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# The migration response to increasing temperatures

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ABSTRACT

Climate change, especially the warming trend experienced in recent years by several countries, could affect agricultural productivity. As a consequence the income of rural populations will change, and with it the incentives for people to remain in rural areas. Using data from 115 countries between 1960 and 2000, we analyze the effect of differential warming trends across countries on the probability of either migrating out of the country or from rural to urban areas. We find that higher temperatures in middle-income economies increased migration rates to urban areas and to other countries. In poor countries, higher temperatures reduced the probability of migration to cities and to other countries, consistently with the presence of severe liquidity constraints. In middle-income countries, migration represents an important margin of adjustment to global warming, potentially contributing to structural change and even increasing income per worker. Such a mechanism, however, does not seem to work in poor economies.



## 1. Introduction

One of the best demonstrated long-run effects of rising average surface temperature is its negative effect on productivity in agriculture. The optimal yield of agricultural products has been adjusted to local temperature for centuries and many studies (e.g. Burke et al., 2015) have shown that agricultural GDP peaks at the average yearly temperature of around 14 °C and declines for higher temperatures. Hence, as most of the world population and economic activity reside in countries with average temperatures around or above 14°, several studies find that productivity decreases as temperature increases beyond a country's historical average (Burke et al., 2015; Cline, 2007; Dell et al., 2014; IPCC, 2014). While some studies find that non-agricultural GDP may also decline for yearly temperatures above 14–15°, it also appears that the productivity decline is less steep and less precisely measured for non-agricultural sectors (see Fig. 2d and e in Burke et al., 2015). Agriculture is still a very relevant source of income and employment in poor countries, especially in rural areas. One potentially important margin of adjustment to declining agricultural productivity in poor countries is migration from rural to urban areas, either within the home country or towards another country. While some papers have begun to analyze how warming may affect income per person across countries over the long run (e.g. Dell et al., 2012), and other studies have analyzed the connection between temperature/precipitation and human migration in some specific countries (e.g. Bohra-Mishra et al., 2014; Dillon et al., 2011; Gray and Mueller, 2012a; Mueller et al., 2014), few studies look at the systematic long-run effect of temperature change on emigration and rural-to-urban migration in poor and middle-income countries in the world.[1] This paper gathers data and proposes a model and simple empirical framework to analyze the impact of temperature change on emigration rates in countries where agriculture is still an important sector and many migrants originate from rural areas.

By impoverishing the rural population of poor countries and worsening their income perspectives, long-term warming may affect migration in different ways, depending on the initial income of those rural populations. As previously suggested by studies such as

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[1] Cai et al. (2014) is probably the paper most closely related to ours. It analyzes specifically the link between temperature, crop yields and migration to OECD countries. However, they use yearly data between 1980–2000 and only migration to OECD countries, therefore capturing short-run relationships and long distance migration.

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Mayda (2010), a decline in the income of the sending country may have a depressing effect on the share of emigrants from very poor countries. In these countries, individuals of rural communities are near subsistence, so a lower income worsens their liquidity constraint, implying that potential migrants have a reduced ability to pay migration costs. In this case, global warming may trap very poor rural workers, making them unable to leave agriculture and potentially worsening their poverty. To the contrary, in countries in which individuals are not extremely poor, a decline in agricultural income may provide incentives to migrate to cities or abroad. Decreasing agricultural productivity may encourage a mechanism that ultimately leads to shifting people out of agriculture into urban environments. The inverted U-shape of migration rates as a function of income per person in the countries of origin is usually rationalized in this type of framework. However, we are not aware of a simple formalization of this model nor of a clean analysis which tests this non-monotonic effect by exploiting variation of an exogenous determinant of productivity, such as temperature.

In this paper we are the first to extend the classical Roy–Borjas model (Borjas, 1987; Roy, 1951) and we use this framework to analyze the effects of exogenous changes in agricultural productivity (due to temperature increase) and its opposite effects on the probability of emigration for poor or middle-income countries. In particular, the model predicts that a long-run increase in temperature decreases the income of rural populations in very poor countries, generates a poverty trap and lowers the probability of emigration. To the contrary, in middle-income countries the decline in agricultural productivity pushes emigrants out of rural areas. This stimulates urbanization and may speed the country's structural transformation, ultimately increasing its income per person. In accordance with the model's predictions, we find that in very poor countries increasing temperature leads to lower emigration and urbanization rates, while in middle-income countries it leads to larger rates. We also show that long-run temperature increase speeds the transition away from agriculture in middle-income countries. Conversely, it slows this transition in poor countries – worsening the poverty trap – as poor rural workers become less likely to move to cities or abroad. We also find, for middle-income countries, emigration induced by higher temperature is local and is associated with growth in average GDP per person, while the decline in emigration and urbanization in poor countries is associated with lower average GDP per person.

The literature has emphasized the relationship between temperature and income per person is likely nonlinear. Changes in income/productivity are either relatively small or even positive for average yearly temperatures between 10 and 20 ◦ C, while a decline occurs for temperatures above a threshold located around 20/25◦. This implies that increases in temperature are more damaging, especially in agricultural output, above a certain value. In our analysis, we consider this type of nonlinearity by testing whether temperature increases have a nonlinear positive (or negative) effect on the migration probability of its citizens. We emphasize, however, that the behavior of migration with respect to temperature largely depends on the initial income of the country of origin. Similarly, a productivity decline will have a different effect in poor or middle-income countries due to prevailing liquidity constraints or incentive mechanisms. We find that the nonlinearity of the temperature effect is less relevant than the interaction of temperature with initial income for the migration response. Poor countries experience different temperature effects on migration relative to middle-income countries because of their lower income (likely to worsen liquidity constraints) and not because they are also hot.

The rest of the paper is organized as follows. Section 2 reviews the literature on climate and international migrations. Section 3 presents a simple variation of the Borjas–Roy model relating agricultural productivity to migration rates at different income levels. Section 4 describes the data and variables, and Section 5 presents the main empirical specifications and the main estimates of the effects of warming on migrations. Section 6 shows some robustness checks, and Section 7 checks that the climate–migration connection is consistent with the estimated effects of climate on structural change and GDP across countries. Section 8 concludes the paper.

## 2. Literature review

The literature analyzing the effects of weather and climate events on migration is recent and growing. Several papers have analyzed the impact of episodes of drought, high temperature, or low precipitation on rural emigration in specific countries.[2] Because of its extreme poverty and its dependence on agricultural production, Sub-Saharan Africa has received great attention. Most of the existing studies on this area analyze the year-to-year correlation between weather phenomena and migration, and mainly identify temporary displacements rather than long-term trends. In multi-country studies of Sub-Saharan Africa, Barrios et al. (2006) analyze the link between average rainfall and urbanization, and Marchiori et al. (2012) estimate how temperature and precipitation anomalies have affected migration.

A case that has also been studied in depth is the connection between weather/climate and migration out of Mexico. Looking at Mexico–US migration, Munshi (2003) is the first to show the connection between low rainfall and migration rates. More recently, Feng et al. (2010) confirm the relation between weather and migration from Mexico. However, Auffhammer and Vincent (2012) demonstrate that this effect vanishes after they control for a richer set of covariates.

Overall, the existing literature on weather change and migration focuses on within country data or uses yearly migration rates. Hence it fails to provide a general picture of the potential long-run effect of weather changes on migration within and across countries that span a range of income levels. Beine and Parsons (2015) use decade data, but they do not directly tackle the question regarding the effect of changes in average temperature on migration in the long-run. The paper produces an accurate study that focuses on bilateral migration and analyzes the impact of extreme weather events, deviations and anomalies in temperatures from the long-run averages, after one controls for many other bilateral factors. An even more recent paper by Backhaus et al. (2015) performs a similar analysis on yearly data, considering average temperature as the main explanatory variable. Both of these papers focus on partial effects of temperature and of extreme weather events as they control for productivity and income of country of origin. We think, however, the more relevant question is to identify the total effect of temperature on emigration, test interactions with the income level of the country of origin, disentangle potential nonlinearities in temperature and suggest potential channels and explanations.

Our paper does exactly this. It differs from previous work by considering all countries of the world, explicitly analyzing the effects of temperature on internal and international migration within a simple Roy–Borjas model of migration and average productivity. In so doing, we are able to identify a crucial and plausible distinction of the effect of temperature increases on migration from poor and middle-income countries and test whether such a distinction, and other

[2] Some examples follow: Dillon et al. (2011) analyzed migration in Nigeria. Mueller et al. (2014) look at the connection between temperature variation and migration in Pakistan. Gray and Mueller (2012a) consider the link between droughts and emigration in Ethiopia, while Gray and Mueller (2012b) analyze the effect of flood on mobility in Bangladesh. Gray and Bilsborrow (2013) and Gray (2009) analyze internal and international migration in Ecuador in response to rainfall. Henry et al. (2004) look at the case of annual precipitation and migration in Burkina Faso. Bohra-Mishra et al. (2014) analyze Indonesia and Kelley et al. (2015) focus on Syria.