Working Papers

Paper 70, May 2013

Climatic Factors as Determinants of International Migration

Michel Beine and Christopher Parsons

This paper is published by the International Migration Institute (IMI), Oxford Department of International Development (QEH), University of Oxford, 3 Mansfield Road, Oxford OX1 3TB, UK (www.imi.ox.ac.uk).

The IMI Working Papers Series

The International Migration Institute (IMI) has been publishing working papers since its foundation in 2006. The series presents current research in the field of international migration. The papers in this series:

- analyse migration as part of broader global change
- contribute to new theoretical approaches
- advance understanding of the multi-level forces driving migration

Abstract

We examine environmental change as a potential determinant of international migration. We distinguish between unexpected short-run factors, captured by natural disasters, as well as long-run climate change and climate variability captured by deviations and volatilities of temperatures and rainfall from and around their long-run averages. Starting from a simple neo-classical model we use a panel dataset of bilateral migration flows for the period 1960-2000 that allows us to control for numerous time-varying and time invariant factors. We find no direct impact of climatic change on international migration across our entire sample. These results are robust when conditioning on characteristics of origin countries as well as when further considering migrants returning home and the potential endogeneity of our network variable. In contrast, there is evidence of indirect effects of environmental factors going through wages. We further find strong evidence that natural disasters beget greater flows of migrants to urban environs.

Keywords: International migration, Climate change, Natural disasters, Income maximization

Author: Michel Beine, University of Luxembourg, CREAM and CES-Ifo, michel.beine@uni.lu; and Christopher Parsons, International Migration Institute, University of Oxford, christopher.parsons@qeh.ox.ac.uk

This paper was commissioned under the auspices of the Foresight Global Environmental Migration project and the authors gratefully acknowledge funding from the UK Government Department for Business, Innovation and Skills. The authors are indebted to Tim Osborn for providing the environmental data and Simon Gosling who went beyond the call of duty to facilitate their use at short notice. Gratitude also needs to be extended to the members of the DEMIG (The Determinants of International Migration) project, based at the International Migration Institute at the University of Oxford, that received funding from the European Research Council under the European Community's Seventh Framework Programme (FP7/2007-2013) / ERC Grant Agreement 240940. (See www.imi.ox.ac.uk/research-projects/demig) for allowing privileged access to their bilateral visa data. The authors also wish to thank the Lead Expert Group of the Foresight Global Environmental Migration project, especially Stefan Dercon, in addition to Cecile Couharde, Richard Disney, Frederic Docquier, Markus Eberhardt, Giovanni Facchini, Katrin Millock, Richard Upward and L. Alan Winters for useful and timely comments.

Contents

1 Introduction

Climate change remains at the vanguard of the international development policy debate. The Stern Review (2007) while analyzing the economic impact of climate change emphasized the global consequences of inaction, the need for a coordinated international response and the fact that developing countries will likely suffer disproportionately. This final point was also stressed in the first UN intergovernmental report on climate change, which further stated that "the gravest effects of climate change may be those on human migration as millions will be displaced" (IPCC 1990). Myers (1996) counted some 25 million 'environmental refugees' in 1995 and forecast some 200 million by 2050 (Myers 2002). Although the term 'environmental migrant' is perhaps not a useful distinction to make (Castles 2002), these estimates nevertheless highlight the magnitude of possible future movements that might at least in part be driven by environmental change. Despite these dire predictions, surprisingly few papers examine either the direct or indirect impacts of environmental factors on international migration. This article contributes to the literature by examining, for the first time, the overall (macroeconomic) impact of the effects of climate change on international migration using a panel of global bilateral migration flows.

Climate change manifests itself in many guises and may impinge upon migration in myriad ways. These include extreme weather phenomena and variability in temperature and precipitation (Boko et al 2007). Marchiori et al (2011) advocate two channels, (one direct, and the other indirect), via which these types of climatic factors beget international migration. Most obviously, climate change has the greatest impact upon countries which rely more heavily upon agricultural activities (Deschenes and Greenstone 2007), which in turn might encourage international migration directly. Most likely such climate change will result in greater urbanisation, the increased pressures from which might foster greater incentives to migrate abroad. Rural-urban migration might also indirectly lead to international migration however, since increased rural-urban migration results in downward pressure on urban wages thus creating greater incentives for emigration. Less obviously, climate change may also directly result in interational migration because of a change of amenities (Rapoport 2007) or else due to changes in non-market costs such as a higher incidence of disease (Patz et al 2001). In either case, the effects of climate change most affect the rural poor in developing countries; exactly those which are least able to self-insure or adopt alternative coping strategies to deal with the onset of climate change.

Piguet et al (2011) emphasize two main, interconnected, arguments concerning the climate change-migration nexus. Their first pertains to the fact that identifying environmental factors as the sole cause of migration may never prove possible, since complex interactions exist between climatic change and other categories of deterministic factors; economic, social (and/or cultural), political and demographic. Societies already vulnerable in some sense therefore, will likely be disproportionately challenged by the onset of climatic change, with the rural poor arguably affected the most. Dell et al 2008 for example, show that a one degree rise in temperature in a given year translates into a reduction of annual economic growth of 1.1%

points in poor countries (but have negligible effects in rich countries) and furthermore than the effects of higher temperatures have widespread effects including reductions in agricultural productivity, industrial output, investment and increasing political stability. Furthermore, Dell et al (2009) show that similar rises in temperature result in reductions in per capita GDP both across and within countries and within states while their theoretical model predicts that approximately half of these reductions in income may be mitigated by 'adapting' to the environment, through migration, changes in fertility rates and mortality. Barrios et al (2010) provide evidence that sub-Saharan Africa would have reduced the gap in per capita GDP (by between 15-40%) vis-à-vis the rest of the developing world should no decline in rainfall have occurred in this region after 1960. Since climatic variations affect both individuals' incentives to migrate, together with their ability to do so; disentangling migrants' primary motivation to migrate, whether it be forced or voluntary, i.e. identifying economic incentives from environmental 'push' factors, proves impossible. At the macroeconomic level, the best we can do is to assess the relative direct impact of climate change and climate variability on international migration, having accounted for other classes of determinants. Since macroeconomic studies examining climate change often suffer from selection biases since unobservable country characteristics are difficult to control for (Lilleør and Van de Broeck 2011), the inclusion of all main classes of determinants together with the implementation of a far more rigorous empirical specification are undoubted strengths of the current paper.

Piguet et al's second argument relates to the political framework in which any environmentally motivated migration flows may occur, and how destination countries' should receive 'environmental migrants'. While their detailed discussion of how such migrants might be received is not directly relevant for the current work; their argument nevertheless serves to highlight the key role of destination country migration policies as determinants of bilateral migration flows.

This paper is most closely related to the wider discourse on climate change and the macroeconomic literature on the determinants of international migration, both areas of which have been remarkably understudied. Climate change no doubt has heterogeneous impacts across countries (Black et al 2011) which are a function of the socio-economic idiosyncrasies at origin, and which in turn determine individuals' vulnerability to climate change. As a result, many existing studies have reached alternative conclusions in a variety of differing contextual settings. Munshi (2003) for example, finds a statistically significant and positive correlation between emigration from rural Mexico to the United States and low rainfall at origin. Similarly, Barrios et al (2006) find rain shortages significantly increase migration from rural areas across Sub-Saharan Africa, but not in other parts of the developing world. Marchiori et al (2011), find that climate variations spur both internal and international migration in sub-Saharan Africa and furthermore that urbanization may mitigate the effects of climate change on international migration. More broadly, Afifi and Warner (2008) find that a number of variables which capture environmental degradation are positively correlated with increased numbers of international migrants. Conversely, Findley (1994) in the case of Mali, finds that episodes of drought led to decreased number of migrants due to the tightening of credit constraints, the result of rising food prices; especially to other African countries and to France. Finally, Kniveton et al (2008) in the context of international migration from two Mexican regions, find (in the case of Durango) that greater amounts of rainfall lead to increased numbers of emigrants to the United States.

The evidence concerning the effects on migration of natural disasters is also mixed. Piguet et al (2011) highlight a range of micro-level studies which conclude that such phenomena result in short-term internal migrations, as opposed to long-distance or international movements. Indeed, Paul (2005) finds evidence that the 2004 tornado in north-central Bangladesh resulted in no migration whatsoever. However, a growing body of macro-level literature instead finds a positive relationship between natural disasters and international migration; see for example Reuveny and Moore (2009) or Drabo and Mbaye (2011). Naudé (2008) finds only very weak evidence of any link between natural disasters and migration, arguing instead that conflicts at origin exert a far greater influence. Halliday (2006) instead finds that earthquakes significantly reduce migration from El Salvador to the United States. Doubts persist however, as to the validity of the econometric approaches adopted in many of these macro-level studies, most notably in their failure to account for unobserved heterogeneity that might be driving their results.

Environmental determinants have remained wholly absent from the macro-economic literature on the determinants of migration. In two of the earliest contributions (of the latest wave of migration research), Hatton and Williamson (2001, 2002) focus on the demographic and economic determinants of international emigration rates from Africa, and more broadly from various countries across differing historical periods, respectively. Using emigration rates at origin (and/or at the destination level) tends to mask the fact that the migration process is extremely heterogeneous across both sending and receiving regions. Rather the implementation of data at the bilateral level allows accounting for the peculiarities between the two countries such as distance, diasporas and cultural proximity that also play important roles.

Pedersen et al (2008) investigate the extent to which selection and network effects foster bilateral migration flows for 27 countries of the OECD.[1] Network effects, i.e. the positive role played by social capital in driving observed migration flows, are found to be strong, but to vary significantly across country-pairs. To examine the role of selection effects, they test the 'welfare magnet' hypothesis (see for example Borjas 1987) i.e. that migrants from poorer countries will be disproportionately attracted to countries with higher levels of social welfare provision. Since data are lacking, the authors' approach is to interact the share of tax revenue collected at destination with origin country income levels. They fail to find any conclusive evidence, which they argue might be due to restrictive destination country migration policies that these authors fail to account for explicitly.

This matter is taken up in more detail in Mayda (2010) who again investigates the OECD as the destination region. A variable is constructed which captures changes in destination country migration policy. The results show that when destination migration policies become less

[1] The focus on the countries of the OECD as destinations in the majority of studies is a consequence of the general paucity of global migration data.

restrictive, positive 'pull' factors are found to exert a larger influence on bilateral emigration rates (as when compared to the sample average). Unfortunately, the important role of migrant networks is largely omitted from the analysis, which might explain some of the low coefficients of determination obtained.

More recently, papers have better emphasized the underlying theory. Based on the income maximisation approach (Roy, 1950; Borjas, 1987), Grogger and Hanson (2011) and Beine et al (2011) investigate the determinants of the size and composition of migration patterns at the world level, again using the OECD as destination countries. Grogger and Hanson (2011) analyse migrant stocks and focus in particular upon the role of the wage differential between the origin and the destination of migrants. They omit the role of migrant networks although some historical diasporic component will likely be captured by their measures of colonial links. Beine et al (2011) instead analyse migration flows in the nineties and the extent to which diasporas have contributed to shaping these flows; while abstracting from explicitly modeling the role of wage differentials. Both of these studies use cross-sectional data however, which necessarily restricts the scope of their analysis. Ortega and Peri (2009) again draw upon the income maximisation approach to investigate the causes (and consequences) of international migration to the OECD in a panel which includes explicit measures of migration policy. These authors utilize the panel dimensions to their fullest, since they employ both destination (time invariant) and origin time-varying fixed effects to account for a multitude of unobserved factors which might otherwise be driving any observed relationship. Unfortunately, environmental determinants are omitted from their study.

The aim of this paper is to reconcile the various innovations from across the literature, to test the overall impact of environmental change on international migration using a previously unexploited panel dataset of international migration. We augment a traditional neo-classical utility maximisation model of migration to incorporate environmental factors in the context of 'amenities' at origin. We consider the onset of sudden climatic phenomena, which are largely unexpected, in addition to long-term changes in both temperature and rainfall. Recognizing the multi-dimensionality of individuals' decision to migrate, we incorporate variables to account for economic, demographic, social (and/or cultural) and political factors which existing studies have shown to be important determinants of international migration. We also account (in part) for the role of immigration policies and welfare systems in receiving countries. To the best of our knowledge, our paper is the first to investigate the impact of long term climate change on international migration using bilateral data and the first to estimate the impact of natural disasters and changes in temperature and precipitation simultaneously. More generally, our paper is the first macroeconomic study to examine the determinants of international migration using a model grounded in micro-economic theory, whilst also accounting for economic, demographic, social, political and environmental determinants.

Importantly, our panel includes countries of the global South as both origins and destinations. The omission of nations of the relatively poorer global 'South', results in the most significant proportion of international migration being completed omitted from analysis. From a sending perspective this is particularly important in the context of climate change because agriculture remains more prevalent in poorer societies. It is also crucial to account for Southern countries from a receiving perspective, since migrants from developing countries often cannot afford to pay the migration costs involved in long-distant emigration to countries of the relatively more affluent global 'North'. The expansive dataset of 166 destinations and 137 origins, therefore allows us to better capture the heterogeneous impacts of climate change across countries and over time. We exploit the longitudinal dimension of the migration data to control for unobserved heterogeneity of different types to provide long-run estimates of the effects of climate change around the globe. Having controlled for differences between countries, we then examine global patterns by conditioning our regressions on particular country characteristics, for example the availability of natural water sources or the relative importance of the agricultural sector at origin.

Using our primary specification, we find no direct evidence of climate change, climate variability or of natural disasters on international migration in the medium to long run across our entire sample. These results are robust when further considering migrants returning home and th potential endogeneity of migrant networks. Further conditioning our regressions upon origin country characteristics, we find evidence that shortfalls in precipitation constrain migration to developing countries from countries which rely more heavily upon agriculture and spur movements to developing countries from countries with fewer groundwater reserves. Further using the rate of urbanization as a proxy for internal migration we find strong evidence that natural disasters beget greater flows of migrants to urban environs. Our results also support some indirect effects of environmental factors on international migration through wage differentials.

2 Theoretical background

2.1 Income maximization approach

Our theoretical foundation is derived from the income maximization framework, which is used to identify the main determinants of international migration and to pin down our empirical specification. The income maximization approach was first introduced by Roy (1951) and Borjas (1987) and further developed by Grogger and Hanson (2011) and Beine et al. (2011). The recent advances further consider migrants' choice of moving to potentially all destinations and yield pseudo-gravity models which can be readily estimated. One of the main strengths of the income maximization approach is the ability to generate predictions in line with the recent (macro-economic) literature on international migration. By grounding our empirical specification in a theory with a well proven track record, we also address one of the main shortcomings of the macro level climate change literature, which generally adopt looser, ad-hoc specifications. This model has been successfully applied to analyze the specific role of wage differentials (Grogger and Hanson, 2011), the significance of social networks (Beine et al. 2011) and the brain drain phenomenon (Gibson and McKenzie, 2011).

Our model comprises homogeneous agents who decide whether or not to migrate, and then their optimal destination should they decide to move. Agents therefore maximize their utility across the full set of destinations which includes the home country as well as all possible foreign countries globally. Let $N_{i,t}$ be the size of the native population in country i at time t. At each period of time, the natives choose their optimal location among a set of n alternative destinations. These alternative destinations include their home country i. The number of natives choosing the optimal destination j is denoted by $N_{ij,t}$.[2] The choice of the optimal location by each native is based on the comparison of the utility associated with each possible destination. An individual's utility is log-linear in income and depends upon the characteristics of their country of residence as well as any migration costs. The utility of an individual born in country i and staying in country i at time t is given by:

$$u_{ii,t} = ln(w_{i,t}) + A_{i,t} + \varepsilon_{i,t} \tag{1}$$

Where $w_{i,t}$ refers to the instantaneous wage in country i at time t; where $A_{i,t}$ denotes country i's characteristics (amenities, public expenditures, employment opportunities) including climate at time t and $\varepsilon_{i,t}$ is a iid extreme-value distributed random term. The utility related to migration from country i to country j at time t is given by:

$$u_{ij,t} = ln(w_{j,t}) + A_{j,t} - C_{ij,t}(.) + \varepsilon_{j,t} \tag{2}$$

where $C_{ij,t}(.)$ denotes the migration costs of moving from i to j at time t.

When the random term follows an iid extreme-value distribution, we can apply the results in McFadden (1984) to write the probability that an agent born in country i will move to country j as:

$$\Pr\left[u_{ij,t} = \max_k u_{ik,t}\right] = \frac{N_{ij,t}}{N_{i,t}} = \frac{\exp\left[ln(w_{j,t}) + A_{j,t} - C_{ij,t}(.)\right]}{\sum_k \exp\left[ln(w_{k,t}) + A_{k,t} - C_{ik,t}\right]}$$

The bilateral migration rate between i and j $(N_{ij,t}/N_{ii,t})$ can therefore be written as:

$$\frac{N_{ij,t}}{N_{ii,t}} = \frac{\exp\left[ln(w_{j,t}) + A_{j,t} - C_{ij,t}(.)\right]}{\exp\left[ln(w_{i,t}) + A_{i,t}\right]} \tag{3}$$

where $N_{ij,t}$ is the number of migrants in the i-j migration corridor at time t. Taking logs, we obtain an expression giving the log of the bilateral migration rate between i and j at time t:

$$\ln\left(\frac{N_{ij,t}}{N_{ii,t}}\right) = ln\left(\frac{w_{j,t}}{w_{i,t}}\right) + A_{j,t} - A_{i,t} - C_{ij,t}(.) \tag{4}$$

[2]It should be clear that while $N_{i,t}$ is a stock, $N_{ij,t}$ is a flow. Furthermore $\sum_j N_{ij,t} = N_{i,t}$. In the Anderson (2011) set-up, $N_{ij,t}$ is the analogue to the export flow from i to j at time t; $N_{ii,t}$ is akin to the value of goods sold by domestic firms in their own country and $N_{i,t}$ is comparable to the total stock of goods available at time t for export and domestic consumption.

Expression (4) therefore identifies the main components of the aggregate bilateral migration rate: the wage differential in the form of the wage ratio ($\frac{w_{j,t}}{w_{i,t}}$), the factors at destination $A_{j,t}$, the factors at origin ($A_{i,t}$) and the migration costs between i and j, $C_{ij,t}$.[3]

Migration costs, $C_{ij,t}$, are in turn themselves a function of components of various dimensions and we assume separability in these costs. They depend upon factors that are dyadic and change over time such as networks, which are captured by the stock of migrants from i living in country j before the migration process takes place and which are denoted by $M_{ij,t}$. Migration costs are also contingent upon factors that are dyadic but time invariant, such as distance (d_{ij}), contiguity i.e. if countries share a common border (b_{ij}) and linguistic proximity (l_{ij}). Migration costs also depend upon factors specific to the origin country but which are constant over time (x_i), for example geographic location. Finally, migration costs include factors that are destination specific, either constant over time (x_j), time specific (x_t) or else time-varying ($x_{j,t}$). Leading candidates for these latter factors include destination countries' migration policies and the benevolence of the welfare state at destination.[4]

Putting everything together, our cost function may be expressed as:

$$C_{ij,t} = c(M_{ij,t}, d_{ij}, b_{ij}, l_{ij}, x_i, x_j, x_t, x_{j,t}) \tag{5}$$

Non-pecuniary costs (and benefits) at origin are collected in $A_{i,t}$[5], and these comprise; political variables ($Pol_{i,t}$), demographic differences across origin countries ($Dep_{i,t}$) and environmental factors $E_{i,t}$. The expected theoretical sign of the political regime at origin is unknown, *a priori*. This is due to the fact that while repressive political regimes might increase residents' desire to leave, they typically also increase the costs of migration. It might be extremely difficult for residents living in a dictatorship to obtain authorization to leave the country for example. Foreign diplomatic representation also tends to be less important in such countries, which in turn, significantly raises the costs of obtaining a visa for emigration candidates. The total

[3]Note that Black et al's (2011) categorisation of deterministic factors which include push, pull and intervening factors is appropriately captured in expression (4)

[4]Anderson (2011) derives a structural gravity model of migration analogous to his (second) seminal contribution on the use of gravity models in the context of international trade (see Anderson and van Wincoop 2003). The key additional insight, in the context of goods, is that trade between pairs of countries depends not only upon the barriers between themselves, but also upon the various barriers (termed multilateral resistances) of both countries with the rest of the world. Should both country's multilateral resistance increase with the rest of the world therefore, then both countries have greater incentives to trade relatively more with one another. The key insight in these authors arguments likely holds in the context of international migration. We opt to use the utility maximisation approach since it has proven itself in numerous applications. However, it is important to note that our inclusion of destination time-varying fixed effects will completely account for any multilateral resistances in receiving countries (see Feenstra 2004), which is arguably the most important aspect in the context of international migration given destination country migration policies.

[5]Note that given the focus of our paper, we do not devote specific attention to factors at destination ($A_{j,t}$). The panel dimension of the data allows us to capture the role of these factors through the inclusion of dummies combining the j and the t dimension. See the following section for details. By construction, their imposition also captures macro economic trend effects over time, which are typically captured with separate time dummies.

dependency ratio is used to capture demographic push factors at origin. This is calculated as the total population aged less than 15 or over 64, divided by those of working age. A higher total dependency ratio therefore, indicates the presence of fewer workers to support both the young and the elderly, either directly or else through the tax system. Conversely, a lower dependency ratio suggests instead, that greater numbers of working age people exist at origin, which are in some sense more free to emigrate abroad. Other variables typically used to capture demographic push factors at origin include the lag (by 20 years) of the birth rate, which is purported to capture a cohort effect at origin, or else the share of young people at origin, typically those aged 15-29, that typically exhibit the greatest propensity to migrate abroad (see Hatton and Williamson 2001, 2002). Typically, we would expect a rise in either of these variables to ultimately beget further migration. Both of these mechanisms are captured through the total dependency ratio however, since an increase in either the lagged birth rate or else greater numbers of those aged between 15-29 in the current period, lead to reductions in the total dependency ratio.

As far as our environmental factors are concerned, we draw upon a similar taxonomy as Piguet et al (2011), who distinguish between two main types of factors. First, we consider short-run factors, i.e. completely unexpected natural disasters such as floods, earthquakes and volcanic eruptions. Such events tend to drive people out of their regions within a short period of time and with a sense of urgency. Second, we capture what we can consider to be long-run environmental factors, which comprise long run deviations or variations in both temperature and precipitation around their long run averages [6]. In contrast to natural disasters, these environmental factors are (partly at least) expected by agents. The expression for non-pecuniary costs and benefits at origin may thus be written as:

$$A_{i,t} = A(Pol_{i,t}, Dep_{i,t}, E_{i,t}) \quad (6)$$

3 Estimation

3.1 From theory to estimation

Combining equations (4), (5) and (6), whilst assuming separability in migration costs and including an error term, leads to the following econometric specification:

$$ln(\frac{N_{ij,t}}{N_{ii,t}}) = ln(\frac{w_{j,t}}{w_{i,t}}) + A_{j,t} - A(Pol_{i,t}) - A(Dep_{i,t}) - A(E_{i,t}) - C(M_{ij,t}) - C(d_{ij}) - C(b_{ij}) - C(l_{ij}) - c(x_{j,t}) - c(x_j) - c(x_i) + \epsilon_{ij,t} \quad (7)$$

[6]This taxonomy is akin to that favoured by Lilleør and Van de Broeck (2011) when distinguishing 'climate change' from 'climate variation'. Note that we do not consider the effects of rising sea levels which are predicted to result in large numbers of 'environmental migrants', see Black et al (2008)

This specification therefore models bilateral migration rates, i.e. the number of migrants from country i in country j as a ratio of natives from i who have chosen to stay at home.[7] Since our primary focus is upon environmental changes as push factors of migration, we use appropriate fixed effects and dummies to capture the impact of destination specific factors and time-invariant origin factors. We first use fixed effects $\alpha_{j,t}$ that are specific to each destination and each period. These capture the role of amenities at destination $A_{j,t}$ as well as the role of destination specific cost variables $c(x_{j,t})$ and $c(x_j)$ as well as time specific $c(x_t)$ (such as the general decrease in transportation costs) . Crucially, these variables also (in part) capture migration policies, which remain largely absent from much of the existing literature. The unavailability of data capturing migration policies has been a recurrent issue in the empirical macroeconomic literature devoted to international migration. The panel dimension of our data allows us to alleviate this problem and significantly lowers the risk of misspecification. Time-invariant origin specific push factors A_i as well as time-invariant origin related cost variables $c(x_i)$, are captured by origin country dummies α_i.

Substituting in (7) leads to the following estimable equation:

$$ln(\frac{N_{ij,t}}{N_{ii,t}}) = \beta_1 ln(\frac{w_{j,t}}{w_{i,t}}) + +\beta_2 ln(1 + M_{ij,t}) + \beta_3 ln(Pol_{i,t}) + \beta_4 ln(Dep_{i,t}) + \beta_5 ln(E_{i,t}) + \beta_6 d_{ij} + \beta_7 b_{ij} + \beta_8 l_{ij} + \alpha_{j,t} + \alpha_i + \epsilon_{ij,t} \quad (8)$$

Given the focus on the impact of environmental factors, we adopt a parsimonious specification in terms of observable controls. With the exception of environmental factors therefore, for which we allow a detailed inspection, we choose a limited number of key indicators which we believe capture the main fundamentals that drive the observed patterns of international migration. Importantly, those factors have a robust impact on bilateral migration with expected signs across the full sample and the many subsamples we consider throughout this paper. In particular, we include variables that capture the wage differential ($\frac{w_{j,t}}{w_{i,t}}$), network ($M_{ij,t}$), political determinants at origin ($Pol_{i,t}$), demographic factors at origin ($Dep_{i,t}$), physical distance (d_{ij}), shared borders (b_{ij}) and linguistic proximity (l_{ij}).

3.2 Econometric issues

The estimation of equation (8) is at first glance straightforward. Indeed, OLS estimation is feasible but is likely to yield inconsistent estimates of the coefficients. One of the main reasons for the inconsistency is the presence of a high proportion of zero values in the dependent

[7] Note that this specification differs from the one of Beine et al. (2011). Beine et al. (2011) analyze migration flows N_{ij} using country fixed effects allowing to control for N_{ii}. The ability to recover N_{ii} from our data allows us to work with a specification that is more closely related to the theoretical equilibrium bilateral migration rate.

variable $N_{ij,t}$, i.e. the bilateral flows. The presence of these zeros generates two important biases in OLS estimation. First, since equation (8) is a pseudo-gravity model in a double log form, the presence of zeros leads to the exclusion of many observations. If the country pairs with zero flows have a different population distribution compared to pairs with positive flows, this exclusion generates the usual selection bias. The second bias is more subtle and has been clearly identified by Santos-Silva and Tenreyro (2006). They show, in particular, that if the variance of $\epsilon_{ij,t}$ depends on the covariates of $\frac{N_{ij,t}}{N_{ii,t}}$, then its expected value will also depend on some of the regressors in the presence of zeros. This in turn invalidates one important assumption of consistency of OLS estimates. Furthermore, they show that the inconsistency of parameter estimates is also found using alternative techniques such as the (threshold) Tobit model. In contrast, in the case of heteroscedasticity and a significant proportion of zero values, the Poisson pseudo maximum likelihood (PPML) estimator generates unbiased estimators of the parameters of (8). As a result, we use the PPML estimator to estimate model (8). This model generates consistent estimates even when the underlying distribution is not strictly Poisson, i.e. in cases of over-dispersion.[8] We calculate robust standard errors to ensure appropriate t-statistics result.

4 Data

4.1 Migration data

The resurgence in migration research has arisen in large part due to the proliferation of available datasets on bilateral migration. This paper draws upon Özden et al (2011), which details bilateral migration stocks between 226 origin and destination countries, territories and dependencies, which correspond to the last five completed census rounds, 1960-2000. Drawing upon the largest depository of censuses and population registers ever collated, the authors pay particularly close attention to the underlying problems encountered when making migration statistics comparable. These include the alternative definitions of migration, how countries variously code their census data (together with how aggregated origin regions recorded in censuses may be disaggregated), the varying years in which censuses are conducted, the changing of borders of nation states over time and cases where census data are missing altogether.

The resulting database therefore addresses the prior lack of migration data for developing countries as destinations, whilst also greatly expanding the number of time periods to which the data pertain. This proves important, not only because South-South migration dominates global migration in levels, but also because climatic change disproportionately affects those in developing nations. Moreover, since liquidity constraints are more likely binding in relatively poorer nations; any international migratory response to climate change is more likely to be

[8] Furthermore, in an extended analysis of their first paper, using Monte Carlo simulations, Santos-Silva and Tenreyro (2011) show that the PPML estimator performs well even in the presence of a large number of zero observations.

regional - most likely to neighbouring countries - as opposed to the countries of the OECD, the only countries for which, until very recently, longitudinal data were available (see for example Docquier and Marfouk 2006). The panel dimensions of the data prove particularly important in the context of an empirical examination at the global level, since it allows controlling for a plethora of time-varying and time invariant factors, across a broad spectrum of countries for which data are unavailable. In other words, we can meaningfully control for myriad unobserved factors that might otherwise confound results. To ensure consistency across countries over time, we implement the version of the data which is merged to the aggregates of the United Nations (see Özden et al 2011).

Several issues remain with regards the way the data are implemented in our empirical model however. First, although the underlying data relate to migrant stocks, we proxy migration flows by differencing these data for contiguous census rounds. Inevitably, negative migration flows result, when bilateral migrant stocks decline over time. This might be due to migrants returning home, moving on to a third-party country or death. In constructing this proxy we assume therefore that both deaths and return migration are small relative to net flows. The relevance of this assumption is difficult if not impossible to test for in the absence of appropriate data. For the sake of robustness however, we re-calculate our migration flows assuming that all negative flows constitute return migration. In other words, we sum our initial positive flows between countries i and j and the absolute value of the negative flow from j to i.

A second key issue relates to the large number of zero stocks and flows which appear in the data. To highlight the significance of this issue, Table 1, shows the proportions of zero values for bilateral stocks for each decade from the underlying migration database. Although the proportion of zeroes declines over time, around half of the observations in the proposed dependent variable are still zero in each decade. In the absence of an appropriate estimator the presence of these zero observations would clearly result in a selection bias.

Table 1: Proportion of Zero values in the underlying migration data

Decade	Pct
1960	62
1970	59
1980	56
1990	51
2000	47

Source: Özden et al (2011).

A final issue is to recover $N_{ii,t}$ from the data to compute bilateral migration rates. $N_{ii,t}$ comprises the number of natives from i having chosen to stay at home. This is recovered from the population data by subtracting the total number of immigrants in country i, which in turn is calculated from the migration data as $\sum_{j=1}^{J} N_{ji,t}$. [9]

4.2 Climatic factors

Our short-term environmental factors are captured through a natural disasters variable, which comprises: droughts, earthquakes, extreme temperatures, floods, storms, volcanic eruptions, epidemics, insect infestations and miscellaneous occurrences. These data are obtained from The International Disaster Database, which is compiled by the Centre for Research on the Epidemiology of Disasters.[10] This variable is simply calculated as the total number of natural disasters in a given decade. The mean number of natural disasters in a given decade in our sample is 13 and the standard deviation is 23. The minimum value of this variable is 0 while the maximum is 250.

To capture long-run environmental factors, we use precipitation and temperature data obtained from the TS3.0 dataset, created under the auspices of the QUEST-GSI project and obtained from the Climatic Research Unit of the University of East Anglia. The original observations correspond to high-resolution 0.5° by 0.5° grids and are collected on a monthly basis. Area weights are used to aggregate the data to the country level. Annual observations are then calculated as the average of monthly observations and decennial observations as the means across years.

While the impact of these variables have found to vary across localities, uncertainty also remains with regards the most appropriate way of formulating these variables for use in our empirical model. Measuring precipitation and temperatures in absolute levels may not be appropriate since this formulation fails to adequately capture migratory responses to changes from standard climatic conditions. Rather these would capture whether migration is more prevalent from rainier or warmer countries. This is unlikely to prove useful since tropical countries, for example, are more likely to be poorer on average. Any significant results would instead likely capture part of the effect of GDP per capita at origin, which in turn would be highly correlated with our measure of wage differentials.

Instead, we calculate two separate measures, termed deviations and (as is standard in the climate change literature), anomalies (Marchiori et al 2011). Deviations (in both temperatures and precipitation) are calculated as the differences of countries' decadal averages from their long-run averages. Across our sample, the average deviation in rainfall from the corresponding decadal average is -1.43mm, its standard deviation is 6.65mm and its minimum and maximum values are -33.3mm and 39.3mm, respectively. The average deviation in temperature from its corresponding decadal average is +0.15 degrees Celsius, its standard deviation is 0.29 degrees Celsius and its minimum and maximum values are -0.54 and +1.24 degrees Celsius, respectively. Collectively, these figures demonstrate the impact of climate change in terms of

[9] Note that only a full bilateral migration matrix allows to do that. This explains why Beine et al. (2011) who rely on the Docquier and Marfouk (2006) database are not able to compute $N_{ii,t}$.

[10] See: http://www.emdat.be.

the planet becoming warmer and recieving less precipitation on average across our sample. Following Marchiori et al (2011), we take the long-run to refer to the period 1901-2000 and anomalies are calculated as the deviations of countries' decadal averages (in temperatures and precipitation) from their long-run average, divided by the corresponding long-run standard deviation, formally defined as:

$$Clim_{i,t} = \frac{Clim_{level,it} - \mu_i^{LR}(Clim_{level})}{\sigma_i^{LR}(Clim_{level})} \tag{9}$$

Where $Clim_{level,it}$ denotes the level of rainfall or temperature of country i in decade t; $\mu_i^{LR}(Clim_{level})$ denotes country i's long-run mean average rainfall or temperature and similarly, $\sigma_i^{LR}(Clim_{level})$ denotes country i's long-run standard deviation of rainfall or temperature. However, we take the absolute value of the numerator of (9) and use positive and negative anomalies separately, since these are likely to cancel one another out.

4.3 Remaining covariates

The remaining covariates come from a variety of sources. The wage differential is proxied as the log of the ratio of per capita GDP in destination and origin. These data are taken from an updated version of (what is described in detail in) Gleditsch (2002), which represents an extension of the Penn World tables (Summers and Heston 1991). Our migrant network or diaspora variable, is again taken from Özden et al (2011), and is defined as the bilateral migrant stock in the beginning year to which a flow corresponds. Measures of geodesic distance, contiguity and linguistic proximity are taken from Head, Mayer and Ries (2010).[11] The language dummy, takes the value one should at least 9% of both populations in a country-pair speak the same language.

Demographic conditions in sending countries are captured using the total dependency ratio at origin; these data are taken from the United Nations World Population Prospects database (2010). Since migration policies are included in the model through destination country time-varying fixed effects, our last variable captures political push factors from origin. This is calculated as the sum of the number of episodes of international violence at origin over the ten-year period to which a particular flow corresponds, with the exception of the last year. For example the number of episodes for 1990-1999 are summed and then equated with the flow from 1990-2000. These data are obtained from the Major Episodes of Political Violence database of the Center for Systemic Peace.[12] Once all of the data are merged, 137 origin and 166 destination countries remain, a full list of which can be found in Appendix 1.[13]

[11] These can be downloaded at: http://www.cepii.fr/anglaisgraph/bdd/gravity.htm.

[12] See: http://www.systemicpeace.org/inscr/inscr.htm.

[13] The resulting number of countries is due to a combination of missing data for our GDP per capita, dependency ratio and international violence variables.

5 Results

5.1 What the model does (and doesn't do)

High frequency migration data are only published by a limited number of countries globally. Adopting a truly international perspective therefore, necessarily involves a trade-off between geographic coverage and the frequency of observations, which in our case are observed decennially. It is important to understand the consequences of this sacrifice. It is not likely that we will capture seasonal or temporary migrations. Instead our results will yield the average effects of climate change both over time and across countries. These will also be the overall impact, so if a particular variable has a heterogenous impact across different countries, only the average impact will be detected. Nor does our model say anything as to the composition of migration flows, i.e. as to migrants' status, since we assume agents are homogenous. The underlying migration database captures migrants of all ages and education levels as well as both genders, but focuses upon an economic concept of migration. Finally, estimations based on equation (8) capture only the direct effect of environmental factors on international emigration. To the extent that climatic factors decrease the income in origin countries, climatic factors might lead to a higher wage differential over time, which in turn is found to lead to more emigration. The absence of a direct effect therefore does not rule out the existence of some significant indirect effect going through economic incentives. This conjecture is explored in section 5.7.

In summary then, our model examines the impacts of both short and long-run climate change on medium to long-run changes in international migration. According to Piguet et al. (2011) the weight of existing evidence suggests that 'rapid onset phenomena' result in short-term internal displacements as opposed to migrations further afield for longer durations. Whereas there is a tendency to associate international migration with migration over long distances, this might not necessarily be the case. In regions with porous borders, such as Africa, the costs of crossing an international border might well be lower than an internal migration over longer distances. On average however, due to the increased costs of obtaining passports and visas, we can assume that this conjecture generally holds. Moreover, Piguet et al. (2011) argue that many of those affected by such events return home quickly to begin rebuilding their lives. These authors conjecture that slower onset phenomena, i.e. gradual and sustained changes in the environment over time, will likely result in longer-term migration, from which we might also infer, migration over greater distances. As previously argued however, the macro level literature paints a very different picture. Naudé (2008) for example, argues that the correlation between natural disasters and migration will be even stronger than the links between migration and long-term climate change since such unforseen events give little time for people to adapt.

5.2 Baseline results

Table 2 shows the results of estimating equation 8. We consider two measures of long-run climatic factors, deviations and anomalies. We further separate positive deviations and anomalies from negative deviations and anomalies, since should they not be separated and instead combined into a single variable, the positive and negative deviations and anomalies may cancel one another out.

In all regressions, both types of fixed effects are included, i.e. origin country fixed effects α_i and time-destination fixed effects $\alpha_{j,t}$. In each regression, short-run climatic factors are captured by the number of natural disasters during the decade in the origin country. Columns (1) and (2) reports the results with anomalies. Columns (3) and (4) report the ones with deviations. Columns (1) and (3) present results relating to positive temperatures and negative rainfall. Columns (2) and (4) instead present the results for negative temperatures and positive rainfall.

*****Table 2 about here*****

The coefficients are elasticities or semi-elasticities such a 10% change corresponds to an equivalent percentage change of the dependent variable equal to the size of the coefficient. For example a 10% rise in the wage ratio between origin and destination is associated with a positive increase in decennial bilateral migration rates of slighter more than 3%. For the dummy variable such as common language, the corresponding coefficient can again be interpreted as a percentage change only this time for switching the dummy from zero to one.

Overall, the regressions explain more than 60% of the variation in the observed migration flows, which is deemed reasonable given that the migration rates are extremely heterogeneous across corridors. Given the breadth of our sample and the fact that our independent variable is proxied by the difference in migrant stocks, the R^2 are deemed reasonable. The coefficients of all of the explanatory variables - with the exception of those which capture long-run environmental change - are highly significant and in the expected direction. The coefficients are also very stable across the various models. Higher wage differentials, a larger diaspora, a lower dependency ratio at origin, shared linguistic roots, contiguity and more frequent episodes of international violence all beget higher migration flows. Conversely, the larger the distance between origin and destination, i.e. the greater the migration costs, the lower, on average, are the associated migration flows.

To give a flavour of what the estimated elasticities of the other covariates imply, starting with the wage ratio, the value of the third quartile of the distribution of the wage ratio is about 3. This means that between countries characterized by such a difference, an increase by 0.3 in the wage ratio will lead to an increase of 3% in the migration rates between the two countries. Similarly, an increase of 10% in the diaspora abroad will lead to an increase of about 4% in the rate of new migrants over the next ten years. The obtained elasticity of the network effect is slightly lower than the one estimated by Beine et al. (2011) which is about 0.65. Nevertheless, Beine et al. (2011) include only OECD countries as destinations, giving important weight to South-North migration. It is expected that migrants involved in this type of migration will heavily rely on networks. Interestingly, our subsequent sub-sample analysis focusing on migration to the global South (Table 6) yields elasticities that are much closer to those obtained by Beine et al. (2011). Common language is also found to be an important determinant. Compared to pairs of countries with similar conditions, countries sharing a common language experience migration rates that are 50% higher. The presence of international violence at origin is a strong push factor as reflected by the estimated elasticity. Nevertheless, it should be emphasized that this concerns only a small set of countries, since more than 90% did not have any episode of this kind over the last forty years under investigation. Finally, the negative effect of the dependency ratio is in line with the fact that a younger population has a higher propensity to migrate, all else being equal.

Turning now to the environmental variables, the unconditional results yield no statistically significant results whatsoever, either concerning long-run or short-run factors. These regressions capture the average impact of the explanatory factors on migration rates over time and across countries. On the face of it, in line with some previous microeconomic findings such as Munshi (2003), we might expect that both rain shortfalls (and high temperatures) provide an additional motivation for residents to become migrants. The insignificance of the response to environmental factors gives rise to various alternative explanations.

First, as previously stated, the environmental variables only capture the direct impact of climatic factors on international migration. To the extent that climatic factors decrease the income in origin countries, climatic factors might lead to a higher wage differential over time, which in turn engenders additional emigration. The fact that we find a significant and stable elasticity of emigration with respect to wage differential opens up the possibility of some indirect effect of climatic factors going through the wage differential. This conjecture is explored in section 5.7.

Second, the results here only concern international migration. As argued by Black et al (2011), these are exactly the same factors which might in turn result in lower incomes from which people have to pay to migrate. This is especially the case in poor countries. In other words, although residents may choose to become international migrants, they might not have the resources to actually move. If liquidity constraints are binding, internal migration to less affected areas within the same country is a valuable option. This case is not captured by our data although we investigate this possibility in an extension. This interpretation in turn calls for some additional inspection however to allow for some heterogenous response across origin countries to climatic events. Generally speaking, one possible interpretation of the results is that our estimation mixes up cases that are very different from one another. If there is some impact of climatic factors, this will depend on one or several factor(s) shaping the sensitivity of people to the climatic events. Regressions that are not conditioned upon various country characteristics would therefore be unable to uncover the heterogeneity in the response.

A third line of reasoning concerns the frequency of our observations, which are decennial. The literature suggests that unexpected climatic shocks likely result in more temporary migrations as opposed to long term climate change or variability which instead result in more permanent migrations. It is quite possible therefore that migrants *are* directly impacted by climatic change and variability as captured by our variables, but are not picked up in estimation due to their returning home. Without more detailed microeconomic or bilateral migration flow data, this hypothesis is impossible to test here however.

5.3 Heterogenous effects

The heterogeneity in the responses of individuals can be related to several dimensions. First, the impact of climatic factors might depend upon initial climatic conditions. Some rise in average temperature might be particularly detrimental in already hot areas. Likewise, shortages in average rainfall will particularly affect those countries with poorer access to natural water sources. We therefore use two conditioning climate variables. The first relates to temperature. We consider hot countries as ones over the median of the world temperatures (about 22.7 degrees). The second instead relates to the presence of groundwater. Again we use the same classification. Countries are classified as having fewer groundwater reserves if they fall below the median of the world groundwater distribution.

Another way to view heterogeneity is to distinguish countries' geographical location. Climate change does not affect countries equally and countries closer to the equator are often reported to be disproportionately affected. They also tend to be poorer compared to countries from the northern hemisphere. Distance to the equator has been used as an instrument for factors such as institutions in empirical studies of growth. Accordingly, we interact the long-run climatic factors with a dummy that takes the value 1 should a country lie below (or above) the median latitude to test whether the impact of temperature and rain anomalies depends upon being located close to the equator. A final conditioning scheme is the economic structure. One might expect that the share of the agricultural sector in the economy will affect the sensitivity of the country to climatic events. Farmers and others living in rural areas are often mentioned as those mostly affected by climate change. As such, we use interaction terms between climatic factors and a dummy variable which takes the value one should the share of agriculture in total GDP be greater than the median.

Tables 3 and 4 about here

The results are reported in Tables 3 and 4. Table 3 gives the results using anomalies involving excess temperature and rainfall shortage. Table 4 reports the findings using anomalies involving rain excess and colder temperatures. In each table, column (1) gives the results conditioned by temperature. Column (2) reports findings conditional on a country's agriculture share. Column (3) reports the results conditioned on the presence of groundwater and finally, column (4), reports the results with latitude as the conditioning variable.

The results in tables 3 and 4 do not support any significant direct impact of either short-run or long-run climatic factors on out migration. Whatever the conditioning scheme, positive or negative rain or temperature anomalies do not seem to lead to more migration. Beyond the comments provided above, one possible interpretation of these results is that climatic impacts are far more complex than can be captured by a single dimension. In fact, it might be possible that excess temperatures or rain shortfalls will lead to more emigration but only in a particular context, for example in middle income countries (so that migration candidates can overcome migration costs) in circumstances in which the agriculture share is significant. Such circumstances are difficult to capture using observed variables corresponding to all these dimensions. As an alternative, a further conditioning strategy is introduced in the following section.

5.4 Sub-Samples, Migrations to the Global 'North' and 'South'

In this section, we continue with our conditioning scheme from the preceding section and continue by further splitting our sample; restricting the regressions to include destinations from the countries of the global 'North' or 'South'.[14] The results for the countries of the 'North' are presented in Table 5, while Table 6 presents the results restricting migrations to the countries of the global 'South'.[15] The results demonstrate marked differences between the forces which shape migration to the North and South. All of the determinants previously tested are important for migrations to the North, with the exception of contiguity and the environmental variables. In comparison with the sample average however, network effects are less important. This reflects the fact that compared to the global sample, migration to the North features greater numbers of skilled agents (Docquier and Rapoport, 2011). Skilled migrants have been found to be less sensitive to networks than unskilled migrants (Beine et al., 2011, McKenzie and Rapoport, 2010). In contrast, wage differentials are found to play a greater role, which is consistent with the main incentives of migrants coming to OECD countries. The elasticity of the wage ratio is approximately 25% higher than the one obtained with the whole sample. The coefficient on distance is around one, while the coefficient of contiguity is insignificant. This reflects the fact that migration to the North involves moves over longer distances. The point estimates on the shared common ethnic language are around twice as large when compared to the sample average. Once again, this reflects the importance of skilled migration for which knowledge of languages proves important.

These results are in stark contrast to those for migrations to the global South. In this case, we find no statistically significant effect of wage differentials, shared linguistic roots or international violence. We do however, find a strong and positive effect on international migration of sharing a common border, reflecting that South-South migration involves moves over shorter distances. In the case of migrations to the global South however, we also find some statistically

[14]The countries of the global 'North' are taken to be those that remained affluent over the period 1960-2000. These include Australia, New Zealand, Japan, Canada, the USA, the EU-15 and the countries of the European Free Trade Association.

[15]These tables only present the results analogous to those presented in Table 3. In other words, we abstract from deviations which involve excess rainfall and colder temperatures. For the sake of brevity we also do not provide unconditioned results across both restricted samples. The coefficients obtained from these latter regressions may be obtained from the authors although the results are not significantly different from those presented in Tables 5 and 6.

significant impacts of long-run environmental change. Across the sample of countries which rely more heavily upon agriculture and which experienced negative volatilities in rainfall, the century average precipitation was 125mm, while the average rainfall in 2000 was 118mm. A 10% rise in this negative volatility, which is equivalent to a decrease in average rainfall across the decade 1990-2000 of approximately 1mm, is associated with a decrease in international migration to the countries of the global South of (2.41-1.14=) 1.27%. This result provides supportive evidence for the conclusions on Findley (1994). This result is similar to those which are conditioned upon the initial level of groundwater, only this time the signs are reversed. Across the sample of countries which have fewer water resources, the century average precipitation was 89mm, while the average decadal rainfall across the decade 1990-2000 was just 80mm. A 10% rise in this negative volatility, which is again equivalent to a decrease in average rainfall across the decade 1990-2000 of approximately 1mm, is associated with an increase in international migration of (3.82-1.37=) 2.45% to the countries of the global South. In both tables, across all the various specifications, we again fail to find any affect of natural disasters on international migration.

*****Tables 5 and 6 about here*****

5.5 Robustness check: adjustment for return migration

In the benchmark estimations, we have made a particular choice regarding the dependent variables, i.e. bilateral migration rates. Indeed, we have excluded from the sample negative flows and have estimated our models on a sample including only zero or positive flows. Negative flows are a result of a reduction in migrant stocks. Decreases in bilateral migration stocks may reflect particular processes regarding demographic developments however. One is the combination of significant death rates of some old diasporas which are not fully counterbalanced by new migration flows. A similar case may emerge if significant emigration to countries other than migrants' country of origin occurs. A final possibility is that return migration outweighs the arrival of new migrants. Ideally, one should account for those flows since return migration actually reflects the impact of push factors at destination or the reduced attractiveness of destination countries over time.

While there is no direct way to account for return migration, migration to third-party countries and deaths, we provide a robustness check based on one particular extreme hypothesis. We recompute the bilateral migration flows assuming that decreases in migration stocks totally reflect the return of migrants to their origin country. We add the opposite value of the negative flows between country i and country j to the observed migration flow between country j and country i. Using the new bilateral migration flows, we re-estimate model (8). We follow the strategy considered in sections 5.2. and 5.3. again considering therefore any unconditional response in addition to interactions conditional on various country characteristics (equivalent to table 3). The results are reported in Tables 7 and 8. Regarding the role of the other covariates such as wages, networks, distance and the factors at origin results are extremely similar to those of the benchmark regressions.

*****Tables 7 and 8 about here*****

The robustness checks yield interesting results. We find that the results peculiar to the impact of natural disasters are quite robust with respect to the benchmark results. We do not find any impact of natural disasters on international emigration. With regards the role of long-run factors, the coefficients are of a similar magnitude and in the same direction as those presented in table 2, but in some cases are now statistically significant, thereby assigning a modest role to excess temperatures as push factors. Further conditioning our results on origin characteristics we find no conclusive evidence of climatic change, climatic variation or of natural disasters upon international migration.

5.6 Robustness check: potential endogeneity of the network

An important econometric issue in our regressions is the potential endogeneity of the diaspora. Endogeneity of the network in migration models mainly arises due to potential omission of unobserved factors that might be correlated with both the error term (and thus migration flows) and with the diaspora. Note that this omitted factor must lie in the ijt dimension to qualify.[16] Potential unobserved factors of that kind include measures of cultural or political proximity between two countries that are often difficult, if not impossible, to measure with quantitative data. One concern in the current context is that the presence of endogeneity might lead to a significant bias in the estimation of the network effect as well as of the other key parameters of the model.

There are basically two procedures to deal with such an issue. The most traditional approach is instrumental variable estimation. In a similar setting, Beine et al (2011), while restricting their analysis to a cross-section comprising migratory movements to the countries of the OECD in the 1990s, implement a set of instruments including guest worker programs and a variable capturing the unobserved diaspora in the 1960s. Importantly for the purposes of the current paper, these authors find that the estimated coefficient on their diaspora variable is robust to reverse causality. Given the panel data dimensions of our data set, such instruments are not valid here. Furthermore, the search of an instrument that has an ijt dimension, which is correlated to the size of the initial bilateral network and uncorrelated with the corresponding subsequent bilateral migration flow proves to be very difficult, if not impossible.

As an alternative, we augment model (7) with the inclusion of an observable variable of dimension ijt which might capture (part) of these unobserved time-varying dyadic factors. In turn, we can check whether our results regarding climatic factors are robust to such an inclusion. One conceivably credible variable, which can be used to capture such omissions, is a bilateral time-varying dummy variable that equals one should nationals of one origin

[16] Another orthadox source of endogeneity, namely reverse causality, does not apply here at first glance, since network measures are predetermined with respect to migration flows.

country require a visa in a specific destination. Presently, these data - originally recorded by the International Air Transport Association in their Travel Information Manuals and collated under the auspices of the Determinants of International Migration (DEMIG) Project at the International Migration Institute based at the University of Oxford - are only available for some 47 destination countries (see Appendix) and only for 3 years; 1979, 1989 and 1999. These data capture whether individuals require visas for the purposes of tourism and social visits in other nations. Nevertheless, given the doubtless fact that the issuance of such visas for foreign nationals is highly correlated with current political realities and historical cultural occurrences, their implementation should be effective in terms of testing for an omitted variable in the ijt dimension.[17]

*****Table 9 about here*****

The visa data for each of the three available years are equated in estimation to the same decade over which the decennial migrant flow occurred.[18] The first column in Table 9 reports the results when including the bilateral visa variable in estimation, while the second column presents the comparable results with the same number of observations when the visa variable is excluded. Given the reduced coverage of this variable in terms of both countries and time periods, the number of observations falls to some 16,135. Broadly, the results are comparable to the unconditional regression results presented in Tables 2 and 3 and the differences that do exist can be attributed to sample selection given the significantly reduced number of observations. These differences include an insignificant impact upon migration flows of countries being contiguously located, a stronger influence of distance and perhaps most starkly, the insignificance of the wage differential. Importantly, the wage differential is insignificant in the results in both columns 1 and 2, i.e. with and without the visa variable, demonstrating the fact that sample selection leads to this result and conversely the importance – in terms of the significance of our wage differential proxy - of maintaining a global sample of countries in our foremost estimations. This insignificance is almost certainly due to the fact that the reduced sample includes many countries at a more similar level of development i.e. the wealthier nations of the world and the few relatively poor countries included in this sample often favour sending migrants to countries omitted from the sample, which conspires to reduce the variability in this variable across countries.

For the sake of our robustness check however, the results in Table 9, which limits the analysis to positive temperature anomalies and negative precipitation anomalies, are heartening. First of

[17]This approach should only be regarded as a robustness check of our results for at least for four reasons. First, the inclusion of the visa data in estimation leads to quite a large decrease in the sample size in terms of i, j and t. In turn, this might generate a sample selection issue. Second, and relatedly, many developing countries are dropped from the sample, while previously we have stressed the importance of South-South migration in the current context. Third, only three years of data are available, which makes the correspondance with the migration flows less optimal (see below). Finally, the bilateral visa variable might also be endogenous itself.

[18]These visa data are therefore not ideal since they refer to the last years in each decade over which the decennial flow occurred. Ideally data would be available for the middle year of each decade since this would be more representative of the availability of visas over the decade but currently the data obtained from the DEMIG project are the only data available.

all, since the coefficient on our newly introduced visa variable is highly significant while its sign is in the predicted direction. Should countries mandate nationals of foreign countries to apply for a visa to enter their borders, the migrant rates between this country-pair will on average be 55% lower. Since the visa data refer to temporary migrations (tourism and social visits), while instead the migration data refer to permanent migration flows and because decennial flows are calculated as the difference in migrant stocks, this reduction in rates can be attributed to factors other than those already captured in estimation. Importantly, the direct effects remain insignificant with the inclusion of the visa variable however, which therefore provides additional evidence as to the exogeneity of the network effect.

5.7 Indirect effects of environmental factors

As emphasized previously, the estimations results based on equation (8) only capture the direct effect(s) of environmental factors on international emigration. An absence of direct effects however does not rule out the existence of indirect effects. Such indirect effects might operate through the mechanism of wages at origin being impacted by climatic shocks, which in turn widens the gap between domestic and foreign wages. The fact that we find a robust and stable positive elasticity of international migration flows with respect to the wage differential suggests that this channel might be operative. Previous evidence in favour of this channel has been provided in particular contexts.[19]

Using our measures of environmental factors, both in terms of short-term and longer-term shocks, we explore the existence of an indirect channel in our full sample of origin and destination countries. Building upon the dyadic nature of our variables, we run the following auxiliary regression:

$$ln(\frac{w_{j,t}}{w_{i,t}}) = \beta_1 ln(E_{i,t}) + \beta_3 ln(Pol_{i,t}) + \beta_4 ln(Dep_{i,t}) + \beta_5 ln(1 + M_{ij,t}) + \beta_6 d_{ij} + \beta_7 b_{ij} + \beta_8 l_{ij} + \alpha_{j,t} + \alpha_i + \epsilon_{ij,t} \quad (10)$$

in which the same notations of the variables apply as before. The environmental long-run factors are once again captured by rainfall and temperature anomalies.[20] As before, we use five different samples: the full sample of countries and subsamples based upon our conditioning

[19]To name but a few studies, Munshi (2003) shows in the case of Mexico-US migration that rainfall affects local labour market conditions, which in turn begets further emigration to the US. Mueller and Quisumbing (2011) find that the 1998 'flood of the century' in Bangladesh induced significant wage losses in affected areas. Mueller and Osgood (2009) conduct a similar analysis in the case of droughts having taken place in Brazil .

[20]We focus here upon rainfall shortages and excess temperature as in Table 3 since these deviations deliver a natural interpretation in terms of economic impact. The theoretical impact of excess rainfall and temperature shortage is less intuitive. However, including those anomalies does not change the current results. Those additional results are available upon request.

variables, namely hotter intitial climate, countries that are more dependent upon agriculture, countries with low endowments of groundwater and countries located closer to the equator. The definition of those countries follows the ones used before in regressions of Tables 3, 4, 5 and 6.

*****Table 10 about here*****

Table 10 reports the estimation results. The results yield three principle messages. First, we find a very robust result for natural disasters, suggesting that the occurrence of natural disasters puts downward pressure on domestic wages thereby widening the wage differential. The positive impact holds for all samples although the impact is found to be stronger in countries that can be expected to be more vulnerable. This is for instance the case in countries with hot climates and with a relatively large share of agriculture in GDP. Second, for these vulnerable countries, we also find a positive and robust impact of the rainfall shortages on the wage differential. This is consistent with the results documented in the microeconomic literature (e.g. Munshi, 2003). In line with the theoretical expectations, the impact is found to be stronger in countries which have fewer groundwater resources. When all countries are considered, with developed countries included, this effect disappears, which is intuitive given the importance of economic activities that are insulated from the influence of rainfalls. Finally, the results concerning anomalies in terms of excess temperature are much less intuitive and suggest that the channel through which temperature can affect local labour market conditions is much more complex.

These results are suggestive of an econometric strategy to deal with the potential endogeneity of wage differentials. Our framework is founded upon dyadic data, which strongly mitigates the potential endogeneity of wages with respect to international migration. With few exceptions, there is no bilateral flow whose magnitude is large enough to generate an impact on the wage at origin or/and at destination. Nevertheless, this concern might be more relevant in studies using unilateral data, i.e. analysis aggregating all destinations by origin. Our benchmark and current results ones suggest that natural disasters (and to a lesser extent rainfall variations) are suitable instruments of the domestic wage level. On the one hand, the presence of indirect effects suggests that these variables qualify as strong instruments. On the other hand, the benchmark results emphasizing the absence of direct effect on the magnitude of emigration supports the validity of the exclusion restriction.

6 The internal migration hypothesis

The previous results provide little support for the hypothesis that long-run climate changes and natural disasters have spurred significant international migration. While we find some role for those phenomena under particular circumstances, the overall impact remains limited. In any case, our results question the idea that climate change will create a large rise in the number of international ('environmental') migrants/refugees. In particular, we provide evidence that environmental factors play little role compared to economic, political, demographic and social variables. Does this imply that climatic factors do not increase people's mobility? Not necessarily. One possibility is that people affected by adverse climatic change or by natural disasters move internally rather than internationally. This possibility might be particularly relevant in developing countries in which people are likely to be financially constrained. If climatic changes tend to depress income, then liquidity constraints might prevent people to move internationally since international migration costs are significantly larger. In that case, internal migration might be preferred instead.

In this section, we investigate whether there is empirical support for a relationship between climatic factors and internal migration in our sample. A direct test in the previous econometric framework we relied upon is impossible, since no data on internal migration is available for all countries for the period of our investigation. Data on migration within the same country definitely exist in some countries. Data on interprovincial migration flows in Canada is for instance available over a 20-year period. Nevertheless, at the world level, there are no data on internal migration which is comparable across countries and over time.

An alternative way of capturing internal migration is to use the evolution of urbanization of countries. The idea is that internal movements of people, dominated by rural to urban migration, leads to an increase in the urbanization rate. This idea has been implemented by Barrios et al. (2006) who look at the impact of climatic change on the pattern of urbanization in sub-Saharan African countries. These authors look specifically at the role of the change in rainfall, which in a context of water shortages, leads people from rural areas to migrate to cities. Their sample comprises developing countries although the authors focus upon sub-Saharan African countries. We extend Barrios et al. (2006)'s work by looking at the role of our climatic variables for the complete sample of countries over the full investigation period. We account for the traditional determinants of the urbanization process identified in the empirical literature (see for example Davis and Henderson, 2003). The controls include the level of democracy, the level of income, population density at the country level as well as openness. The estimated relationship takes the following form:

$$ln(Urb_{i,t}) = \beta_1 ln(X_{i,t}) + \beta_2 ln(E_{i,t}) + \alpha_t + \alpha_i + \epsilon_{i,t} \quad (11)$$

where $X_{i,t}$ comprises the controls of urbanization of country i at time t, and $E_{i,t}$ includes as before the environmental factors. The model includes country and time fixed effects controlling for the time-invariant country specific factors and for the country-invariant time specific factors, respectively. The model is estimated for two samples over the full period (1960-2000) again using decennial data. The first sample includes all countries, while the second includes only developing countries. Since the inclusion of $X_{i,t}$ significantly reduces the number of observations due to missing data, we start with the full model but also present the results of more parsimonious specifications. Regarding the long-run climatic factors, we implement those which capture excess temperatures and rain shortages as in Tables 3 and 5.[21]

[21]We obtain similar results with excess of rain and negative deviations of temperature as well as with

*****Table 10 about here*****

The results of Table 11 provide some interesting insights. First, the process of urbanization is found to be significantly different between developed and developing countries. This is not surprizing given the importance of factors such as income or the industrial development. With respect to sensitivities of internal migration (as proxied by urbanization), there are also some significant differences. Climatic factors play little role at the world level, i.e. when mixing up developed and developing countries. Neither the long-run deviation of temperature and rainfall nor the occurrence of natural disasters appear to be robust determinants of internal mobility. In contrast, for developing countries, natural disasters turn out to increase urbanization, even when accounting for its traditional correlates. The positive elasticity of urbanization to the number of natural disasters is consistent with the fact that people from rural areas affected by natural disasters tend to migrate primarily to the cities of their country. This is also consistent with the fact that potential migrants from developing countries will favour domestic destinations that involve lower migration costs, in turn implying that liquidity constraints might be binding for a significant number of movers.

7 Conclusion

In this paper we first derive a simple utility maximization model, which incorporates environmental change at origin. We then test this model using a previously unexploited panel dataset of bilateral migration flows, which cover the period 1960-2000. We account for all classifications of usual determinants of migration and additionally implement origin specific and destination country-year fixed effects to account for numerous unobserved factors. To date, this is arguably the most sophisticated macroeconomic model used to assess the effects of climate change on international migration.

First, we find little to no support for any direct relationship between either short-run or long-run climatic change on international migration. These results are robust when further considering migrants returning home and the potential endogeneity of our network variable. While our findings are certainly at odds with the macro-level literature, our results offer support to much of the micro-level climate change literature which instead argues that the environmental change tends to result in shorter, internal movements. Further conditioning our regressions upon origin country characteristics, we find evidence that shortfalls in precipitation constrain migration to developing countries from countries which rely more heavily upon agriculture and spur movements to developing countries from countries with fewer groundwater reserves.

Second, we subsequently use the rate of urbanization as a proxy for internal migration and find strong evidence that natural disasters beget greater flows of migrants to urban environs.

volatility measures in the sense that we do not find any significant effect. These are available upon request.

Finally, although our results show that climate change and climatic variations have little direct impact upon long-run international migration we find evidence of the indirect effects of climatic factors. In particular, natural disasters and rainfall shortages at origin are found to result in a widening gap between wages at origin (in countries already vulnerable to climate change) and at destination.

8 References

Anderson, J. E. and E. can Wincoop (2003),"Gravity with Gravitas: A Solution to the Border Puzzle", *American Economic Review*, vol. 69 (1), pp. 106-116.

Anderson, J. E. (2011), "The Gravity Model", *Annual Review of Economics*, vol. 3 *forthcoming*

Afifi, T. and K., Warner, (2008), "The Impact of Environmental Degradation on Migration Flows across Countries". Working Paper No.5/2008, UNU-EHS, Bonn.

Barrios, S., L., Bertinelli, and E., Strobl, (2006), "Climatic change and rural-urban migration: The case of sub-Saharan Africa," *Journal of Urban Economics*, vol. 60(3), pages 357-371, November.

Barrios, S., L., Bertinelli, and E., Strobl, (2010). "Trends in Rainfall and Economic Growth in Africa: A Neglected Cause of the African Growth Tragedy", *The Review of Economics and Statistics*, vol. 92(2), pages 350-366, 08.

Beine, M., F. Docquier and C. Özden (2011), "Diasporas", *Journal of Development Economics*, 95(1), 30-41.

Black, R., Kniveton, D., Skeldon, R., Coppard, D., Murata, A., and Schmidt-Verkerk, K., (2008). "Demographics and Climate Change: Future Trends and their Policy Implications for Migration". Working Paper T-27, Development Research Centre on Migration, Globalisation and Poverty, University of Sussex, Brighton, UK.

Black, R., D. Kniveton and K. Schmidt-Verkerk, (2011), "Migration and climate change: towards an integrated assessment of sensitivity", *Environment and Planning A*, volume 43.

Boko, M., I. Niang, A., Nyong, C., Vogel, A., Githeko, M., Medany, B., Osman-Elasha, R., Tabo, and O., Yanda, (2007), "Africa. Climate Change 2007: Impacts, adaption and vulnerability". Contribution of working group II. In Parry, M., Canziana, O., Palutikof, J., can der Linden, P. J., and Hanson, C., editors, Forth assessment report of the intergovernmental panel on climate change. Cambridge University Press, Cambridge.

Borjas, G (1987), "Self-selection and the earnings of migrants", *American Economic Review*, 77 (4), 531-53.

Castles, S. (2002), "Environmental Change and Forced Migration: Making Sense of the Debate, New Issues in Refugee Research", *UNHCR Research Paper* (70)

Davis, J.C. and J.V. Henderson (2003), "Evidence on the Political Economy of the Urbanization Process", *Journal of Urban Economics*, 53, 98-125.

Dell, M., B. F. Jones and B. A. Olken, (2008), "Climate Change and Economic Growth: Evidence from the Last Half Century". *NBER Working Paper Series*, Vol. w14132, pp. -, 2008.

Dell, M., B. F. Jones and B. A. Olken, (2009), "Temperature and Income: Reconciling New

Cross-Sectional and Panel Estimates." *American Economic Review Papers & Proceedings*, 99, 2 (2009): 198-204.

Deschenes, O. and M. Greenstone (2007), "The Economic Impacts of Climate Change: Evidence from Agricultural Output and Random Fluctuations", American Economic Review, 99, 2:198-204.

Docquier, F. and A. Marfouk (2006), "International migration by educational attainment (1990-2000)", in C. Özden and M. Schiff (eds). International Migration, Remittances and Development, Palgrave Macmillan: New York (2006), chapter 5.

Docquier, F. and H. Rapoport (2011), "Globalization, Brain Drain and Development", Journal of Economic Literature, Forthcoming.

Drabo A. , and M. K., Mbaye, (2011), "Climate Change, Natural Disasters and Migration: An Empirical Approach according to Educational Level, the Gender and the Geographical Position", Conference Paper presented at the 17th Annual International Sustainable Development Research Conference, 8-10 May, 2011.

Feenstra, R. (2004), "Advanced International Trade: Theory and Evidence", Princeton University Press, Princeton, NJ.

Findley S. E., (1994), "Does Drought Increase Migration? A Study of Migration from Rural Mali during the 1983-85 Drought", *International Migration Review*, Vol. 28, No. 3.

Gibson, J. and D. McKenzie (2011), "The Microeconomic Determinants of Emigration and Return Migration of the Best and Brightest: Evidence from the Pacific", *Journal of Development Economics*, 95(1), 18-29.

Gleditsch, Kristian S. 2002. "Expanded Trade and GDP Data," Journal of Conflict Resolution 46: 712-24.

Grogger, J., and G.H. Hanson, (2011), "Income Maximisation and the selection and sorting of international Migrants, *Journal of Development Economics*, 95(1), 42-54.

Halliday T., (2006) "Migration, risk, and liquidity constraints in El Salvador", *Economic Development and Cultural Change*, University of Chicago, Chicago.

Hatton, T. J. and J. G., Williamson, (2001). "Demographic and Economic Pressure on Emigration out of Africa," IZA Discussion Papers 250, Institute for the Study of Labor, Bonn (IZA).

Hatton, T. J. and J. G., Williamson, (2002) "What Fundamentals Drive World Migration?". NBER Working Paper Series, Vol. w9159, pp. -, 2002.

Head, K., T., Mayer and J., Ries, (2010). "The erosion of colonial trade linkages after independence," *Journal of International Economics*, Elsevier, vol. 81(1), pages 1-14, May.

International Panel on Climate Change (IPCC-I), (1990), Policymaker's summary of the potential impacts of climate change (Report from Working Group II to IPCC)

Kniveton D, K., Schmidt-Verkerk, C., Smith, and R., Black, (2008), "Climate change and migration: improving methodologies to estimate flows", Migration Research Series paper 33, International Organization for Migration, Geneva.

Lilleør H, B., and Van de Broeck K., (2011), "Economic drivers of migration and climate change in LDCs", *Global Environmental Change*.

Marchiori, L., J-F. Maystadt and I. Schumacher (2011), The Impact of Weather Anomalies on Migration in Sub-Saharan Africa, *Journal of Environmental Economics and Management*, 63(3), 355-374.

Mayda, A. M., (2010), "International migration: A panel data analysis of the determinants of bilateral flows", *Journal of Population Economics*.

McFadden, D. (1984), "Econometric analysis of qualitative response models", in: Z. Griliches and M. Intriligator, eds., Handbook of Econometrics, Volume 2, Amsterdam. Elsevier/North-Holland.

McKenzie, D. and H. Rapoport (2010), "Self-selection patterns in Mexico-US migration: the role of migration networks", *Review of Economics and Statistics*, 92(4), 811-821.

Mueller, V. and D. Osgood (2009), Long-term Impacts of Droughts on Labour Market in Developing Countries: Evidence from Brazil, Journal of Development Studies, 45(10), 1651-1662.

Mueller, V. and A. Quisumbing (2011), How Resilient are Labour Marlets to Natural Disasters: The Case of the 1998 Bangladesh Flood, Journal of Development Studies, 47(12), 1954-1971.

Munshi, K. (2003), "Networks in the modern economy: Mexican migrants in the US labor market", *Quarterly Journal of Economics*, 118 (2), 549-99.

Myers, N. (1996), "Environmentally-induced displacements: the state of the art. Technical report", Environmentally-Induced Population Displacements and Environmental Impacts Resulting from Mass Migration, International Symposium.

Myers, N. (2002), "Environmental Refugees: A Growing Phenomenon of the 21st century", *Philosophical Transactions of the Royal Society B*, 357(1420), 609–613.

Naudé W., (2008), "Conflict, Disasters and No Jobs: Reasons for International Migration in sub-Saharan Africa", UNU-WIDER, Helsinki, Research Paper No. 2008/85.

Ortega, F., and G., Peri, (2009), "The Causes and Effects of International Migrations: Evidence from OECD Countries 1980-2005". NBER Working Paper Series, Vol. w14833, pp. -, 2009.

Özden, C., C. Parsons, M. Schiff, and T. Walmsley, (2011) "Where on Earth is Everybody? The Evolution of International Bilateral Migrant Stocks 1960-2000", *World Bank Economic Review* (forthcoming).

Patz, J. A., P. R., Epstein, T. A. Burke and J. M., Balbus, (1996) "Global climate change and emerging infectious diseases", *Journal of the American Medical Association.*

Paul, B. K. (2005), "Evidence against disaster-induced migration: the 2004 tornado in north-central Bangladesh", *Disasters*, 29(4).

Pedersen, P.J., M. Pytlikova and N. Smith (2008),. "Selection and network effects–Migration flows into OECD countries 1990-2000", *European Economic Review*, 52 (7), 1160-1186.

Piguet, E., A. , Pecoud, and P. de Guchteneire (2011), "Migration and Climate Change: An overview", *Refugee Survey Quarterly*, pp. 1-23.

Reuveny R., and W. H., Moore, "Does Environmental Degredation Influence Migration? Emigration to Developed Countries in the late 1980s and 1990s", *Social Science Quarterly.*

Roy, A.D. (1951), "Some thoughts on the distribution of earnings", *Oxford Economic Paper*s, 3 (2), 135-46.

Santos Silva, J.M.C. and S. Tenreyro (2006), "The Log of Gravity", *Review of Economics and Statistics*, 88 (4): 641-658.

Santos Silva, J. M. C. and S. Tenreyro, (2011), "Further Simulation Evidence on the Performance of the Poisson-PML Estimator", *Economic Letters*, 112(2), 220-222.

Stern , N. (2007), "The Economics of Climate Change: The Stern Review", (Cambridge University Press, Cambridge)

Summers, R. and A. Heston, (1991). "The Penn World Table (Mark 5): An Expanded Set of International Comparisons, 1950-1988," *The Quarterly Journal of Economics.*

United Nations, (2011), "World Population Prospects: The 2010 Revision", Department of Economic and Social Affairs, Population Division , New York

9 Appendix: list of countries

9.1 Destinations (166)

Afghanistan Albania Algeria Andorra Angola Antigua and Barbuda Argentina Australia Austria Bahamas Bahrain Bangladesh Barbados Belgium Belize Benin Bhutan Bolivia Botswana Brazil Brunei Darussalam Bulgaria Burkina Faso Burundi Cambodia Cameroon Canada Cape Verde Central African Republic Chad Chile China Colombia Comoros Congo Congo, the Democratic Republic of the Costa Rica Cote d'Ivoire Cuba Cyprus Denmark Djibouti Dominica Dominican Republic Ecuador Egypt El Salvador Equatorial Guinea Ethiopia Fiji Finland France Gabon Gambia Germany Ghana Greece Grenada Guatemala Guinea Guinea-Bissau Guyana Haiti Honduras Hungary Iceland India Indonesia Iran, Islamic Republic of Iraq Ireland Israel Italy Jamaica Japan Jordan Kenya Kiribati Korea, Democratic People's Republic of Korea, Republic of Kuwait Lao People's Democratic Republic Lebanon Lesotho Liberia Libyan Arab Jamahiriya Luxembourg Madagascar Malawi Malaysia Maldives Mali Malta Marshall Islands Mauritania Mauritius Mexico Micronesia, Federated States of Mongolia Morocco Mozambique Myanmar Namibia Nauru Nepal Netherlands New Zealand Nicaragua Niger Nigeria Norway Oman Pakistan Panama Papua New Guinea Paraguay Peru Philippines Poland Portugal Qatar Romania Russian Federation Rwanda Saint Kitts and Nevis Saint Lucia Saint Vincent and the Grenadines Samoa San Marino Sao Tome and Principe Saudi Arabia Senegal Serbia and Montenegro Seychelles Sierra Leone Singapore Solomon Islands Somalia South Africa Spain Sri Lanka Sudan Suriname Swaziland Sweden Switzerland Syrian Arab Republic Tanzania, United Republic of Thailand Togo Tonga Trinidad and Tobago Tunisia Turkey Tuvalu Uganda United Arab Emirates United Kingdom United States of America Uruguay Vanuatu Venezuela Viet Nam Yemen Zambia Zimbabwe

9.2 Origins (137)

Afghanistan Albania Algeria Angola Argentina Australia Austria Bahrain Bangladesh Belgium Benin Bhutan Bolivia Botswana Brazil Bulgaria Burkina Faso Burundi Cambodia Cameroon Canada Central African Republic Chad Chile China Colombia Comoros Congo Congo, the Democratic Republic of the Costa Rica Cote d'Ivoire Cuba Cyprus Denmark Djibouti Dominican Republic Ecuador Egypt El Salvador Equatorial Guinea Ethiopia Fiji Finland France Gabon Gambia Germany Ghana Greece Guatemala Guinea Guinea-Bissau Guyana Haiti Honduras Hungary India Indonesia Iran, Islamic Republic of Iraq Ireland Israel Italy Jamaica Japan Jordan Kenya Korea, Democratic People's Republic of Korea, Republic of Kuwait Lao People's Democratic Republic Lebanon Lesotho Liberia Libyan Arab Jamahiriya Madagascar Malawi Malaysia Mali Mauritania Mexico Mongolia Morocco Mozambique Myanmar Namibia Nepal Netherlands New Zealand Nicaragua Niger Nigeria Norway Oman Pakistan Panama Papua New Guinea Paraguay Peru Philippines Poland Portugal Qatar Romania Russian Federation Rwanda Saudi Arabia Senegal Serbia and Montenegro Sierra Leone Singapore Solomon

Islands Somalia South Africa Spain Sri Lanka Sudan Swaziland Sweden Switzerland Syrian Arab Republic Tanzania, United Republic of Thailand Togo Trinidad and Tobago Tunisia Turkey Uganda United Arab Emirates United Kingdom United States of America Uruguay Venezuela Viet Nam Yemen Zambia Zimbabwe

9.3 Visa destinations (47)

Afghanistan, Albania, Algeria, Angola, Argentina, Australia, Austria, Barbados, Belgium, Bulgaria, Brazil, Canada, Chile, China, Denmark, Egypt, Finland, France, Germany, Greece, Hungary, Indonesia, Ireland, Israel, Italy, Japan, Korea, Luxembourg, Mexico, Morocco, Nigeria, Netherlands, Norway, New Zealand, Pakistan, Philippines, Poland, Portugal, Russia. Saudi Arabia. Spain, Sweden, Switzerland, Turkey, United States, Vietnam, South Africa.

Table 2: Impact of climate on migration: unconditional results

Variables	(1)	(2)	(3)	(4)
Constant	-4.130***	-4.102***	-4.167***	-4.151***
	(1.234)	(1.223)	(1.226)	(1.288)
Wage ratio	0.319**	0.326**	0.325**	0.338**
	(0.150)	(0.153)	(0.152)	(0.148)
Distance	-0.766***	-0.764***	-0.767***	-0.765***
	(0.090)	(0.089)	(0.091)	(0.091)
Network	0.398***	0.399***	0.398***	0.399***
	(0.044)	(0.043)	(0.045)	(0.046)
Common Language	0.460***	0.459***	0.461***	0.458***
	(0.136)	(0.136)	(0.136)	(0.138)
Contiguity	0.409**	0.409**	0.409**	0.409**
	(0.166)	(0.168)	(0.168)	(0.171)
Dependency	-0.013**	-0.013**	-0.013**	-0.013**
	(0.005)	(0.005)	(0.005)	(0.005)
International Violence	0.379***	0.374***	0.381***	0.372***
	(0.092)	(0.092)	(0.091)	(0.091)
Natural Disasters	0.062	0.072	0.059	0.057
	(0.084)	(0.089)	(0.089)	(0.085)
Rain Deviation/Anomaly	-0.003	0.025	0.007	0.037
	(0.058)	(0.039)	(0.042)	(0.055)
Temperature Deviation/Anomaly	0.040	0.018	0.049	-0.004
	(0.0453)	(0.055)	(0.037)	(0.040)
Origin country Dummies (α_i)	Yes	Yes	Yes	Yes
Destination-Year Dummies (α_{jt})	Yes	Yes	Yes	Yes
# observations	62,234	62,234	62,234	62,234
R^2	0.626	0.628	0.626	0.625

Dependent variable: decadal bilateral migration rates. Estimation period: 1960-2000.
Cols (1) and (2): anomalies. Cols (3) and (4): absolute deviations.
Cols (1) and (3): excess temperatures and rainfall shortages.
Cols (2) and (4): temperature shortages and excess rainfall.
Superscripts ***, **, * denote statistical significance at 1, 5 and 10% respectively.
Robust standard errors are provided in parentheses.

Table 3: Conditional impact of climate on migration: excess temperature and rain shortage.

Variables Conditioning	(1) temp	(2) agricult	(3) water	(4) latitude
Constant	-4.175***	-4.080***	-4.137***	-4.121***
	(1.213)	(1.255)	(1.233)	(1.229)
Wage ratio	0.320**	0.340**	0.298**	0.314**
	(0.150)	(0.154)	(0.152)	(0.150)
Distance	-0.766***	-0.765***	-0.768***	-0.766***
	(0.088)	(0.089)	(0.089)	(0.089)
Network	0.400***	0.399***	0.398***	0.398***
	(0.043)	(0.043)	(0.044)	(0.044)
Common Language	0.456***	0.456***	0.460***	0.459***
	(0.132)	(0.133)	(0.135)	(0.135)
Contiguity	0.400**	0.409**	0.406**	0.408**
	(0.163)	(0.164)	(0.165)	(0.165)
Dependency	-0.013**	-0.014**	-0.013**	-0.013**
	(0.005)	(0.005)	(0.005)	(0.005)
International Violence	0.405***	0.394***	0.387***	0.382***
	(0.092)	(0.092)	(0.092)	(0.092)
Natural Disasters	0.061	0.047	0.062	0.068
	(0.084)	(0.087)	(0.084)	(0.084)
Rain Anomaly	-0.069	-0.026	-0.027	-0.014
	(0.082)	(0.087)	(0.069)	(0.061)
Temperature Anomaly	0.089	-0.005	0.053	0.041
	(0.061)	(0.058)	(0.057)	(0.047)
Rain*condition	0.145	0.061	-0.026	0.172
	(0.098)	(0.106)	(0.090)	(0.112)
Temperature*condition	-0.106	0.114	-0.026	-0.005
	(0.094)	(0.093)	(0.090)	(0.125)
Origin country Dummies (α_i)	Yes	Yes	Yes	Yes
Destination-Year Dummies (α_{jt})	Yes	Yes	Yes	Yes
# observations	62,234	62,234	62,234	62,234
R^2	0.630	0.629	0.625	0.626

Dependent variable: decadal bilateral migration rates. Estimation period: 1960-2000.
Superscripts ***, **, * denote statistical significance at 1, 5 and 10% respectively.
Robust standard errors are provided in parentheses.

Table 4: Conditional impact of climate on migration: temperature shortage and rain excess.

Variables Conditioning	(1) temp	(2) agricult	(3) water	(4) latitude
Constant	-4.117***	-4.239***	-3.940***	-4.073***
	(1.201)	(1.192)	(1.214)	(1.227)
Wage ratio	0.352**	0.324**	0.357**	0.328**
	(0.156)	(0.155)	(0.155)	(0.154)
Distance	-0.764***	-0.765***	-0.763***	-0.764***
	(0.087)	(0.088)	(0.085)	(0.088)
Network	0.400***	0.399***	0.400***	0.399***
	(0.042)	(0.043)	(0.041)	(0.043)
Common Language	0.453***	0.461***	0.456***	0.458***
	(0.133)	(0.135)	(0.132)	(0.136)
Contiguity	0.410**	0.405**	0.414**	0.409**
	(0.166)	(0.167)	(0.165)	(0.167)
Dependency	-0.013**	-0.012**	-0.015***	-0.013**
	(0.005)	(0.006)	(0.005)	(0.005)
International Violence	0.382***	0.395***	0.328***	0.374***
	(0.092)	(0.094)	(0.098)	(0.092)
Natural Disasters	0.054	0.065	0.078	0.072
	(0.096)	(0.091)	(0.088)	(0.089)
Rain Anomaly	0.064	-0.006	0.010	0.029
	(0.052)	(0.048)	(0.039)	(0.040)
Temperature Anomaly	0.034	0.057	0.056	0.019
	(0.076)	(0.079)	(0.067)	(0.057)
Rain*condition	-0.099	0.064	0.085	-0.093
	(0.080)	(0.072)	(0.110)	(0.125)
Temperature*condition	-0.048	-0.084	-0.200*	-0.025
	(0.086)	(0.088)	(0.112)	(0.088)
Origin country Dummies (α_i)	Yes	Yes	Yes	Yes
Destination-Year Dummies (α_{jt})	Yes	Yes	Yes	Yes
# observations	62,234	62,234	62,234	62,234
R^2	0.630	0.629	0.636	0.628

Dependent variable: decadal bilateral migration rates. Estimation period: 1960-2000.
Superscripts ***, **, * denote statistical significance at 1, 5 and 10% respectively.
Robust standard errors are provided in parentheses.

Table 5: Conditional impact of climate on migration, to the countries of the Global North: excess temperatures and rain shortages.

Variables Conditioning	(1) temp	(2) agricult	(3) water	(4) latitude
Constant	1.245	1.504	1.447	1.318
	(1.405)	(1.412)	(1.415)	(1.411)
Wage ratio	0.500***	0.556***	0.554***	0.523***
	(0.194)	(0.196)	(0.192)	(0.193)
Distance	-1.098***	-1.100***	-1.103***	-1.102***
	(0.099)	(0.098)	(0.099)	(0.099)
Network	0.173***	0.173***	0.170***	0.172***
	(0.037)	(0.037)	(0.038)	(0.037)
Common Language	0.941***	0.930***	0.943***	0.938***
	(0.180)	(0.178)	(0.182)	(0.180)
Contiguity	0.460	0.465	0.483	0.470
	(0.317)	(0.315)	(0.323)	(0.319)
Dependency	-0.013*	-0.015**	-0.014*	-0.012*
	(0.007)	(0.007)	(0.007)	(0.007)
International Violence	0.467***	0.474***	0.442***	0.465***
	(0.101)	(0.104)	(0.101)	(0.103)
Natural Disasters	0.084	0.029	0.045	0.058
	(0.108)	(0.114)	(0.105)	(0.109)
Rain Anomaly	-0.071	-0.075	0.028	-0.049
	(0.072)	(0.074)	(0.060)	(0.084)
Temperature Anomaly	0.119	0.015	0.068	0.039
	(0.075)	(0.080)	(0.067)	(0.081)
Rain*condition	0.136	0.180	-0.148	0.084
	(0.097)	(0.113)	(0.097)	(0.102)
Temperature*condition	-0.180	0.096	-0.059	0.044
	(0.125)	(0.128)	(0.141)	(0.123)
Origin country Dummies (α_i)	Yes	Yes	Yes	Yes
Destination-Year Dummies (α_{jt})	Yes	Yes	Yes	Yes
# observations	11,393	11,393	11,393	11,393
R^2	0.685	0.687	0.679	0.684

Dependent variable: decadal bilateral migration rates. Estimation period: 1960-2000.
Superscripts ***, **, * denote statistical significance at 1, 5 and 10% respectively.
Robust standard errors are provided in parentheses.

Table 6: Conditional impact of climate on migration, to the countries of the Global South: excess temperatures and rain shortages.

Variables Conditioning	(1) temp	(2) agricult	(3) water	(4) latitude
Constant	-7.997***	-7.622***	-7.515***	-7.852***
	(1.392)	(1.376)	(1.375)	(1.382)
Wage ratio	0.150	0.109	0.068	0.124
	(0.175)	(0.178)	(0.181)	(0.175)
Distance	-0.467***	-0.468***	-0.479***	-0.468***
	(0.087)	(0.087)	(0.086)	(0.088)
Network	0.573***	0.572***	0.571***	0.573***
	(0.039)	(0.039)	(0.039)	(0.039)
Common Language	0.140	0.142	0.143	0.145
	(0.119)	(0.117)	(0.117)	(0.119)
Contiguity	0.272**	0.277**	0.265**	0.275**
	(0.116)	(0.116)	(0.117)	(0.117)
Dependency	-0.010	-0.013*	-0.013*	-0.011
	(0.007)	(0.007)	(0.007)	(0.007)
International Violence	0.126	0.096	0.110	0.097
	(0.241)	(0.244)	(0.238)	(0.241)
Natural Disasters	0.001	-0.020	-0.032	-0.008
	(0.097)	(0.094)	(0.093)	(0.096)
Rain Anomaly	-0.028	0.114*	-0.137*	0.071
	(0.067)	(0.061)	(0.070)	(0.066)
Temperature Anomaly	0.009	0.007	0.008	0.035
	(0.078)	(0.060)	(0.064)	(0.059)
Rain*condition	0.061	-0.241**	0.382**	-0.166*
	(0.093)	(0.105)	(0.129)	(0.099)
Temperature*condition	0.007	0.012	0.035	-0.044
	(0.105)	(0.094)	(0.095)	(0.096)
Origin country Dummies (α_i)	Yes	Yes	Yes	Yes
Destination-Year Dummies (α_{jt})	Yes	Yes	Yes	Yes
# observations	50,841	50,841	50,841	50,841
R^2	0.833	0.835	0.834	0.834

Dependent variable: decadal bilateral migration rates. Estimation period: 1960-2000.
Superscripts ***, **, * denote statistical significance at 1, 5 and 10% respectively.
Robust standard errors are provided in parentheses.

Table 7: Accounting for return migration: unconditional results

Variables	(1)	(2)	(3)	(4)
Constant	-5.438***	-5.379***	-5.405***	-5.562***
	(1.186)	(1.181)	(1.152)	(1.212)
Wage ratio	0.344**	0.363**	0.355**	0.372**
	(0.161)	(0.163)	(0.160)	(0.162)
Distance	-0.792***	-0.789***	-0.792***	-0.791***
	(0.080)	(0.079)	(0.080)	(0.080)
Network	0.413***	0.414***	0.413***	0.415***
	(0.036)	(0.036)	(0.036)	(0.037)
Common Language	0.551***	0.546***	0.552***	0.545***
	(0.134)	(0.134)	(0.133)	(0.134)
Contiguity	0.0120	0.011	0.012	0.011
	(0.156)	(0.156)	(0.155)	(0.158)
Dependency	-0.016***	-0.017***	-0.016***	-0.016***
	(0.005)	(0.005)	(0.005)	(0.005)
International Violence	0.376***	0.361***	0.373***	0.361***
	(0.086)	(0.085)	(0.084)	(0.085)
Natural Disasters	0.021	0.034	0.022	0.018
	(0.078)	(0.079)	(0.078)	(0.078)
Rain Anomaly	0.003	0.039	-0.015	0.088*
	(0.059)	(0.038)	(0.042)	(0.052)
Temperature Anomaly	0.082*	-0.031	0.079**	-0.041
	(0.042)	(0.052)	(0.035)	(0.039)
Origin country Dummies (α_i)	Yes	Yes	Yes	Yes
Destination-Year Dummies (α_{jt})	Yes	Yes	Yes	Yes
# observations	71,696	71,696	71,696	71,696
R^2	0.579	0.576	0.579	0.578

Dependent variable: decadal bilateral migration rates. Estimation period: 1960-2000.
Cols (1) and (2): anomalies. Cols (3) and (4): absolute deviations.
Cols (1) and (3): excess temperatures and rainfall shortages.
Cols (2) and (4): temperature shortages and excess rainfall.
Superscripts ***, **, * denote statistical significance at 1, 5 and 10% respectively.
Robust standard errors are provided in parentheses.

Table 8: Accounting for return migration: conditional impact

Variables Conditioning	(1) temp	(2) agricult	(3) water	(4) latitude
Constant	-5.542***	-5.420***	-5.549***	-5.455***
	(1.162)	(1.217)	(1.176)	(1.183)
Wage ratio	0.299*	0.352**	0.263*	0.350**
	(0.155)	(0.165)	(0.155)	(0.162)
Distance	-0.791***	-0.791***	-0.794***	-0.791***
	(0.079)	(0.080)	(0.080)	(0.080)
Network	0.415***	0.413***	0.413***	0.413***
	(0.035)	(0.036)	(0.036)	(0.036)
Common Language	0.544***	0.548***	0.552***	0.551***
	(0.130)	(0.134)	(0.132)	(0.134)
Contiguity	0.007	0.013	0.009	0.012
	(0.153)	(0.156)	(0.154)	(0.155)
Dependency	-0.015***	-0.016***	-0.015***	-0.016***
	(0.005)	(0.005)	(0.005)	(0.005)
International Violence	0.404***	0.383***	0.378***	0.392***
	(0.085)	(0.086)	(0.085)	(0.086)
Natural Disasters	0.031	0.012	0.035	0.031
	(0.076)	(0.079)	(0.075)	(0.078)
Rain Anomaly	-0.084	0.003	-0.033	-0.014
	(0.078)	(0.088)	(0.064)	(0.062)
Temperature Anomaly	0.113**	0.057	0.059	0.086**
	(0.055)	(0.053)	(0.048)	(0.044)
Rain*condition	0.174*	0.003	0.103	0.212*
	((0.094)	(0.103)	(0.097)	(0.110)
Temperature*condition	-0.070	0.072	0.068	-0.065
	(0.084)	(0.084)	(0.086)	(0.122)
Origin country Dummies (α_i)	Yes	Yes	Yes	Yes
Destination-Year Dummies (α_{jt})	Yes	Yes	Yes	Yes
# observations	71,696	71,696	71,696	71,696
R^2	0.585	0.579	0.581	0.577

Dependent variable: decadal bilateral migration rates. Estimation period: 1960-2000.
Anomalies refer here to excess temperatures and rainfall shortages.
Superscripts ***, **, * denote statistical significance at 1, 5 and 10% respectively.
Robust standard errors are provided in parentheses.

Table 9: Bilateral visa requirements and endogeneity of the network.

Variables	(1)	(2)
Constant	-3.914***	-4.280***
	(1.492)	(1.509)
Wage ratio	0.179	0.092
	(0.182)	(0.185)
Distance	-0.896***	-0.919***
	(0.102)	(0.106)
Network	0.349***	0.351***
	(0.040)	(0.040)
Common Language	0.526**	0.525**
	(0.151)	(0.152)
Contiguity	0.257	0.336*
	(0.201)	(0.193)
Dependency	-0.015**	-0.014**
	(0.006)	(0.006)
International Violence	0.512***	0.498***
	(0.102)	(0.101)
Natural Disasters	0.176	0.198*
	(0.110)	(0.113)
Rain Deviation/Anomaly	0.021	0.013
	(0.043)	(0.043)
Temperature Deviation/Anomaly	0.060	0.059
	(0.052)	(0.054)
Bilateral visa requirement	-0.554***	-
	(0.128)	
Origin country Dummies (α_i)	Yes	Yes
Destination-Year Dummies (α_{jt})	Yes	Yes
# observations	16135	16135
R^2	0.809	0.807

Dependent variable: decadal bilateral migration rates.
Anomalies refer here to excess temperatures and rainfall shortages.
Estimation period: 1970-2000. Superscripts ***, **, * denote statistical significance at 1, 5 and 10% respectively.
Robust standard errors are provided in parentheses.

Table 10: Indirect effects of climate shocks: impact on the wage ratio

Variables Conditioning	(1) Full	(2) temp	(3) agricult	(4) water	(5) latitude
Constant	-0.510	-0.357	-0.452	-0.218	-0.418
	(0.304)	(0.296)	(0.313)	(0.266)	(0.331)
Distance	-0.003*	-0.0001	-0.0003	0.0013	0.0001
	(0.002)	(0.003)	(0.002)	(0.003)	(0.002)
Network	.0006	-0.0008	0.0004	-0.0001	-0.0002
	(0.0005)	(0.0006)	(0.0005)	(0.0009)	(0.0007)
Common Lang.	-0.0003	0.008	0.002	0.004	0.007**
	(0.003)	(0.004)	(0.003)	(0.005)	(0.003)
Contiguity	-0.0093	-0.0021	-0.002	-0.012	0.0007
	(0.006)	(0.009)	(0.007)	(0.012)	(0.008)
Dependency	0.0123***	0.0128***	0.0055***	0.0109***	0.0123***
	(0.0001)	(0.0002)	(0.0002)	(0.0002)	(0.0002)
Intern. Violence	0.052***	0.064***	-0.002	-0.088	0.032***
	(0.003)	(0.004)	(0.003)	(0.006)	(0.003)
Natural Disasters	0.033***	0.073***	0.050***	0.048***	0.048***
	(0.002)	(0.003)	(0.002)	(0.003)	(0.003)
Temp. anomaly	-0.031***	-0.056***	-0.044***	-0.027***	-0.053***
	(0.001)	(0.002)	(0.001)	(0.002)	(0.002)
Rain anomaly	-0.0003	0.006***	0.007***	0.011***	0.009***
	(0.001)	(0.002)	(0.001)	(0.002)	(0.001)
Orig-Count FE (α_i)	Yes	Yes	Yes	Yes	Yes
Dest-Year FE (α_{jt})	Yes	Yes	Yes	Yes	Yes
# observations	71,696	35,069	42,937	28,399	35821
R^2	0.980	0.977	0.982	0.976	0.980

Dependent variable: (log of) wage ratio between origin and destination.

Anomalies refer to excess temperatures and rainfall shortages.

Estimation period: 1960-2000.

Superscripts ***, **, * denote statistical significance at 1, 5 and 10% respectively.

Robust standard errors are provided in parentheses.

Table 11: Internal migration and environmental factors

	Full sample			Developing Countries		
variables	(1)	(2)	(3)	(4)	(5)	(6)
Constant	0.913***	2.311***	2.230***	1.419***	2.044***	2.186***
	(0.258)	(0.121)	(0.096)	(0.295)	(0.117)	(0.097)
Nat. Disasters	0.028	0.016	0.054***	0.045**	0.035**	0.070***
	(0.017)	(0.015)	(0.013)	(0.020)	(0.016)	(0.014)
Rain shortages	-0.011	-0.008	-0.007	-0.019	-0.005	-0.003
	(0.009)	(0.007)	(0.007)	(0.010)	(0.009)	(0.008)
Excess temp	-0.017*	-0.015*	-0.007	-0.004	-0.015	-0.003
	(0.009)	(0.008)	(0.008)	(0.010)	(0.010)	(0.009)
Pop. density	0.034***	-	-	0.013*	-	-
	(0.005)			(0.007)		
income	0.034	-0.012	-	0.061***	0.033*	-
	(0.020)	(0.016)		(0.023)	(0.016)	
democracy	-0.0012**	-	-	-0.0010**	-	-
	(0.0005)			(0.0005)		
openness	0.0009*	-	-	0.0009*	-	-
	(0.0005)			(0.0006)		
Country dummies	Yes	Yes	Yes	Yes	Yes	Yes
Time dummies	Yes	Yes	Yes	Yes	Yes	Yes
# observations	570	828	1010	468	713	895
R^2	0.955	0.939	0.933	0.951	0.939	0.932

Dependent variable: log of (urbanization rate). Estimation period: 1960-2000.
Superscripts ***, **, * denote statistical significance at 1, 5 and 10% respectively.
Robust standard errors are provided in parentheses.