Barcelona Graduate School of Economics

Economics Program

Modelling Migration Choices in the Context of Climate Change and Income Heterogeneity

Authors

Ayah BOHSALI,
Enrichetta GIURICKOVIC
Yuva S. KORLABANDI
Jiayi LIN
Francesco SAVAZZI

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Barcelona GSE
Graduate School of Economics

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Abstract

The paper focuses on the impact of climate-induced shocks in developing countries. Natural disasters affect households by increasing the risk of falling further into poverty and depleting their resources up to the point where migration is not an affordable risk-reduction strategy. We consider several factors affecting the climate-induced migration decision and develop a novel micro-founded model of aggregate migration flows to study the change in the composition of migrants who face a negative climate-induced productivity shock. We provide a theoretical framework with which we can track the change in the composition of migrants according to their income. Our results counter the conventional belief that migration will be mostly characterized by the poorest participants becoming internationally displaced. Instead, our model predicts that it is not those in extreme poverty, nor those in the highest income brackets, that are driven to climate-induced migration. In fact, the composition of these migrants changes based on different values of relevant parameters. [1]

Keywords: Climate Change, Environmental Migration, International Migration, Wealth Heterogeneity, Liquidity Constraints

1 Introduction

The impact of climate change on human displacement is a theme of increasing interest among scholars and policymakers. In the first two decades of the 21^{st} century, it has become clear that climate change should not be considered a distant worry, but rather a threat that has already manifested itself pervasively all over the world, with different locations being impacted in various degrees of severity. Natural disasters of unprecedented calibre are already causing human migration locally, regionally, and overseas. According to the Internal Displacement Monitoring Centre, 17.2 million people were displaced domestically and overseas in 2018 due to climate related reasons. Climate change is indeed recognized as a key driver of mobility [2]. The World Bank projections forecast 143 million people to migrate by 2050 if no climate action is taken. This and higher numbers are asserted by a broad literature estimating hundreds of millions of climate-induced migrants likely moving by 2050 from areas at greater

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[2] Agenda for Humanity; 2016 United Nations Summit for Refugees and Migrants; Global Compact for Migration and the Global Compact on Refugees.

risk of being affected by temperature changes, floods, sea-level rises (SLRs), desertification, and droughts (Myers, 2002; Biermann and Boas, 2010; Rigaud et al., 2018). These estimates suggest that in the next few decades a significant portion of overall global migration could be explained by environmental-induced mobility.

One recent phenomenon has captured our attention. During the six-year period between 2003 and 2009 an area equal to all the water in the Dead Sea[3] vanished from the Tigris-Euphrates Basin[4] region as a result of droughts and poor water management policies[5]. As a consequence, millions of people were displaced and 1.5 millions are estimated to be environmental migrants (Jägerskog and Swain, 2016). 38% of these refugees in three European countries were highly educated (Betts et al., 2017). On the contrary, in Lebanon 45% of Syrians were unskilled workers while 43% were semi-skilled (Errighi et al., 2016). The situation is similar in Jordan, where only 5% of Syrians are employed in skilled white collar jobs (Stave and Hillesund, 2015). These trends describing the migratory flows after the Syrian crisis go against the conventional belief that migration mostly concerns poor-unskilled people and suggest that specific shocks may lead to a change in the composition of migrants.

This scenario leads to a fundamental question that we will try to address in this study: *How does the increase in the risk of a climate disaster, and knowledge of this risk, affect the natural flow and composition of migrants?*

Climate shocks affect households' capacity to live the desired standard of life (Sen et al., 1999) by depleting their assets (e.g. lands and natural resources) and affecting their wages. For instance, adverse shocks, such as sea level rises or persistent droughts, reduce long-term productivity of households' land (Gray and Mueller, 2012b; Feng et al., 2010). However, an adverse shock not only has an effect in the present but it also increases the risk that households fall (further) into poverty in the future (Calvo and Dercon, 2013), leading them to choose a risk reduction strategy (migration).

[3] 117 million acre-feet of stored freshwater

[4] Tigris-Euphrates Basin comprises Turkey, Syria, Iraq and Western Iran.

[5] The Gravity Recovery and Climate Experiment (GRACE) refers to a pair of NASA satellites that have flown in low-Earth orbit since 2002.

Again, this setting gives rise to two questions that do not find a consistent answer in the existing literature: *How do potential environmental disasters affect the migration decisions of people of different wealth levels? How can knowledge and education in the hands of the wealthy and more skilled citizens of a country give them an advantage over their less skilled poorer counterparts?*

Despite cultural and geographical diversity across countries, a systemic review of the literature[6] shows some consistencies about how migration flows change (in terms of both, migrants composition and destination choice) depending on the household's capability to move. Two recurring patterns shape the intuition on which our proposed theoretical framework relies. First, climate-induced migration seems to be more frequent for wealthier than poorer agents. This might at first seem surprising since poorer agents are at greater risk to be affected by a climate shock and, when they face damages to the point of not being able to adapt to the shock, we expect them to be "forced to leave" and migrate. However, the damage caused by the shock might lead to a financial barrier that may prevent poor agents to afford the migration cost (Laczko et al., 2009). Second, climate shocks seem to drive more long-distance domestic displacement, rather than local or international migration. The location choice, clearly, depends on other factors - such as wealth and income - playing a role in the way households are affected by climate change, and so in their capability to migrate (Adger et al., 2009; Black et al., 2011). In response to a shock that leads (or is expected to lead) poor agricultural harvests, vulnerable agents may prefer to opt for low cost migration to nearby areas. More skilled and less vulnerable agents, on the other hand, may invest in high cost international migration, aiming to increase expected income or welfare in other forms. Furthermore, the impact of land ownership, a major factor in the migration decision, is ambiguous. Although land tenure (as a source of wealth) should lead to higher capability to migrate, it also means higher exposure to climate shocks and consequential changes in agricultural productivity. That is because land tenure is an indicator of wealth and social status, so it is certainly positively correlated with the ability of agents to afford the migration cost (and the higher cost of migrating to more distant destinations). However, land ownership may imply higher ability to adapt and less need to migrate. Also, land ownership *per se* constitutes a tie to the home-location and disincentivizes migration as it could result

[6] See Section 2 for a detailed analysis of recent empirical findings on the climate-migration *nexus*.

in land holdings loss[7].

In this paper, we present a novel theoretical framework that rationalizes the empirical findings on the migration literature. The existing literature on the climate-migration nexus fails to provide a general all-encompassing answer (i.e. valid for *any* climate shock) to these queries. In contrast to empirical studies, the general theoretical model presented here can be adapted to different observable phenomena. We focus on expected sudden climate shocks (i.e. agents observe the probability of the shock happening), hence disregarding unexpected natural disaster and expected but gradual events. These expected shocks encompass all the sudden natural events that are driven by other (observed) environmental factors (e.g. increasing temperatures, natural disasters such as floods, etc.). We assess the impact of (non-uniformly) perceived climate change on post-disaster migration, welfare, and inequality (see Alam et al. (2017); Etzold et al. (2014); Koubi et al. (2016) for empirical analysis on the impact of *expected* shocks on migration). Borjas (1987) gives a pioneering contribution on framing migration theoretically by providing a simple formulation of the self-selection Roy model (Roy, 1951) where migration between two countries is the simple result of different skills and wages distributions of economies in equilibrium. However, based on the evidence from data and empirical studies discussed above, we expect that, when a climate shock is involved, the composition of migrants changes greatly from what Borjas predicts (that only the lowest skilled people choose to migrate from a country with unequal income distributions to a country with more equal income distributions). Existing theoretical frameworks describing the spatial aspects of the multi-destination migration phenomenon are mainly focused on econometric modelling (e.g. the gravity model). We provide a simple two-period micro-founded macroeconomic model to help understanding present and future changes in the composition of climate-induced migrants based on two socioeconomic factors: income and wealth/land-tenure. Following the neoclassical approach, agents consider the costs and benefits (primarily wages) of current and alternative locations (Castles, 2014), however, according to the push-pull theory (Lee, 1966), we incorporate the climate threat as an additional characteristic of the source and host countries which goes beyond merely wages discrepancies.

[7]Consistently with the literature on the endowment effect and loss aversion (Kahneman et al. (1990), (1991), List (2011)), land owners would be willing to migrate only if they get a reward for the loss of what they own in their country of origin.

Our model differs from previous research in that it is able to predict - based on agents' wages and skills - the portion of migrants who stay in the home country, the one moving to the neighbour country, and the one moving to a far and less unequal country. Our interest is in the climate impacts in developing countries, which are more vulnerable to shocks and likely to face a greater adverse effect on human welfare (Eckstein et al., 2019; Cai et al., 2016; Cattaneo and Peri, 2016)). In particular, we assume a three-country world where households decide whether to stay in their home-developing country ("country 0") or to migrate to either the neighbour-developing ("country 1") or the distant-developed country ("country 2"). In our setting, the neighbour country 1 has very similar characteristics to the origin country 0. In this sense, we can interpret it not only as short-distance international but also as a within-border migration destination which is not affected by the climate shock that hits part of the same country (i.e. long distance "domestic" or short-distance "cross-border" displacement). Hence, we disregard domestic-local migration and focus our analysis on long-distance domestic versus international displacement. The income distribution across agents of country 2 (the further-developed destination) is assumed to be more equal than that of the developing countries (0 and 1). From the data of the World Inequality Database, we choose our shape parameter of the distribution of country 0 and 1 to be between the mean of the parameters for wealth and income of the developing countries, while for country 2 this parameter is chosen close to the mean of the shape parameters for wealth and income of OECD countries.

Households will take the decision that maximizes their utility subject to a budget constraint including a migration cost, which differs based on the destination due to factors such as distance and cultural adaptation costs (Rothenberg, 1977). We compare agents' decision of migration from country 0 in different cases that take into account: probability of an environmental shock (negligible, medium and high), damage of the shock (mild versus severe), and different migration costs. In particular we assume the cost to be linearly increasing with the wages and with a minimum fixed cost. [8]

[8] It is important to understand what the migration costs are representing. Migrants have to face both monetary and psychological costs of moving. Following the estimates of the International Organization for Migration (MINDS/ČTK, 2017), the price of smugglers from Syria to Greece is around €4,800 and from Bangladesh to the USA €24,000. Moreover, the migration process can take several years and therefore may lead to a large opportunity cost of not working. Although it is very difficult to estimate, and far beyond our intentions, the physiological costs of the journey, the integration in the host country and the homesickness can further explain the apparently unjustified high costs assumed in our model.

The portion of the population that migrates to the developed country in the low probability-low damage-scenario is the low-middle income bracket of the economy as in Borjas (1987). However, as the probability of the shock and the potential damage increase, also higher income people will prefer to migrate. The choice of migrating to country 1 is instead taken only if the cost of migration is lower than the impact of the shock. Indeed if the migration cost is zero even if we introduce a very small shock everybody would be willing to migrate. However, in the more realistic case of a positive migration cost, only those people that can afford it would migrate and by increasing the probability and the impact of the shock, more and more poor people will decide to incur the cost of migration.

To make the model more realistic we also introduced the possibility for agents to lose some skills by moving from one country to the other. This phenomenon, called skill downgrading, is of high interest in the literature of labor economics. As a result, high skilled agents are less inclined to migrate compared to low skilled.

To explore the effects of climate disasters on an economy with an already existing (and high) level of inequality, we also extend the model to include distortions of the perceived probability of the disaster. Studies have shown that people tend to underestimate the potential impact of climate change, and the more educated and skilled they are, the more they are able to adapt to this impact (Apata et al., 2009; Deressa et al., 2010, 2009)[9]. Thus, we model this distortion by including a perceived probability of a shock happening, whose accuracy (i.e. proximity to the "true" probability) is increasing in the level of skill of agents. We show that this enlarges the welfare gap between high and low income agents in the case of an observed shock. This happens because, in anticipation of a lower probability shock, less people migrate and those who stay under-save below the true optimal savings level. As a consequence of the lower awareness of climate change, the impact of an observed shock will make lower income agents worse off than their wealthier counterparts. This scenario prompts a discussion about policies that governments may implement to protect citizens from the damages of climate change.

The rest of the paper is structured in the following way. In Section 2 we go further in details in the - sometimes controversial - empirical findings on migration behaviour based

[9] Apata et al. (2009) find that education influenced adaptation positively; Deressa et al. (2009) and Deressa et al. (2010) find that education of households increased the probability of adapting to climate change.

on two crucial aspects: socioeconomic factors (wealth in the form of income and assets) and migration destination (international, long-distance domestic, or local). In Section 3, we introduce our model and in Section 4 we present and discuss the results. In Section 5 we provide extended versions of the model where some assumptions are relaxed to better depict what we see in the real world. Discussion of new results from these extensions follow. In Section 6 we conclude. Policy implications and future research avenues are briefly discussed.

2 Empirical Findings

We focused our empirical literature review on two different aspects of the migration phenomenon: (i) modifying social factors (e.g. poverty, land ownership) and (ii) migration destination. In this section we intend to present, separately, the findings related to both aspects and highlight the controversial effect of land ownership.

2.1 Socioeconomic Factors

Socioeconomic factors (e.g. poverty, land tenure) have an ambiguous effect on climate-induced migration decisions. Hence, shock-induced environmental migration does not necessarily affect prevalently poorer households.

Bohra-Mishra et al. (2017) find that households with higher levels of education are more sensitive to rising temperature and typhoons. Gray and Mueller (2012b) investigate the consequence of climate shocks in rural Bangladesh, a region particularly vulnerable to environmental change, for long-term migration and recognize significant barriers to migration for vulnerable households. In both studies education is a proxy for financial resources, suggesting that higher-skilled agents have higher probability to migrate due to climatic shocks. However, when income and/or asset ownership is used as a proxy of wealth, findings are ambiguous. Thiede and Gray (2017), Gray and Mueller (2012a,b) find no impact of wealth on the likelihood of environmental migration. Hirvonen et al. (2016) finds that in Tanzania the effect of heatwaves on migration is significantly weakened among wealthier agents. Mastrorillo et al. (2016) find a stronger positive climate effect for low-income households (although still positive for high-income agents). These mixed findings are partially explained by income being endogenous to climate shocks.

From this evidence we conjecture that, although we would expect agents to be "forced to leave" due to the impact of the climate shock, the financial barrier might lead poor people to be "forced to stay". Hence, climate change may affect positively migration of wealthier agents because their assets, especially agricultural land, could have higher exposure to climate shocks, while the likelihood of migrating is reduced for poorer agents that face a significant decrease of their financial capability to move. In this sense, migration is a costly adaptation strategy that might be affordable only for a wealthier fraction of households, whereas poorer agents might face a financial constraint that leads them to be "forced to stay". In this regard, another factor playing an important role is land ownership, which often discourages migration for financially stable households. Hence, the composition of environmental migrants is different from what we see in overall migratory patterns (i.e. climate-induced migration does not necessarily regard poorer household in the first place).

2.2 Migration Destination

Earlier literature on general (not climate-induced) migration appears consistent in finding that more educated/skilled and wealthier agents are more likely to migrate internationally relatively to less educated and poorer people, who would rather migrate nationally or locally (Laczko et al., 2009). However, when considering climate-induced migration, findings suggest a different pattern. Gray and Mueller (2012a) find that droughts in Ethiopia induce long-distance domestic, rather than local, migration. Gray and Bilsborrow (2013) found that droughts in Ecuador increased both local and international mobility but decreased internal migration, perhaps due to the fact that internal migrants originate from poor areas and do not have the resources to invest in internal migration. Also, they find that rainfalls (a positive agricultural shock) decrease local and international migration but increased domestic migration. Henry et al. (2004) find that as a consequence of droughts in Burkina Faso people are less likely to move internationally than domestically. More evidence regarding this trend is observed in studies on climate-induced migration from Mexico to the USA (Jessoe et al., 2018; Nawrotzki and DeWaard, 2016; Nawrotzki et al., 2013). In particular, Jessoe et al. (2018) and Nawrotzki and DeWaard (2016) find that when temperature shocks are extreme, migration to the USA increases, while moderate shocks induce more domestic/local migration. This evidence puts in light the importance of the nature and intensity of the climate shock on the destination choice.

The multi-causal nature of the phenomenon makes difficult the identification of causality behind migration decisions. Hence, attempting to answer these questions through an empirical approach would require very specific and rich data, that are sparse and hard to find and collect, and would require dealing with many other issues (e.g. illegal immigration). In addition, climate change can have either direct or indirect effects on the migration decision (e.g. through socioeconomic or political channels). For these reasons, the existing literature on the *nexus* between climate change and migration fails to provide a consistent answer to our questions which is encompassing any type of climate shock affecting land productivity and households' income.

3 The Baseline Model

In this section we develop a two-period microfounded model of migration decisions. We consider a home country (country 0), with a continuum of agents $i \in [0,1]$, heterogeneous in skill (and so in wage), to capture unequal income distribution across the citizens. There are two potential destinations: country 1, a neighboring developing country with identical characteristics to the country of origin, and country 2, a developed country with a more equal income distribution. Migration to country 1 can also be interpreted as long-distance internal migration.

Following similar literature, we assume that agents' individual productivity, or skill, is Pareto distributed with parameter θ that indicates variability: $Z_j \sim 1 - Z^{-\theta_j}$ and $Z \geq 1$, with j denoting the country, $j \in \{0,1,2\}$. We assume that $Z_0^i = Z_1^i$. Moreover, we assume that skills are maintained with migration. The assumption that skills and wages follow the same distribution and are proportional is present also in the Roy Model adjusted by Borjas (1987) in which he models the self selection of migrants based on the difference in inequalities between the source and host countries. In the first period, t_0, agents choose whether to save or not, and whether to migrate to another country or not. In the second period, they earn a wage and consume what is left of their income. Most importantly, at the time of the decision-making, agents face uncertainty regarding the events of the second period: they know that at t_1, with a probability p, a climate disaster will occur in country 0 in the form of a shock to TFP $A_{0,t_1} \in \{A^L, A^H\}$ with A^L representing the TFP in case a climate shock happens, and A^H represents no climate shock, which will directly impact their income and consumption.

3.1 Economic Environment

3.1.1 Preferences

To emphasize a decreasing marginal utility for agents, we choose preferences to be logarithmic:

$$u(C_t) = \log(C_t)$$

3.1.2 Production

Agent i supplies L units of labor inelastically, earning a wage $W^i_{j,t}$. Output in country j at time t, is given by:

$$Y_{j,t} = A_{j,t} \int_0^1 Z^i_{j,t} L^i_{j,t} di$$

where $Z^i_{j,t}$ is the labor ability, or "skill" of citizen of type i in country j, and $A_{j,t}$ is the aggregate productivity in the country at time t, and country 0 faces an aggregate productivity shock due to a climate disaster that is translated through a decrease in A (A_L). The profit

$$\max_{L^i_{j,t}} Y_{j,t} - \int_0^1 W^i_{j,t} L^i_{j,t} di$$

Plugging in the production function and taking FOCs with respect to each $L^i_{j,t}$:

$$A_{j,t} Z^i_{j,t} = W^i_{j,t}$$

(i.e. zero-profits). Given labor market clearing, $\int_0^1 L^i_{j,t} di = L = 1$ (normalization) for $i \in [0, 1]$.

3.1.3 Agents' Choices

In this model, at $t = t_0$ each agent receives a wage W^i_{0,t_0} and decides whether to stay in country 0, and have the option to save, or to migrate to country 1, which requires a payment of m_1, or to country 2, which also requires a payment of m_2. Staying in country 0 requires no payments, i.e. $m_0 = 0$. We are allowing for saving/ investing by letting households accumulate some of their wealth, which earns an exogenous interest rate R_t on their savings each period **only** if they are in the same country in the next period. We would like to think of these savings going into an illiquid investment such as "land" that can help sustain the agent in the period after. As such, he can access the returns in the next period only if he stays in the same country.

Given that the savings and migration decisions are made simultaneously, the agent will only choose to save if he intends to stay in country 0 in the next period (it would not be optimal to do so otherwise). In other words, there is a dichotomous choice between holding land and migrating, as in Jayachandran (2006). In the second time period, t_1, agents earn W^i_{j,t_1} depending on the country they are in, and consume all their income (which includes the returns to savings if at t_1 they choose to stay in country 0). More formally, the agent's problem can be written as:

$$\max_{a_t, m_j} u(C^i_{0,t_0}) + \beta E[u(C^i_{0,t_1})]$$

subject to:

$$C^i_{0,t_0} \leq W^i_{0,t_0} - a - m_j$$

$$C^i_{j,t_1} \leq W^i_{j,t_1} + R_t a$$

$$A_{j,t} Z^i_{j,t} = W^i_{j,t}$$

The problem can be simplified because of local non-satiation of preferences, by Walras's Law the inequalities are binding.
With optimal savings:

$$a^*_t = \begin{cases} \text{a}^* & \text{if m}_j = m_0 = 0 \\ 0 & \text{otherwise} \end{cases}$$

A note on migration costs: in our baseline model we assume that migration costs are not fixed, as done in Bazzi (2017), but increasing in the skills of the agents. This highlights the idea that high income agents have more to lose from migrating, because they own more land, houses, and businesses. Without adding this variable cost, there is not much diversity in how the migration decision affects agents in different income brackets.

3.2 Solving the Model

3.2.1 Optimal Savings

Solving for a^*: For $m_0 = 0$,

$$\max_{a_t} u(W^i_{0,t_0} - a) + \beta E[u(W^i_{j,t_1} + R_t a)]$$

Taking FOC w.r.t a, we get the Euler equation:

$$u'(C^i_{0,t_0}) = \beta E[R_t u'(C^i_{0,t_1})]$$

After substituting the functional form of $u(C_t)$, we get

$$a^* = \frac{-\Omega + \sqrt{\Omega^2 - 4(1+\beta)\bar{W} + 4\beta(1+\beta)R_t W^i_{0,t_0}\hat{W})}}{2(1+\beta)R_t} \tag{1}$$

where

$$W^H = A^H Z^i_{0,t_1}; W^L = A^L Z^i_{0,t_1}$$

$$\Omega = W^L + W^H + \beta(\hat{W} - R_t W^i_{0,t_0})$$

$$\hat{W} = pW^H + (1-p)W^L$$

$$\bar{W} = W^H W^L$$

Proposition 1: *Optimal savings a^* are increasing in initial wage W^i_{0,t_0}.*
This means that higher income agents find it optimal to save more of their income than their lower income counterparts. To see that, we can use the implicit function theorem to take the derivative of optimal savings with respect to W^i_{0,t_0} from the Euler equation:

$$\frac{\partial a^*}{\partial W^i_{0,t_0}} = \frac{(W^i_{0,t_0} - a^*)^{-2}}{(W^i_{0,t_0} - a^*)^{-2} + \beta E[R_t^2 (W^i_{0,t_1} + R_t a^*)^{-2}]} > 0 \tag{2}$$

Proposition 2: *Optimal savings a^* are increasing in p, the probability of the realization of a climate shock.*
This is in line with consumption smoothing behavior: the higher the probability of a bad

state occurring, the more agents want to save to avoid having a too high marginal utility of consumption in period t_1. This means that higher income agents will have more of their wealth "locked in" until the next period. To show this, again we use the implicit function theorem to get the derivative of optimal savings with respect to p. After expanding the expectations, we get:

$$\frac{\partial a^*}{\partial p} = \frac{\beta R_t((W^L + R_t a^*)^{-1} - (W^H + R_t a^*)^{-1})}{(W^i_{0,t_0} - a^*)^{-2} + \beta R_t^2[(W^H + R_t a^*)^{-2} + p(W^L + R_t a^*)^{-2} + p(W^L + R_t a^*)^{-2}]} > 0 \tag{3}$$

3.2.2 Migration Decision

Now we can take a closer look at how the migration decision is being made. Let s be the set of the states of the world. As mentioned before, we only consider two states: on where a climate shock that occurs with probability p, and a state with characteristics identical to those of t_0. Let $C^i_{j,t}|m_j$ be the consumption of i in t_0 conditional on choosing to move to country j in t_1. An agent from country 0 prefers migrating to neighboring country 1 if the expected net present value of migrating to country 1 is greater than that of staying in country 0:

$$u(C^i_{0,t_0}|m_1) + \beta E[u(C^i_{1,t_1})] \geq u(C^i_{0,t_0}|m_0) + \beta E[u(C^i_{0,t_1})]$$

After substituting the budget constraints in each case and rearranging to have the terms with the expectations on one side, we get that:

$$\beta \sum_s \pi(s)(\log(W^i_{1,t_1}) - \log(W^i_{0,t_1} + R_t a^*)) \geq \log(W^i_{0,t_0} - a^*) - \log(W^i_{0,t_0} - m_1)$$

After some manipulations, we get that

$$(W^i_{1,t_1})^\beta \frac{(W^H + R_t a^*)^{\beta(p-1)}}{(W^L + R_t a^*)^{\beta p}} \geq \frac{W^i_{0,t_0} - a^*}{W^i_{0,t_0} - m_1} \tag{4}$$

Similarly, an agent from country 0 prefers to migrate to country 2 if:

$$(W^i_{2,t_1})^\beta \frac{(W^H + R_t a^*)^{\beta(p-1)}}{(W^L + R_t a^*)^{\beta p}} \geq \frac{W^i_{0,t_0} - a^*}{W^i_{0,t_0} - m_2} \tag{5}$$

The choice of migration is to country 2 if

$$(\frac{W^i_{2,t_1}}{W^i_{1,t_1}})^\beta \geq \frac{W^i_{0,t_0} - m_1}{W^i_{0,t_0} - m_2}$$

Inequalities (4) and (5) reflect the fundamental comparison that citizens from country 0 will make to decide whether migration is worthwhile for them. In particular, if the left-hand side is larger, people will choose to migrate to the other country.

In terms of implementation (i.e. solving the model), once we assign values to β, p, m_1, and m_2 we will be able to determine, for people who live in country 0 and receive a given wage W^i_{0,t_0} at initial period, the threshold wage that they should be attainable in another country for them to find it optimal to migrate. Our numerical solution based on these two inequalities will allow us to graphically depict the different migration-decision regions given parameters of the model.

4 Analysis of Migration Choices

To analyze the behavior of agents in response to a climate shock we substitute in the model different values of the probability of the shock happening (p), the intensity of the shock (A_L) and different migration costs. We assume the cost to be composed of a fixed component, which we vary in the graphs, so when we use low or high migration costs we refer to low and high additive component of the costs, and a variable component which is linearly increasing with the wages. So $m_j = MC + 0.2W_0$[10]. In this way richer people will have a relatively higher cost of migration.

For the aim of our paper, which is to show in which way the composition of migrants changes when a climate shock takes place, it is important to first understand the behavior of agents when the shock does not happen. To do so we start describing the case in which $p = 0.01$ (Figure 1, row 1) and A_L is high and equal to 0.7, meaning that the severity of the shock is low. To read the graphs we need to focus on the intersection between the (EW) curves in yellow (EW_1) and red (EW_2) and the (IC) curves in blue (IC_1) and black (IC_2). (EW) represents how much each individual i would earn in country 0 at time t_0 (X-axis) versus how much

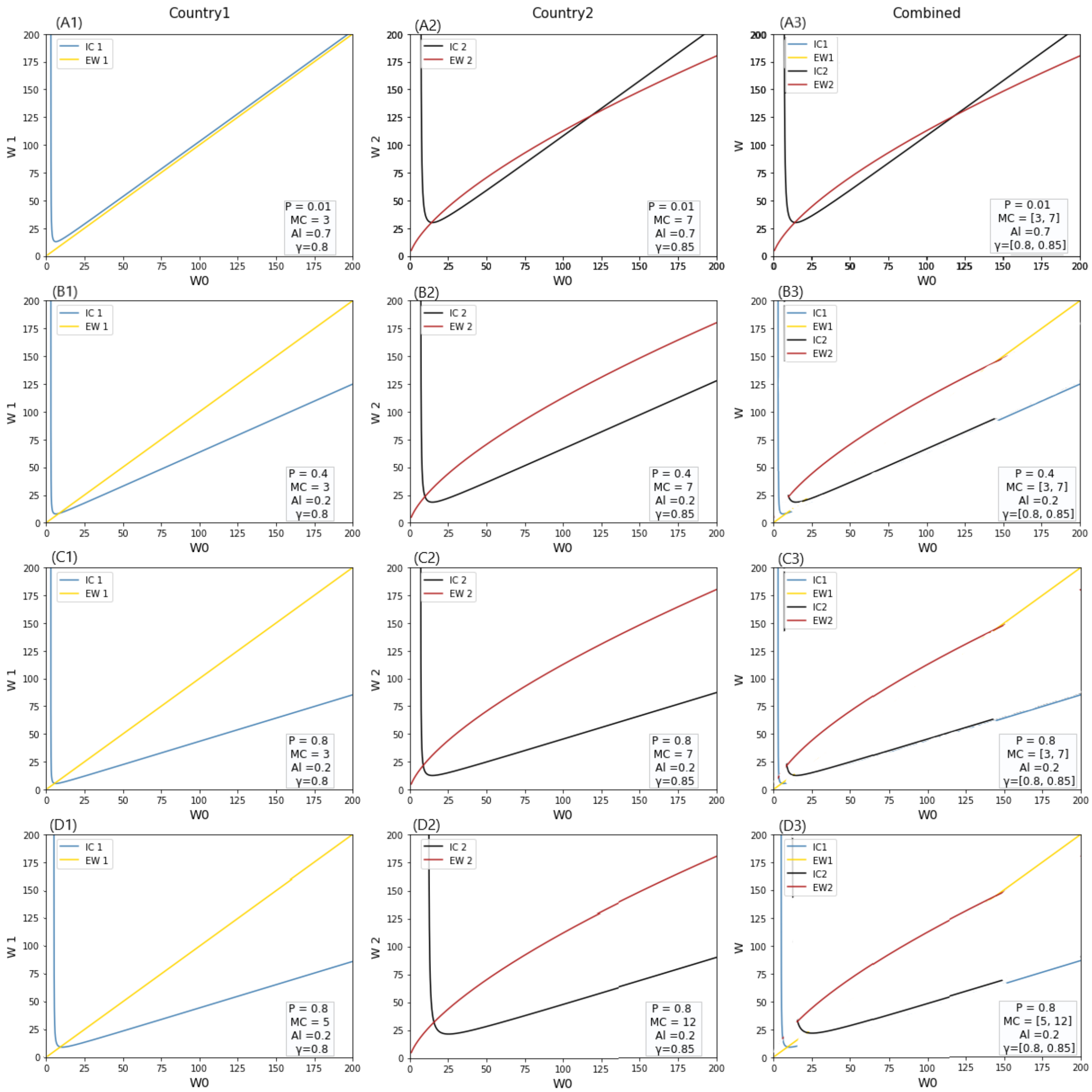
[10]The slope of the migration cost (0.2) is subject to change and depends entirely on the case we are analyzing. Since we chose to showcase the cases when damage is high ($A_L = 0.2$), keeping the slope 0.2 is enough to give us the intuition we need.

he/she would earn in the destination country at t_1 (Y-axis). Therefore any wage (on the Y-axis) above this line is unattainable for each individual. The (IC) curve represents the states at which individual is indifferent between staying in country 0 and migrating to country 1 or 2. Individual i is willing to migrate to the destination country if and only if his wage in that country is to the left of the curve. Since the economies of country 0 and 1 are identical, (EW_1) is a 45 degree line when the destination country is country 1, meaning that the wage of agents migrating would be the same as at t_0 in country 0. (EW_2) is logarithmic, showing that agents with low wages in the home country would earn more in country 2, but high income agents of country 0 would earn less in country 2. This is because the income distribution in country 0 is less equal (has a smaller shape parameter in the Pareto distribution than that of country 2: $\theta_0 = 1.16$ and $\theta_2 = 1.7$). These values are in line with the data from the World Inequality Database. The shape of (EW) also depends on the fact that the TFP of country 0, A_{0,t_0}, is much less than that of country 2, to capture the difference in productivity between countries 0/1 and 2. In particular, according to Kim and Loayza (2017), we choose $A_2 = 5A_{0,t_0} = 5A_1$. Therefore the values on the X-axis corresponding to when (IC) is to the right of (or below) (EW) represent the wage of those people that are migrating to the country of destination. Vice-versa when (IC) is to the left of (EW) it means that the corresponding agent on the X-axis is not moving to the destination country.

4.1 Who is leaving?

When migration costs are low, nobody is willing to migrate to country 1 if the probability of the shock is close to 0 (graph A1). As the (IC_1) curve is always to the left of the (EW_1) curve nobody migrates to country 1. The reason is that, in absence of a shock and two identical economies, even a low cost of migration would prevent people from moving. The same is not true for migration to country 2. From graph (A2) we can see that agents with a wage between 15 and 120 (the values are indicative and read from the graphs as they have meaning only in relative terms) are migrating to country 2. The reason is all in the difference between the two economies and the logic is the same as the one shown by Borjas (1987), even if we assume a Pareto distribution and not a Normal distribution. As the economy of country 2 is more equal, and in our case also on average richer, there is a negative selection of agents migrating.

Figure 1: Migration Decisions



Only low skilled - low wages agents prefer to migrate from a unequal to a more equal country. Different from Borjas (1987), we also introduce a cost of migration and this creates a threshold under which some agents can not afford to migrate. We can now analyze what happens when we increase the probability of the shock. By looking at graphs (B1) and (B2) in which the probability of the shock is now 0.4, the migration cost is still low ($m_1 = 3 + 0.2W_0$ and $m_2 = 7 + 0.2W_0$) and the severity of the shock is high ($A_L = 0.2$), we can see that the (IC)

curves become flatter and therefore more people are willing to migrate. In particular, the increase in p is enough to drive every agent with a wage higher than 10 to prefer migration to country 1, and all the rest will be trapped by the migration costs. This result is again a consequence of the fact that the economies of country 0 and 1 are identical, although in the extension including skill downgrading we will see that this counter-intuitive result will not be reached anymore. Moreover, for country 2 we obtain that more people are migrating and these people are wealthier compared to the results of the baseline model (graph (A2)). Indeed, not only those with a wage between 15 and 120 are migrating, but also those with a wage between 120 and some value around 500 (which is too high to appear in the graph). After this value, as the curves in the graph of country 1 are diverging, we still have some people with extremely high income migrating to country 1. The final migration destination can be seen from the graphs in the third column, which are explained in the following subsection. However, we can already understand, just by comparing graphs (B1) and (B2), that people with a wage higher than 500 migrate to country 1. This result might seem counterintuitive. However, it is important to understand that, with the shape parameter θ that we set, the vast majority of the population earns less than 100, which is why we focus our analysis on wages between 0 and 200. Therefore, even if it is important for the intuition, what happens after this value concerns only few people and, therefore, the effects are negligible. Increasing the probability of the shock p even more to 0.8 (graphs (C1) and (C2)) we get very similar results, in addition to the fact that now even more poor people are willing to bear the costs of migration in order to escape the almost certain climate catastrophe.

Therefore, an increase in the probability and severity of a shock will push more and more people to move as long as the migration costs are kept constant. In comparison to the case with low probability, there is an increase in more skilled migrants choosing to move to country 2. This is consistent with the empirical findings that 38% of Syrian refugees in developed countries are highly educated. At the same time, the highest income brackets will choose to move to country 1 instead of country 2, which is due to the assumption that wages in country 2 are more equally distributed, and so, for high income individuals in country 0, moving to country 2 is equivalent to earning a lower wage there, whereas moving to country 1 allows the agent to maintain his previous wage.

Now we analyze what happens when we increase the migration costs (graphs (D1) and (D2)), i.e. $m_1 = 5 + 0.2W_0$ and $m_2 = 12 + 0.2W_0$. As we expected, the (IC) curves are shifted up, from the comparison with (C1) and (C2). Therefore less poor people are able to migrate to country 1 and to country 2, meaning they remain trapped in their home country. This also results in a curious case when comparing (C2) to (D2). The second intersection between(IC_2) and (EW_2) will occur at a lower level of W_0 than before, reducing the share of high income people who choose to migrate to country 2. This is not due to an impossibility to afford the costs of migration, but rather to the fact that these people are the agents at the margin close to the indifference between migrating or not and even a very small change in the costs, compared to their wages, makes them prefer to stay rather than migrate to country 2.

4.2 Where do they move?

To get a better picture of the exact combination of migrants and to investigate who is moving where, we combine the two graphs for each scenario (values of m_j, p, and A_L), in the third column. To read the graph, all one needs to do is to see which indifference curve (IC_j) lies below the expected wage curve (EW_j). The X-axis values corresponding to when the (IC_2) curve is below the (EW_2) curve represent the income levels of those who choose to migrate to country 2. Similarly, the X-axis values corresponding to when the curve (IC_1) is below the (EW_1) curve represent the income levels of those who choose to migrate to country 1. If there is no value of W_0 such that neither (IC_1) is below (EW_1) one nor (IC_2) is below (EW_2), that means the agent with that W_0 chooses to stay in country 0.

This way we have a mapping for where each individual in country 0 chooses to be the next time period. The logic is that if an agents prefers both migration to country 1 and to country 2 to staying she will choose the country with the higher expected wage. We can easily see that low skilled - low wage people are only able to migrate to country 1 while richer people prefer to move to a far and wealthier country as they can afford the high migration costs. This is once again consistent with the literature.

Finally, with a cross-graph analysis we can understand what happens when we increase the gap between m_1 and m_2. By looking at graph (C1) and comparing it first to (C2) and then to (D2) we can see that by increasing the relative costs of m_2, more and more people will be in a situation in which they can only migrate to a neighbouring country. As the density of population in this wage range is high, the effect of a relative increase of m_2 over m_1 would have large implications in absolute terms.

5 Extensions

5.1 Skill Downgrading

In order to make the model more realistic, we explore another challenge faced by migrants that might affect the migration decisions of agents in country 1 and 2: possible skill downgrading. In particular, Dustmann et al. (2008) show that the loss in skills is on average higher for high skilled people relatively to low skilled. With this assumption we obtain that less rich people are willing to migrate to country 1 and to country 2. Realistically we assume the downgrading to be more severe if agents move to country 2 than to country 1 to capture the more likely difference in language and culture.

We assume that each agent choosing to migrate faces a probability $\rho(Z^i)$ of getting a skill downgrade in the host country. More formally, let $Z_j'^i$ be the actual skill level of a migrant upon arrival in the host country. Then $Z_j'^i = Z_j^i$ with probability $(1-\rho(Z_j^i))$ and $Z_j'^i = \alpha_j Z_j^i$ with probability $\rho(Z_j^i)$. Where $0 < \alpha_j < 1$ and $\alpha_1 \geq \alpha_2$, so that the downgrade is higher if the agent is moving to country 2 than to country 1. The savings decision is not affected by this new modification. As before, the migration decision is determined by the magnitude of the discounted present value of the utility from migrating to each country/ staying: An agent chooses to migrate to country j only if:

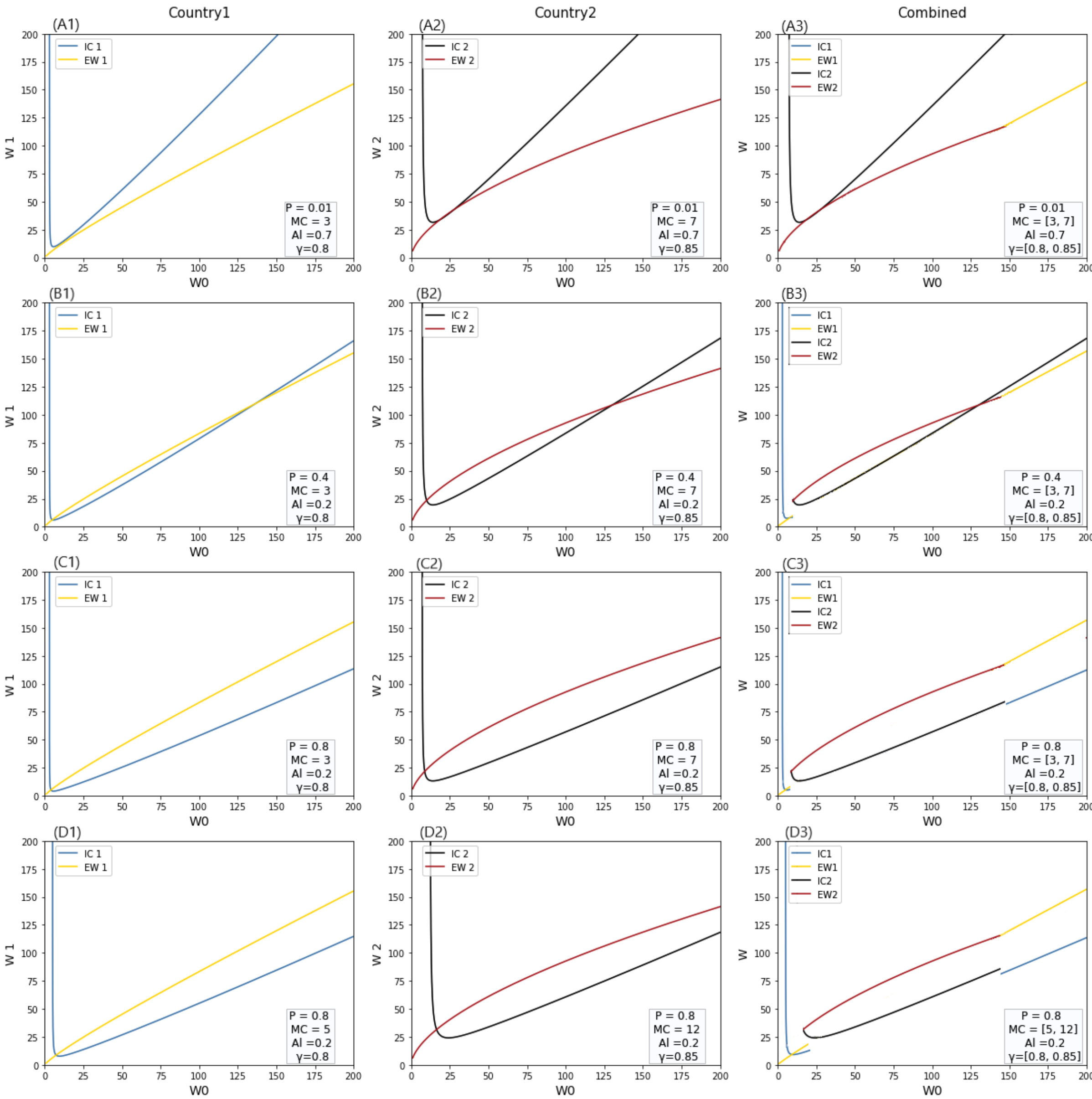
$$\beta \sum_s \pi(s) \sum_{s'} \eta(s')(\log(W_{j,t_1}^i) - \log(W_{0,t_1}^i + R_t a^*)) \geq \log(W_{0,t_0}^i - a^*) - \log(W_{0,t_0}^i - m_j)$$

This can be rewritten as

$$W_{j,t_1}^i = \alpha_j^{-\rho(Z^i)} (W^L + R_t a^*)^p (W^H + R_t a^*)^{1-p} (\frac{W_{0,t_0}^i - a^*}{W_{0,t_0}^i - m_j})^{1/\beta}$$

Where s' is the state such that $s' \in \{downgrade, nodowngrade\}$, and $\eta(s')$ is the probability distribution over these states. It's important to notice that the state s' is contingent on the original level of skill Z_0^i. To graph our results, we assume that $\alpha_1 = \alpha_2 = 0.6$, and that $\rho(Z^i)$ is a concave function that tends asymptotically to 1 multiplied by a factor γ_j such that $\gamma_1 < \gamma_2$, so that the probability of a downgrade is less for migrants moving to country 1.

Figure 2: Migration Decisions with Skill Downgrading



Results: After plotting the graphs with the same value of the parameters as before, this time we get that the expected wage curves are flatter than in the baseline model and, more interestingly, both (EW_1) and (EW_2) are concave. With skill downgrading, now instead of having the agents of the highest income brackets migrating to country 1 when the probability of a shock is high enough, we now have a much more limited number of these agents migrating. This phenomenon is clear from graph (B1) where agents earning more than 130 prefer to stay in their home country. This means that the lowest and highest income agents are in fact not displaced by a climate shock. This is because the highest income agents prefer not to migrate, whereas the lowest income agents cannot afford to. We can now see by comparing (C3) and (D3) how the difference in migration cost m_1 and m_2 forcibly displaces low income agents who prefer to move to country 2, to country 1, increasing the share of migrants to country 1.

How do we justify the majority of migrants moving to the neighboring country (or a domestic-long distance location), in accordance with the empirical findings of Gray and Mueller (2012a) and Gray and Bilsborrow (2013)? For our model, to get this result we have to increase the difference between the migration costs to country 1 and 2. This could mean taking into account additional factors such as network effects, language differences, and other socioeconomic drivers that would make an overseas move unpleasant to a large share of migrants, and that would be reflected in the cost.

5.2 Varying the Perceived Probability of a Climate Disaster

In another attempt to make the model more realistic and interpret better a climate related shock, we extend the model by removing the assumption that people's expectation of the shock is equal to the real probability of it happening. To capture the fact that climate change effects are in general underestimated by the population, we impose the expected probability of a shock q^i to be smaller than the true probability p. In particular, to reflect that higher skilled agents possess better knowledge of the future, we made the difference between p and q^i decreasing with the skills:

$$p - q^i = \frac{1}{f(Z^i)} \tag{6}$$

We let $f(Z^i) = \log(Z^i)$. The log form of the function captures the diminishing marginal returns of education. In this way we demonstrate that poor people are going to be affected and exposed to more harm than the rich by a climate shock. A widely spread explanation is that rich people can adapt better to difficult conditions imposed by climate change (Kates 2000)Wilbanks and Kates (2010).

To analyze the implications of this new assumption, we solve the model again, in the same fashion as before.

Proposition 3: *The larger the difference between q^i and p, the more agent i under-saves compared to the full information benchmark.*
The expression for a^* is the same as before, since we solve the same FOC. Rearranging that expression, we get:

$$\{\frac{1}{W^i_{0,t_0} - a} - \frac{\beta R_t}{W^H + R_t a}\}\{\frac{1}{W^H + R_t a} - \frac{1}{W^H + R_t a}\}^{-1} = \beta R_t(q^i - p) + p\beta R_t$$

This implication is consistent with the data shown by Székely et al. (2000)Behrman et al. (2000) who analyze the saving rates in four developing countries, and show that the savings rate of poor people is smaller than that of rich people.

Proposition 4: *The larger the gap between q^i and p, the less likely that agents will choose to migrate.*
Consider how the decision to migrate to country 2 is taken, as before in equation (3). We can expand and rearrange the expression to get:

$$(q^i - p)\{\log(\frac{W^L + R_t a^*}{W^H + R_t a^*})\} + p\log(\frac{W^L + R_t a^*}{W^H + R_t a^*}) \leq \log(\frac{C^i_{0,t_0}|m_2}{C^i_{0,t_0}|m_0}\{(W^H + R_t a^*)W^i_{2,t_1}\}^{\beta}) \quad (7)$$

How does this new distortion affect inequality in country 0? We choose to focus on the subset of agents who choose to stay in country 0 instead of migrate, and analyze what happens to the heterogeneous agents after a climate shock has occurred.

Proposition 5: *Inequality is higher in the case of varying perceived probabilities than in the common knowledge benchmark.*
To illustrate more clearly how this distortion increases inequality, consider two individuals P and R who choose to remain in country 0 with skill levels Z^P and Z^R respectively, such that $Z^P < Z^R$. Also consider the case when a climate shock has already occurred.
Under the common information benchmark, the gap in the total utility between P and R is:

$$Gap_T = \log(\frac{W^R_{0,t_0} - a^R_T}{W^P_{0,t_0} - a^P_T}) + \beta\log(\frac{W^{L,R} + a^R_T R_t}{W^{L,P} + a^R_T R_t}) \quad (8)$$

Under varying perceived probabilities of a shock, this gap is:

$$Gap_D = \log(\frac{W^R_{0,t_0} - a^R_D}{W^P_{0,t_0} - a^P_D}) + \beta \log(\frac{W^{L,R} + a^R_D R_t}{W^{L,P} + a^R_D R_t}) \tag{9}$$

The results from Propositions 1 and 4 allow us to write

$$a^R_T = a^R_D + \lambda$$

and

$$a^P_T = a^P_D + \Lambda$$

where $\Lambda > \lambda$. From here we can easily deduce that $Gap_D > Gap_T$. Thus, the losses in the bad state are much higher for less skilled people than the richer more skilled people, because of the wider gap in optimal savings between the two cases. The marginal utility of consumption for a less skilled person will be significantly higher in the state with the climate shock when there is a distortion in the perceived probability of that state, and he will not be able to smooth consumption as in the benchmark case.

6 Discussion and Conclusion

Weather shocks and climate change have gained global importance at any policy debate and they arguably represent one of the greatest challenges of our times. In fact, these two phenomena can have large economic consequences across many realms. Nowadays, increasing attention is directed towards the determinants of migration destination choices and the consequences of forced and non-forced displacement. Given the multi-causal nature of the migration phenomenon, an empirical approach would require hard to collect and rich data. Indeed, any attempt of the previous literature lacks in external validity. A correct understanding of the different mechanisms driving migration choices is crucial for better policy design. In this paper we propose a two-period model to build the fundamentals of a solid theoretical framework that goes in this direction.

The results and extensions of our model point out that, depending on households' location on the income distribution, diverse factors can affect the decisions of potential migrants differently. Specifically, in our baseline model higher-income people move only when the likelihood of an environmental disaster is relatively high. When they choose to move, they will more likely migrate to the neighboring country, rather than to the developed country. This is a consequence of allowing higher-income agents to take advantage of similar levels of inequality between the neighboring countries by allowing them to maintain the same skill- and status-level as in their country of origin. By introducing the concept of skill-downgrading, the decision of people changes (i.e. they are less willing to move to country 1 than they were before). Also, our model shows that people living in extreme poverty, who cannot afford the migration cost, will have to suffer the consequences of climate change and will lose the majority of their resources. In contrast, higher-income people can adapt to the adverse situation and migrate to avoid major losses. This context highlights the necessity of adaptation policies that countries should implement to protect the lowest income brackets from further welfare losses and reduce the massive flow of migration that would be detrimental to any economy. Clearly, this is even more crucial for agricultural economies, whose production process is labor-intensive. It should be noted that we did not define an equilibrium. A decrease in available labor would lead to higher marginal productivity of labor and wages and this would make staying in the home country more attractive for some agents in the economy. Instead, we focus on the *potential* movement of labor. We do not imply that everyone, except for the poorest agents, will actually remain, but rather that not-poorest people will have the ability to afford the migration cost.

In our second extension we take into account that, in reality, less skilled people are at a disadvantage compared to more skilled people not only in terms of resources, but also in terms of being informed. As we show, this fact increases the welfare gap between high- and low-income agents since the less skilled an agent is, the further away his decisions are from an optimal choice. This suggests that campaigns and education systems that inform citizens of the dangers of climate change and warn them of the consequences, will allow them to adapt more optimally in anticipation of an environmental disaster, and can help avoid major welfare losses.

Therefore, a direct impact of our model is that if a government promises aid contingent on a climate shock happening, it will prevent additional migration and increase post-shock welfare. To grasp this insight, possible future extensions of the model can include the role of government, and further provide a counterfactual analysis of, for instance, subsidizing permanence in a location. The model could also be framed as an infinite-horizon problem where individuals regard migration as a long-run investment. This would allow us to address other questions (e.g. the optimal timing for migration) and let us model different manifestations of climate change as they really are, instead of just having them as shocks to productivity.

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