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Climate instability and international migration

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Abstract

The importance of international migration for its economic and social implications is nowadays widely acknowledged both in the academic literature and advocacy reports. Recently the debate has stimulated the inclusion of environmental factors into the possible explanations of migration, in order to account for the specificity of south-south migration. To assess the indirect linkages between climate change, agricultural share over GDP and migration, this study exploits an instrumental variable approach, using data for 108 countries for the period 1960-2000. Our model emphasises that anomalies in temperature and rainfalls accelerate the urbanization process, implying a decline in the agricultural share in the GDP. Within-borders migration from rural to urban area leads workers to engage in cross-border migration. We find that cross-border migration induced by a two standard deviation increase in precipitation (temperature) anomalies represents up to 8% (4%) of total migration.

JEL classification: F22; J61; O15; Q54
Keywords: International migration; Climate change; Agriculture; Panel analysis

1. Introduction

The importance of international migration for its economic and social implications is nowadays widely acknowledged both in the academic literature and advocacy reports. The number of migrants worldwide speaks for itself: 150 million individuals engaged in migration flows in 2000, and this figure almost doubled ten years after, reaching 214 million migrants in 2010. If the stock of migrants maintains the same growth rate of the last 20 years, it is estimated to reach 405 million by 2050, exasperating existing difficulties and introducing new challenges (Koser and Laczko, 2010). However, in spite of the magnitude of people moving across borders, empirical studies on the determinants of migration have evolved very slowly in comparison with the theoretical literature and policy debate (Özden et al., 2011). The majority of previous analysis focused on factors such as war, poverty, hunger and violation of human rights (Afifi and Warner, 2008). Only recently the debate has stimulated the inclusion of environmental factors into the possible explanations of migration, as a consequence of the globally-growing attention to climate change. In fact, evidence shows that lack of water, soil degradation, environmental hazards and global warming may drive people to migrate in search for better environmental and working conditions (Tacoli, 2009).

Often presented as a new topic or part of future trends (Piguet et al., 2011), the relationship between climate change and migration has been analysed theoretically and empirically only after the 1990s, and it has then evolved in a vibrant debate around the terminology to use (Castles, 2002) and the approximate estimations of potential climate migrants (Black, 2001; Myers, 2002). While some authors found no relationship whatsoever (Mortreux and Barnett, 2009; Paul, 2005), more recent works have focused on the impact of climate change on internal migration, reaching a statistically significant and positive correlation between migration and climatic factors within national borders (Joseph and Wodon, 2013). However, there is still limited literature on the effects of environmental determinants on international migration. This research aims at filling the gap and contributing to the debate by exploring, for the first time in a systematic way, the indirect effects of climate change on international migration using a panel of global bilateral migration flows.

This is a worthwhile question, since the patterns of movement of migrants have significant effects on the economic, social, political and environmental landscapes of the countries they leave and the countries they settle in. Understanding the forces that drive international migration is essential to put in place policies that intend to smooth the transition of people, create significant financial and social benefits for the migrants and their families, and boost competitiveness and economic stability in both the countries of origin and destination. In particular, this study assumes relevant significance in its attempt to evaluate the impacts of environmental degradation on the economy. In fact, climate change shifts the distribution of economic opportunities across regions over a progressive period, making it essential to build a stock of knowledge that would help policy makers to assure sustainable economic development paths.

To achieve its objective, this paper starts from the observation made by several authors that climate change may drive people displacement through many channels (Perch-Nielsen et al., 2008). The direct effects of climatic determinants reflecting changes in amenities or pure externalities demonstrated to be weak. In a recent contribution, Beine and Parsons (2013) analyse the direct impact of climate change on international migration, concluding with no significant evidence in the medium and long term. Conversely, the indirect channels through which climatic factors affect people displacement across national borders have never been quantitatively analysed yet.

Among the possible indirect channels that influence international migration, agricultural production is one of the most promising. Indeed, the literature agrees on the fact that agriculture is the most vulnerable sector to climate change, since its productivity is clearly linked to rainfall patterns, temperature, water availability and changing in sowing. It is feasible to expect that climate variations reduce agricultural wages, pushing rural workers to look for better conditions elsewhere, and reducing therefore the share of agriculture over GDP. Variations in crop yields resulting from environmental degradation are likely to lead to long-term migration from rural to urban area and to subsequently broader geographical areas, unlike sea level rise, which affects only coastal regions (Feng et al., 2010).

The present research quantitatively assesses the linkages between climate change, agricultural share over GDP and international migration by using an instrumental variables approach. Our method identifies the environmental impact in the agricultural production equation, while the relationship between international migration and crop yields controls for the other traditional determinants. We exploit bilateral data on international migration for 108 countries for the period 1960-2000, using a recent panel dataset of Özden et al. (2011). We find that anomalies in temperature and precipitations reduce crop yields over time throughout the whole sample. In turn, declines in agricultural share over GDP lead workers to engage in cross-border migration.

The remainder of the paper is organized as follows. Section 2 presents a brief review of the current scholarly understanding of the climate-migration nexus. In Section 3, we outline a simple theoretical framework to assess the linkages between climate change and international migration. Section 4 introduces data and stylised facts from summary statistics. The econometric framework and estimation results are discussed in Section 5, while Section 6 concludes.

2. The climate-migration nexus

The initial debate on climate change and migration tended to focus on approximate estimations of the number of people involved. In 2002, Myers' 25 million environmental refugees and his projection of 200 million people displaced by environmental change by 2050 caused a public stir (Myers, 2002). When the famous Stern Review on the Economics of Climate Change cited Myers' figure in 2007 (Stern, 2007), advocacy groups and mass media rushed into the discussion, with images of people forced to leave their houses by extreme weather events. However, following studies criticize these first estimates as based on broad-brush assumptions about trends in climate and population dynamics (McLeman, 2013). Tacoli (2009) emphasizes that the main problem of the concept of environmental refugees is the implicit assumption of a direct casual link between climate change and migration. In fact, the figures so far proposed were more likely estimates of the number of people at risk, rather than the amount of real migrants.

We must acknowledge that quantitatively estimating the impact of environmental change on migration has been demonstrated a hard task (De Sherbinin et al., 2008). In fact, a multitude of factors intervenes at the same time: the environmental determinants are various (including floods, global warming, sea-level rise, deforestation), as well as the types of migration responses (permanent, temporary, seasonal, long-distance, internal, forced) and intervening variables (migrant selectivity, network effects, socioeconomic status). The challenge is made even more complex by the lack of reliable data on migration flows and the high level of uncertainty about the specific effects of climate change (Tacoli, 2009). It has also to be noticed that the households more likely to be affected by climate change are the very poor, which however are also those less likely to migrate due to lack of resources and education[1]. Therefore, another challenge is posed by the necessity to control for a large set of variables that may influence migration, in order to isolate the effect of climate (Joseph and Wodon, 2013).

Some success has been achieved in modelling the effects of climate change on migration patterns at national or sub-regional levels, where the collection of data over time is less demanding. Using longitudinal multilevel data on Burkina Faso, Henry et al. (2004) find no evidence of a direct impact of rainfall variations on the probability of migration if no distinction by destination or duration is made. When instead they distinguish between destinations, findings suggest that individuals from arid regions are more likely to migrate to other rural areas and less likely to invest in long-distance moves. Similar results have been achieved by Gray (2009) in Ecuador. With a multinomial discrete-time event history model, he finds that international migration is least influenced by environmental determinants, while local mobility is especially responsive. Internal migration due to environmental factors is also estimated in a recent paper by Joseph and Wodon (2013), who find that climate variables account for 10-14 per cent of the explained variance in migration rates between districts in Yemen.

However, as pointed out by Marchiori et al. (2012), most of previous studies did not control for endogeneity affecting income and employment opportunities which in turn may influence the incentive to migrate. Whether this endogenity is not properly addressed, results would be biased. Munshi (2003) starts a now well-established approach by instrumenting networks with rainfall variables. In this way, he finds that less rainfall is correlated with higher levels of migration from Mexico to US. Same results but with different methodology is estimated by Feng et al. (2010). In fact, they examine the linkages between climate change and Mexico-US migration through an

[1] This phenomena is known under the name of the U-shaped pattern of migration. See Beuran, Berthélémy and Maurel (2009), and Berthélémy and Maurel (2009).

indirect channel passing by agricultural productivity. They instrument crop yields with temperature and precipitation variables and they find that a 10 per cent reduction in agricultural productivity due to climate change lead an additional 2 per cent of the population to emigrate.

On the other side, robust evidence of climate-driven international migration still lacks. One of the few successful attempts is Afifi and Warner (2008), who implement a gravity model including 172 countries and 13 environmental variables. For instance, after controlling for several socio-economic factors, they are able to conclude with a positive significant effect of the environment on international migration. A gravity model is also used by Bettin and Nicolli (2012). The authors find that international migration flows are positively affected by climate change indicators, especially when Africa and Asia are the regions of origin. Marchiori and Schumacher (2011), instead, construct a two-country, general equilibrium, overlapping-generations model and demonstrate that even small impacts of climate change have significant effects on the number of international migrants. Nevertheless, one of the most recent contributions on the topic reverses all these conclusions. Beine and Parsons (2013) find no direct impact of climatic change on international migration, and their results are robust to different specifications, adjustments and sub-samples.

One of the reasons why most previous works have been unable to identify a nexus between climate change and international migration has been recently emphasized by the environmental and geography literature. More and more studies are now reaching the conclusion that the relationship between environment and human displacement is not straightforward. The determinants of migrations are numerous and eventually no individual will migrate simply because local weather does not satisfy any longer his climate preferences (Lilleør and Van den Broeck, 2011). Changes in amenities alone are usually not enough to push people across the borders, as also shown by the research of Mortreux and Barnett (2009) in Tuvalu.

Indirect effects on other drivers are likely to be the channels through which climate change impacts migration. Specifically, environmental change may affect agricultural productivity and the locations of industries, conflicts and human settlements, and these in turn may influence migration patterns (Black et al., 2011). When focusing on developing countries, agriculture is likely to be the most affected sector by climate change. By lowering crop, livestock and fisheries yields, environmental shocks cut household incomes, pushing individuals to look for employment opportunities elsewhere. Barbieri et al. (2010) suggest that climate variations over time will drastically reduce agricultural income in Brazil's Northeast, acting as a migration push factor. The argument is also supported by Feng et al. (2010) for Mexico-US migration. The present paper aims at contributing to the literature by extending the indirect-channel of climate change on migration to a macroeconomic analysis of international bilateral migration flows.

3. Theoretical framework

As emphasised in the previous section, we understand the link from climate to migration as arising mainly at the agricultural production level. In our model, migration is a two-step phenomena. It starts when climate change affects the overall environement faced by household individuals by reducing their expected agricultural income. For those households, migration is a risk-coping strategy: it happen whenever the expected utility from consumption with migration is higher than the utility with no migration. This expected utility depends mainly upon income, which in developing countries consists mainly upon agricultural production.

Migration = 1 if U(Agricultural Production_with migration, Amenities_with migration) > U(Agricultural Producation_without migration, Amenities_without migration) (Eq.1)

Climate can enter the utility function of a farmer in two ways. It can be considered as an amenity, in which case it enters directly the utility function. The idea is that migrants choose to migrate towards regions according to the regional climate advantages. Beine and Parsson (2013) have followed this strategy, and their main conclusion is that if climate has an effect on migration, it is an indirect effect. Borrowing their conclusion, we assume therefore that the effect of climate is indirect, by affecting the share of agricultural production over GDP as follows:

Agricultural Share = function (labor, land, climate variables) (Eq.2)

The second equation of the model explains *Agricultural Share*, namely the share of the traditional sector, and emphasises its shriking over time. It describes the implicit internal migration from the traditional to the modern sector, which in turn will push international migration. We assume that climate change – proxied by temperature and precipitation anomalies – are key. They exacerbate income volatility (Dillon et al., 2011), which drives in turn the decline of *Agricultural Share*.

Let's consider two locations: a rural location, where the agricultural sector is the main source of income, and an urban location, where income is derived from manufacturing and services. If agricultural income is made unstable by climatic anomalies, and in the absence of available instruments to hedge the risk, the utility of remaining in the countryside decreases, while the utility derived from migrating to urban centers becomes more attractive. According to equation 1, households have incentive to migrate to urban centres, which offers a source of income diversification.[2]

It is important to notice that the resulting transition from the rural to the urban sector is driven by income volatility, and to a lesser extent by income expectations, as in the seminal model of Harris and Todaro (1970). In other words, our main emphasis in equation 2 is the role played by climate anomalies in pushing rural-urban migrations, more than climate levels. The former explain

[2] Other sources may be available, such as drawing down on assets, or searching for employment in the non agricultural sector, for example.

migration, that is the schrinking of *Agricultural Share* over time, while the latter explain the distribution of agricultural activities across countries/regions, and the types of crops.

However, immigration from the rural to the modern sector pushes wages in cities down, due to the increasing demand of labour. This in turn boosts the stimulus for urban-international migration, which gives the following migration equation:

Migration = function (wage differential, Agricultural Share, control variables) (Eq.3)

As more individuals converge in urban centres, urban wages are pushed down by the demographic pressures and the greater labour supply. Migrants therefore will move across border from cities in the origin country, in search of better opportunities and wages abroad. This framework is empirically confirmed by the research of Barrios et al. (2006). Using data for 78 countries from 1960 to 1990, they demonstrate that a decline in rainfall raises the urbanization rate in sub-Saharan Africa according to these channels. Additional evidence is supported by a study conducted in Brazil, which finds a long-term negative effect of past rainfall shocks on the current income of rural workers that migrated to cities permanently (Mueller and Osgood, 2009). Marchiori et al. (2012) apply a similar framework to sub-Saharian Africa, concluding that weather anomalies are important causes of international migration, especially for countries dependent on agriculture. Generalizing those micro-based evidences, Beine and Parsons (2013) use macro data and provide evidence of a direct link between urbanization and climate variability.

4. Data and stylized facts

4.1. Migration data

Part of the reason why empirical analysis of migration flows have been lagged behind is the absence of comprehensive and reliable data on international migration patterns until very recently (McLeman, 2013). This research makes use of a dataset produced by Özden et al. (2011), which reports bilateral migration stocks between 226 countries for the last five completed census rounds, 1960-2000. The authors address several problems of collecting census data over time, including the shifting of borders, the various definitions of migration used by national statistical institutes, and the different times of data collection. The final result is a comprehensive panel dataset, which allows to control for both country-fixed and time-fixed effects.

However, relying on simple stock measures may not properly capture the impact of climate change on migration. Following previous studies (Beine and Parsons, 2013; Bettin and Nicolli, 2012), we proxy migration flows as the variation in the stock of migrants of origin country in destination country for contiguous census rounds. The resulting database also presents negative migration flows. Possible explanations of these declining stocks over time include migrants who return to their origin country, or die or move to third-countries.

This work acknowledges for the literature's claim that climate variations bear the toughest effects on agricultural activities, leaving manufacturing less damaged (IPCC, 2007). Developing countries are considered to be more vulnerable to climate change due to their large rural population receiving income directly from agriculture (Deschenes and Greenston, 2007). Moreover, poor countries have less capacity to adapt to climate change and they are usually located in hotter regions where temperatures are already very high for agriculture (Cline, 2008). Therefore, this study pays special attention to South-South migration, also taking into account the fact that approximately 78 million out of 191 million migrants were residing in a developing country in 2005, and almost all of them (74 million) were coming from other LDCs (Ratha and Shaw, 2007). For this reason, we aggregate countries from the South by continent (namely, Africa, America, Asia, Europe, and Oceania) and keep OECD countries aside. The full list of countries included in the dataset is presented in Table 1.

Table 1: Country list in regressions

Regions	Countries
Africa	Algeria, Botswana, Burkina Faso, Burundi, Cameroon, Cape Verde, Congo, Côte d'Ivoire, Egypt, El Salvador, Equatorial Guinea, Gambia, Ghana, Guinea, Guinea-Bissau, Kenya, Madagascar, Malawi, Mali, Mauritius, Morocco, Namibia, Niger, Nigeria, Rwanda, Senegal, South Africa, Sudan, Suriname, Togo, Tunisia, Zambia.
America	Antigua and Barbuda, Argentina, Barbados, Belize, Plurinational State of Bolivia, Brazil, Chile, Colombia, Costa Rica, Dominican Republic, Ecuador, Honduras, Jamaica, Nicaragua, Panama, Paraguay, Peru, Puerto Rico, Trinidad and Tobago, Uruguay, Bolivarian Republic of Venezuela.
Asia	Bangladesh, Bhutan, Cambodia, China, India, Indonesia, Islamic Republic of Iran, Israel, Jordan, People's Democratic Republic of Lao, Malaysia, Mongolia, Nepal, Pakistan, Philippines, Qatar, Saudi Arabia, Singapore, Sri Lanka, Thailand, Viet Nam, Yemen.
Europe	Albania, Bulgaria, Cyprus, Malta.
Oceania	Cook Islands, Fiji, Vanuatu.
OECD	Australia, Austria, Canada, Germany, Denmark, Finland, France, Greece, Hungary, Iceland, Ireland, Italy, Japan, Republic of Korea, Mexico, Netherlands, New Zealand, Norway, Poland, Portugal, Sweden, Spain, Turkey, United States.

Figure 1 shows which are the most common regions of origin in our sample, using data on migration flows for the period 1990-2000. OECD countries are excluded in order to shed light on South-South migration. Interesting findings result from the analysis. While Africa is commonly believed to be the continent more affected by international out-migration, the African countries included in our dataset show a minor impact of emigration in comparison to European and Asian countries. Examining destination regions, instead, indicates the high attractiveness of Asia and Africa (Figure 2). However, it is worth to note that most migrants are likely to come from common-border states, looking for better conditions in neighborhood countries (Ratha and Shaw, 2007).

Figure 1: Regions of origin for bilateral migration flows from 1990 to 2000 (excluded OECD countries)

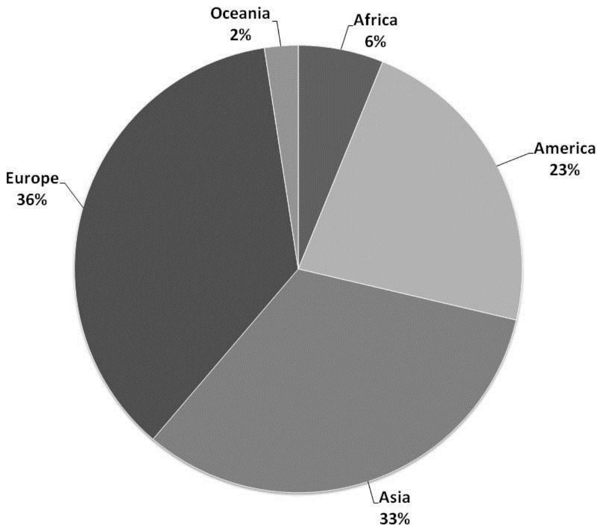
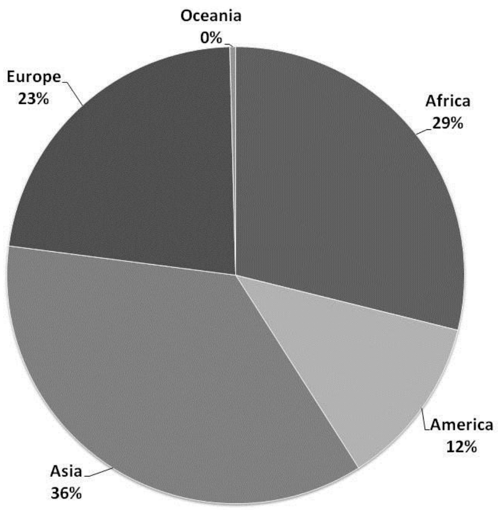


Figure 2: Regions of destination for bilateral migration flows from 1990 to 2000 (excluded OECD countries)



4.2. Climatic data

The environmental literature has stressed the dichotomy of climate change phenomena on several occasions (Piguet et al., 2011). On one hand, tropical cyclones, torrential rains and floods are classical patterns of rapid-onset events inducing population displacement. On the other hand, drought, global warming and desertification bear much slower impacts. Following previous works (Beine and Parsons, 2013; Paul, 2005), this research assumes that rapid-onset phenomena generally cause short-term internal migration, due to the fact that victims, who mainly live in poor countries, lack the immediate resources to engage in long-term emigration across borders. For this reason, in order to achieve our purpose of assessing the impacts of climate change on international migration, we will only focus on slow-onset phenomena.

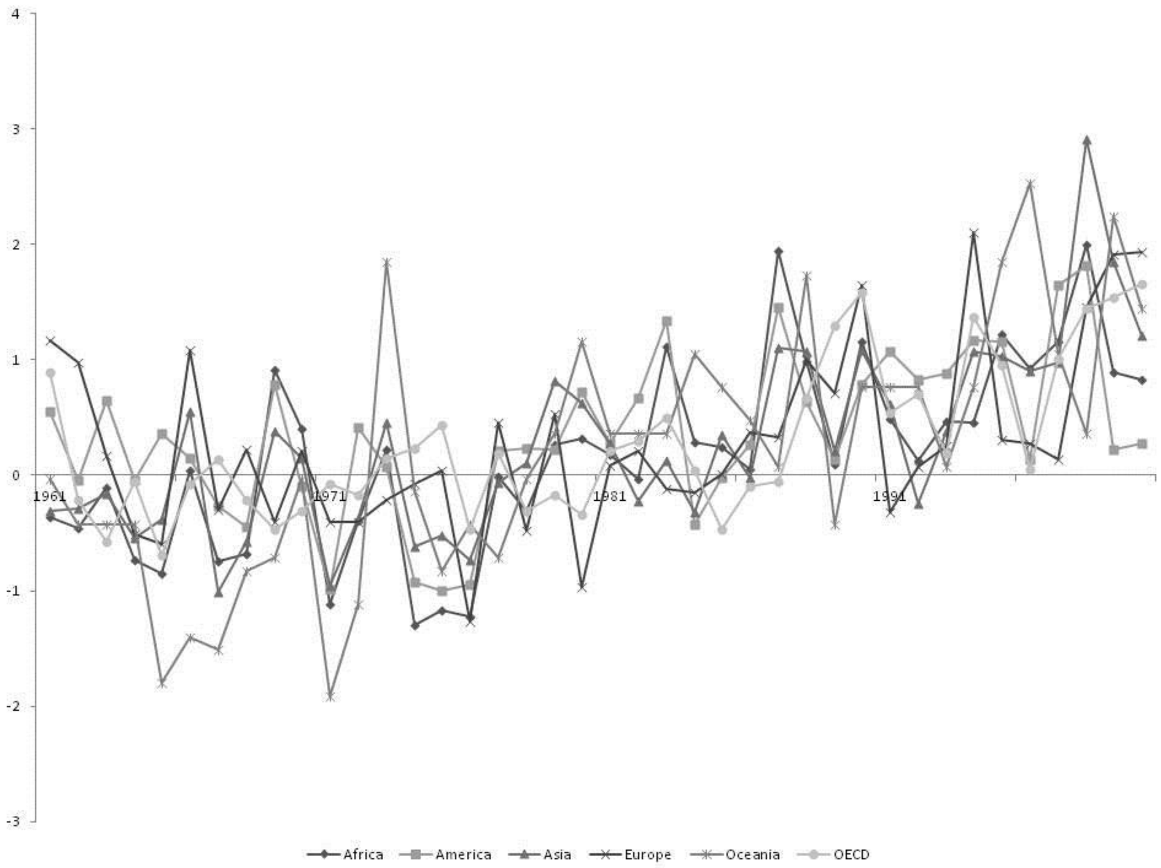
The majority of former studies proxies this kind of climatic determinants by variations in rainfalls (Barrios et al., 2006). However, the environmental literature well-established also the important role of increasing temperatures, that can be decisive especially for arid regions, such as Namibia (Dell et al., 2012; Marchiori et al., 2012). Therefore, the present paper aims at looking namely at both rainfall and temperature variations in order to give an adequately complete picture of the true extent of climate changes on international migration (IPCC, 2007). Variables are taken from the TYN CY 1.1 dataset of the Tyndall Centre for Climate Change Research, which provides climatic data for 289 countries from 1901 to 2000. The original time series were constructed by aggregating observations from meteorological stations all over the world into high-resolution 0.5° by 0.5° grids; see Mitchell et al. (2004) for a complete description of the dataset.

A major concern rises when trying to estimate the linkages between climate change and international migration: the use of climate measures in absolute values is indeed misleading. But as emphasised previously, the push factor that boost migration is the frequency of anomalies in precipitations and temperature that occur over time. The advantages of anomalies are the elimination of eventual scale effects and the awareness of the fact that countries with less precipitations have a larger variability compared to the mean (Barrios et al., 2010). Following Marchiori et al. (2012), we calculate climate anomalies as the differences from countries' long-run mean, divided by their long-term standard deviations. Consistently with the literature, the long-run is assumed to be from 1901 to 2000. Another option could have be to resort to the index of physical vulnerability to climate change designed and computed by Guillaumont and Simonet (2011) and used in Guillaumont, Maurel and Simonet (2012).[3]

Figure 3 presents the variation of temperature anomalies over time, by region. Overall, an increasing trend in frequencies of climate anomalies emerges from the analysis of data for the period 1961-2000.

[3] This index relies on various components, reflecting the risks of progressive shocks (sea level, increasing aridity,…) and the risks of increasing recurrent shocks (in rainfall or temperature). Its main source of variation being across countries and not over time, we could not make use of it in this work.

Figure 3: Trend in temperature anomalies by region, 1961-2000



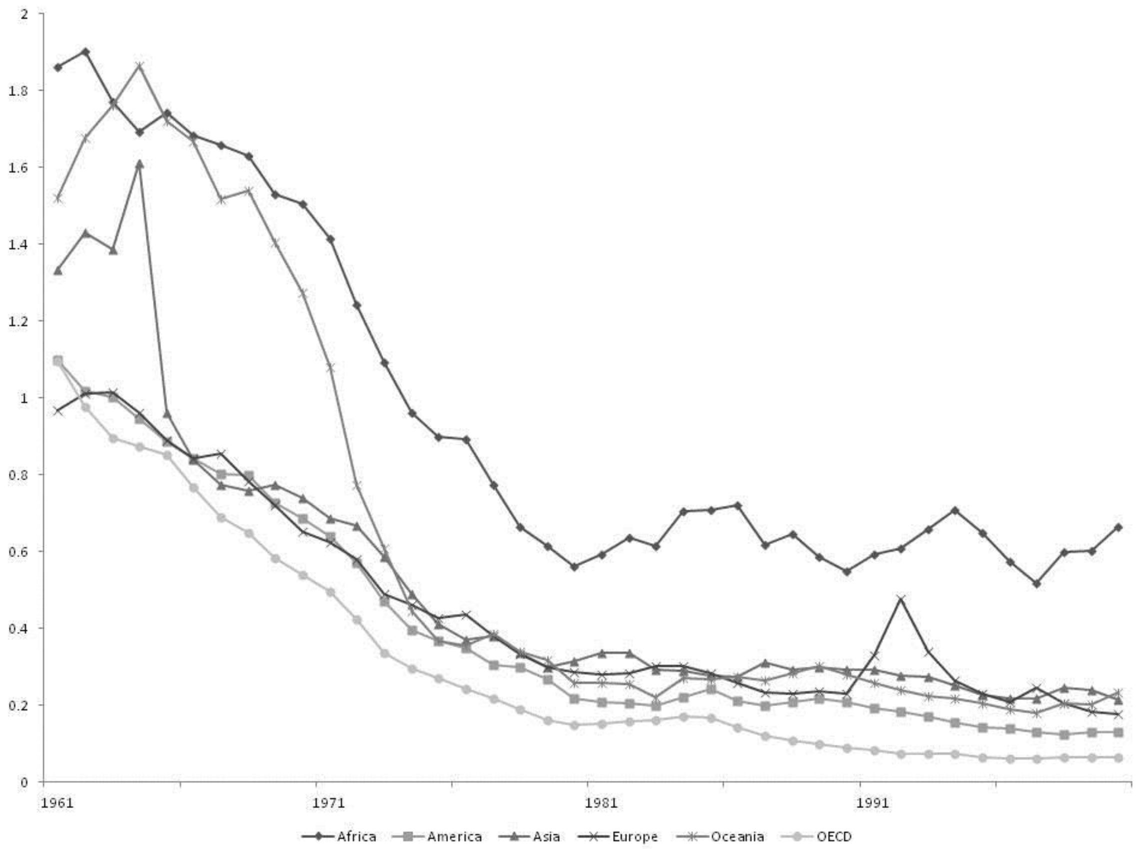
4.3 Agricultural data

Macro-based approaches to model agricultural responses to environmental change are still at the centre of the debate (Lobell and Burke, 2010). Few studies have been yet undertaken using statistical methodologies, and the evidence is mixed (Lilleør and Van den Broeck, 2011). Barrios et al. (2010) estimate a large positive effect of rainfall on economic growth for sub-Saharian Africa, but not for other developing countries. They do not find any relationship with temperature. On the contrary, Dell et al. (2012) measure the same relationship with a larger country sample and conclude with a negative impact of temperature on GDP growth, but no significant correlation with rainfall.

Despite of the heterogeneity in results, most researches tend to analyse the impact of climatic variations on crop yields. This paper uses the agriculture gross Production Index Number (PIN), measured in constant 2004-2006 million US$. This index shows the relative level of the aggregate volume of agricultural production for each year in comparison with the base period 2004-2006. It is based on the sum of price-weighted quantities of different agricultural commodities produced, and it is taken from FAOStat. Since intermediate uses within the agricultural sector (seed and feed) have not been subtracted from production data, it refers to the notion of "gross production". In the regression, agricultural share is compiled as agricultural production over GDP. In addition, we use arable land in the country (from FAOStat) and population (from CEPII Gravity Dataset) as control variables.

Figure 4 shows how the agricultural share in the economy changes over time in the different regions. It is worth to notice that there has been a decreasing trend for all the regions of the sample, for the period 1961-2000. In particular, African countries and Oceania had the largest reduction in agricultural share over GDP (respectively -1.19 per cent and -1.29 per cent).

Figure 4: Trend in agricultural share of GDP by region, 1961-2000



5. Econometric results

In order to empirically test the theoretical framework, this paper makes use of a gravity model. This approach, widely used in trade estimations, have been increasingly applied to migration flows over the last few years (Lewer and Van den Berg, 2008). The gravity theory expects migration to be negatively affected by distance, and positively related to population of origin and destination (Henry et al., 2003). We first estimate the following empirical specification in order to demonstrate that the direct channel between climate change and international migration is inconsistent:

$$\ln(M_{ijt}) = \propto_0 + \propto_1 \ln(C_{it}) + \propto_2 \ln(D_{ij}) + \propto_3 \ln(P_{it}) + \propto_4 \ln(P_{jt}) + \propto_5 \mathrm{X_{ij}} + \propto_t + \propto_{ij} + \varepsilon_{ijt}$$

where M_{ijt} is the bilateral migration flow between origin country i and destination country j at time t and C_{it} represents climatic measureas in country i in period t. The time specific effects $\propto_t$ account for variables that are changing over time but are common among all countries, while a set of unrestricted country-pair fixed-effects, represented by $\propto_{ij}$, captures time-invariant dyadic factors. Distance D_{ij} and population P_{it} and P_{jt} are taken from Head et al. (2010), as well as control variables $\mathrm{X_{ij}}$. Namely, we control for contiguity (dummy variable being 1 if the two countries share a common border), official common language (dummy variable being 1 if the two countries share a common official language), ethnical common language (dummy variable being 1 if the two countries share a language spoken by at least 9 per cent of the population), colony (dummy variable being 1 if the two countries have ever been in colonial relationship) and common legal origin.

Results are estimated using temperature and precipitation anomalies both simultaneously and separately (Table 2). We perform the Hausman's specification test in order to compare the fixed-effects estimator versus random-effects. The Hausman statistics being associated with a p-value close to 0, we report below the fixed-effects estimation. The findings confirms the literature's claim of difficulties in modelling climate-driven migration. Coefficients for temperature and precipitations anomalies are often insignificant, in addition to the wrong expected sign of the coefficient of population at destination. Thus, we can reject the hypothesis of a direct link between climate change and international migration.

Table 2: Estimating the direct channel through fixed effects

	(I)	(II)	(III)
Temperature (anomalies)	0.052	0.013	
	(0.028)*	(0.015)	
Precipitation (anomalies)	-0.003		0.010
	(0.023)		(0.014)
Income differential	0.287	0.327	0.266
	(0.055)***	(0.032)***	(0.040)***
Population (origin)	0.352	0.388	0.468
	(0.228)	(0.118)***	(0.152)***
Population (destination)	-0.694	-0.704	-0.446
	(0.184)***	(0.111)***	(0.133)***
Time dummies	Yes	Yes	Yes
Region dummies	No	No	No
Country-pair FE	Yes	Yes	Yes
R-squared	0.22	0.24	0.20
N	8,441	18,642	13,798

Notes. (1) Dependent variable: Logarithm of decadal bilateral migration flows. Estimation period 1960-2000. (2) Robust standard errors are provided in parentheses. (3) Time dummies are included in all specifications. (4) ***, **, and * constitute 1%, 5%, and 10% significance levels, respectively.

In order to estimate the indirect channel, we rely upon our two-stage model, which consists in extending the models by Feng et al. (2010) and Beine and Parsons (2013) as follows:

$$\ln(M_{ijt}) = \propto_0 + \propto_1 \ln(A_{it}) + \propto_2 \ln(D_{ij}) + \propto_3 \ln(P_{it}) + \propto_4 \ln(P_{jt}) + \propto_5 \mathrm{X_{ij}} + \propto_t + \propto_{ij} + \varepsilon_{ijt}$$

and

$$\ln(A_{it}) = \gamma_0 + \gamma_1 \ln(C_{it}) + \gamma_2 \ln(L_{it}) + \gamma_3 \ln(P_{it}) + \gamma_t + \gamma_{ij} + u_{it}$$

where A_{it} represents the 10-year average agricultural share of GDP in country i at period t and L_{it} is the amount of agricultural land in country i at t. Since agricultural production may be correlated with the error term ε_{ijt}, we estimate the model using fixed-effects in the migration equation. Identification in this equation arises from climate measures, represented by the vector C_{it}, used as instrumental variables for agricultural share. As climate change is likely to be uncorrelated with factors that influence international migration except through its impact on agricultural production (Lilleør and Van den Broeck, 2011), then our strategy should provide consistent estimates of $\propto_1$.

Column III of Table 3 presents the main results. Anomalies in temperature and precipitations have a negative and significant effect on the share of agriculture over GDP (Panel A). In turn, as the share of agriculture increases, the migration flow decreases (Panel B). Otherwise said, the decline in the share of agriculture in national economy due to climate change leads migrants to cross the border. In addition, the rest of explanatory and control variables have all the expected sign and significance. An overidentification test has been estimated in order to confirm the validity of the instruments. The joint null hypoythesis of the Hansen J statistic is that instruments are uncorrelated with the error term, and consequentely valid. Since the statistic is 0.670 and its p-value is 0.4129, the null is not rejected and we can consider the overidentification restrictions valid.

Estimates of climate anomalies (columns I and III, Panel A) and agricultural share (column III, Panel B), allow to compute the climate induced migration flows. A two-standard deviation increase in temperature anomalies (precipitation anomalies) leads to an increase in migration of respectively 3,8% (7,7%) of average migration flows.

Table 3: Estimating the indirect channel through 2SLS

	(I)	(II)	(III)
Panel A. First stage.		Dependent variable = Agricultural share	
Temperature (anomalies)	-0.027		-0.005
	(0.006)***		(0.009)**
Precipitation (anomalies)		-0.008	-0.022
		(0.006)*	(0.009)***
Panel B. IV.		Dependent variable = Migration flow	
Agricultural share	-2.441	-2.233	-4.434
	(0.814)***	(2.520)	(1.886)**
Income differential	1.332	1.243	2.053
	(0.334)***	(0.954)	(0.696)***
Population (origin)	3.222	2.966	5.535
	(0.915)***	(2.785)	(2.132)***
Population (destination)	0.709	0.698	0.851
	(0.070)***	(0.173)***	(0.129)***
Distance	-1.144	-0.939	-0.612
	(0.038)***	(0.114)***	(0.179)***
Contiguity	2.046	1.920	1.840
	(0.206)***	(0.326)***	(0.463)***
Common language (off.)	0.480	0.950	1.331
	(0.144)***	(0.312)***	(0.347)***
Common language (ethn.)	0.669	0.507	0.213
	(0.166)***	(0.496)	(0.365)
Colony	1.311	1.276	1.249
	(0.185)***	(0.233)***	(0.326)***
Common legal origin	0.535	0.363	0.700
	(0.111)***	(0.232)	(0.234)***
Time dummies	Yes	Yes	Yes
Region dummies	Yes	Yes	Yes
F	356.08	317.49	80.73
N	12,746	9,683	5,727

Notes. (1) Dependent variable for IV: Logarithm of decadal bilateral migration flows. Estimation period 1960-2000. (2) Robust standard errors are provided in parentheses. (3) Time and region dummies are included in all specifications. (4) ***, **, and * constitute 1%, 5%, and 10% significance levels, respectively.

These results are robust to different specifications. For instance, we calculate a new measure of environmental change: a variable that takes the value of the average climate index over the previous 10-years. Running the regression with this different instrumental variable does not change the significance and the sign of agricultural share over GDP (Column I of Table 4). Finally, we restrict the sample to only North-North migration (i.e. bilateral migration flows between OECD countries). It is feasible to expect that the outlined econometric strategy will not work for intra-OECD migration, since the agricultural share of the economy of rich countries is typically low. Findings confirm this hypothesis: the coefficient of agricultural share indeed becomes insignificant (Column II).

Table 4: Robustness checks

	(I)	(II)
Panel A. First stage.	Dependent variable = Agricultural share	
Temperature (anomalies)		0.125
		(0.016)***
Precipitation (anomalies)		-0.035
		(0.028)*
Temperature (mean)	0.032	
	(0.016)***	
Precipitation (mean)	0.175	
	(0.009)***	
Panel B. IV.	Dependent variable = Migration flow	
Agricultural share	-0.672	0.645
	(0.114)***	(0.696)
Income differential	0.631	0.436
	(0.049)***	(0.198)**
Population (origin)	1.202	-0.190
	(0.125)***	(0.658)
Population (destination)	0.575	0.704
	(0.014)***	(0.062)***
Distance	-1.105	-0.804
	(0.022)***	(0.111)***
Contiguity	1.982	1.133
	(0.112)***	(0.343)***
Common language (off.)	0.527	1.144
	(0.090)***	(0.529)**
Common language (ethn.)	0.929	1.042
	(0.084)***	(0.412)**
Colony	1.304	0.461
	(0.128)***	(0.340)
Common legal origin	(0.340)	-0.031
	(0.038)***	(0.244)
Time dummies	Yes	Yes
Region dummies	Yes	No
F	807.85	41.95
N	18,888	669

Notes. (1) Dependent variable for IV: Logarithm of decadal bilateral migration flows. Estimation period 1960-2000. (2) Robust standard errors are provided in parentheses. (3) Time dummies are included in all specifications. (4) ***, **, and * constitute 1%, 5%, and 10% significance levels, respectively.

To summarize, these econometric results confirm the difficulties found by the previous literature in quantitatively estimating climate-driven migration. Specifically, using a linear gravity model, the present paper excludes a direct relationship between climatic variations and international migration. On the contrary, an instrumental variable approach is able to estimate an indirect channel passing through agricultural production. In particular, climate change reduces the share of agriculture over national economy, leading people to engage in cross-border movements.

6. Conclusions

The present paper attempts to investigate the channel through which climate change impacts international migration. While previous studies are mainly micro studies, with the exception of Beine and Parsson (2013), our approach is tested with macro data and we are able to generalize previous results according to which climatic instability leads to higher migration. In accordance with the environmental literature, we construct a simple theoretical framework where climate anomalies accelerate the transition from the traditional to the modern sector, leading rural workers to move to urban centres within national borders. Downward pressure on wages due to demographic pressures and the high labour supply pushes people to engage in international migration, looking for better working opportunities elsewhere.

We exploit a new panel dataset of bilateral migration stocks and climatic data for 108 countries for the period 1960-2000. Consistently with the theoretical framework, a direct channel between environmental change and international migration is excluded. Thus, we specify an instrumental variable model to test the existence of indirect linkages. Anomalies in temperature and precipitations reduce the agricultural share in national economy, and this in turn spurs international bilateral migration flows. Additional, climate-induced, migration flows may represent up to 8% out of total migration flows. The results are robust to different samples and specifications. Our work echoes the recent work of Beine and Parsons (2013), who conclude that the effect of climate, if any, is due to the greater flows of migrants to urban centres induced by natural disasters.

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