oxford Bulletin of Economics and Statistics*, 63, 409–436.
- Hsiang, S. M., Burke, M., & Miguel, E. (2013). Quantifying the influence of climate on human conflict. *Science*, 341, 1255367.
- Jayachandran, S. (2006). Selling labor low: Wage responses to productivity shocks in developing countries. *Journal of Political Economy*, 114, 538–575.
- Kazianga, H., & Udry, C. (2006). Consumption smoothing? Livestock, insurance and drought in rural Burkina Faso. *Journal of Development Economics*, 79, 413–446.
- Kumar, K. K., & Viswanathan, B. (2012). *Weather variability and agriculture-implications for long and short-term migration in India* (Working Paper n. 220). New Delhi: Centre for Development Economics, Delhi School of Economics.
- Lewin, P., Fisher, M., & Weber, B. (2012). Do rainfall conditions push or pull rural migrants: Evidence from Malawi. *Agricultural Economics*, 43, 191–204.
- Lilleør, H. B., & Van den Broeck, K. (2011). Economic drivers of migration and climate change in LDCs. *Global Environmental Change*, 21, S70–S81.
- Marchiori, L., Maystadt, J.-F., & Schumacher, I. (2011). *The impact of weather anomalies on migration in sub-Saharan Africa* (Discussion Paper n. 2011034). Louvain-la-Neuve: Institut de Recherches Economiques et Sociales (IRES), Université catholique de Louvain.
- Marchiori, L., Maystadt, J.-F., & Schumacher, I. (2012). The impact of weather anomalies on migration in sub-Saharan Africa. *Journal of Environmental Economics and Management*, 63, 355–374.
- Massey, D. S., Axinn, W. G., & Ghimire, D. J. (2010). Environmental change and out-migration: Evidence from Nepal. *Population and Environment*, 32, 109–136.
- Meze-Hausken, E. (2004). Contrasting climate variability and meteorological drought with perceived drought and climate change in northern Ethiopia. *Climate Research*, 27, 19–31.
- Miguel, E., & Satyanath, S. (2011). Re-examining economic shocks and civil conflict. *American Economic Journal: Applied Economics*, 3, 228–232.
- Miguel, E., Satyanath, S., & Sergenti, E. (2004). Economic shocks and civil conflict: An instrumental variables approach. *Journal of Political Economy*, 112, 725–753.
- Mueller, V., Gray, C., & Kosec, K. (2014). Heat stress increases long-term human migration in rural Pakistan. *Nature Climate Change*, 4, 182–185.

- Mueller, V., & Osgood, D. (2009). Long-term impacts of droughts on labour markets in developing countries: Evidence from Brazil. *Journal of Development Studies*, 45, 1651–1662.
- Munshi, K. (2003). Networks in the modern economy: Mexican migrants in the U.S. labor market. *The Quarterly Journal of Economics*, 118, 549–599.
- Naude, W. (2010). The determinants of migration from sub-Saharan African countries. *Journal of African Economies*, 19, 330–356.
- Paul, B. (2005). Evidence against disaster-induced migration: The 2004 tornado in North-Central Bangladesh. *Disasters*, 29, 370–385.
- Rappaport, J. (2007). Moving to nice weather. *Regional Science and Urban Economics*, 37, 375–398.
- Reuveny, R., & Moore, W. H. (2009). Does environmental degradation influence migration? Emigration to developed countries in the late 1980s and 1990s. *Social Science Quarterly*, 90, 461–479.
- Rose, E. (2001). Ex ante and ex post labor supply response to risk in a low-income area. *Journal of Development Economics*, 64, 371–388.
- Rosenzweig, M. R., & Stark, O. (1989). Consumption smoothing, migration, and marriage: Evidence from rural India. *Journal of Political Economy*, 97, 905–926.
- Rowhani, P., Lobell, D. B., Linderman, M., & Navin, R. (2011). Climate variability and crop production in Tanzania. *Agricultural and Forest Meteorology*, 151, 449–460.
- Saldaña-Zorrilla, S. O., & Sandberg, K. (2009). Impact of climate-related disasters on human migration in Mexico: A spatial model. *Climatic Change*, 96, 97–118.
- Schlenker, W., Hanemann, W. M., & Fisher, A. C. (2006). The impact of global warming on U.S. agriculture: An econometric analysis of optimal growing conditions. *Review of Economics and Statistics*, 88, 113–125.
- Schlenker, W., & Lobell, D. (2010). Robust negative impacts of climate change on African agriculture. *Environmental Research Letters*, 5(1), 1–8.
- Schlenker, W., & Roberts, M. (2009). Nonlinear temperature effects indicate severe damages to U.S. crop yields under climate change. *Proceedings of the National Academy of Sciences*, 106, 15594–15598.
- Stern, N., Peters, S., Bakhshi, V., Bowen, A., Cameron, C., Catovsky, S., & Crane, D. (2006). *Stern review: The economics of climate change*. Cambridge: Cambridge University Press.
- Strobl, E., & Valfort, M.-A. (in press). The effect of weather-induced internal migration on local labor markets. Evidence from Uganda. *The World Bank Economic Review*. doi: [10.1093/wber/lht029](https://doi.org/10.1093/wber/lht029)
- Warner, K. (2010). Global environmental change and migration: Governance challenges. *Global Environmental Change*, 20, 402–413.
- World Bank. (2010). *World development report 2010: Development and climate change*. Washington, DC: World Bank.
- Yang, D., & Choi, H. (2007). Are remittances insurance? Evidence from rainfall shocks in the Philippines. *The World Bank Economic Review*, 21, 219–248.