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RESEARCH ARTICLE

# Climate, conflict and internal migration in Colombia

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**ABSTRACT** Robust empirical evidence on the potential causal linkages between environmental change, conflict and migration is scarce. We evaluate this relationship in the context of internal migration in Colombia for the period from 2000 to 2005. Using municipality-level data in a gravity model that considers the issue of endogenous selection regarding both the outbreak of conflicts and the existence of non-zero migration flows, we establish an empirical causal link between droughts, conflict and migration. Our results show a positive relationship between the severity of droughts and the likelihood of conflicts, as well as between conflicts and human mobility, suggesting an indirect effect of climate on internal migration in Colombia.

**KEYWORDS** Migration • Environmental change • Conflict • SPEI • Endogenous selection • Gravity model

## Introduction

Especially since the refugee crisis in Europe in 2015, climate change has often been linked to conflict and migration, and different inferential strategies have been proposed to gain a better understanding of these relationships using data (see Hoffmann et al., 2020, for a thorough meta-analysis on the effects of environmental change on migration). The existing literature generally acknowledges five major categories of phenomena acting as determinants of migration flows, which can be summarized as economic, political, social, demographic and environmental drivers (Black et al., 2011; Lee, 1966). Most studies consider these factors simultaneously and do not focus on the pathway through which these drivers affect migration, as well as each other. While there is a strand of research analyzing how climatic change might foster migration and how this could lead to conflicts in countries that are receiving migrants (Reuveny, 2007), there is not a lot of empirical evidence supporting this narrative (Brzoska and Fröhlich, 2016; Raleigh and Urdal, 2007). In this contribution, we advance the literature by assessing empirically the role of violent conflict as a mechanism through which environmental shocks lead to internal migration flows. We do so by

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concentrating on the case of Colombia, a country that has experienced low-intensity war for a long period of time and for which data on internal mobility have recently become available (Siraj et al., 2020). Until the peace agreement of 2016, Colombia suffered from armed conflict for more than 50 years, which caused over 200,000 causalities. Our analysis thus contributes to the understanding of human mobility in the context of long-term conflict and examines the role played by environmental shocks as a driver of violent episodes leading to internal migration.

Abel et al. (2019) proposed a statistical approach that explicitly assesses the causal linkages surrounding the environment-conflict-migration pathway, and then rigorously tests, whether environmental change fuels the emergence of conflicts, which in turn promote forced migration. The focus of Abel et al. (2019) was on global international refugee flows, and their research showed that, at least for certain regions and points in time, this chain of events plays a significant role in explaining the connection between drought shocks, violent conflicts and human mobility. In particular, this pathway appears to be statistically relevant for the years 2010 to 2012 in Northern and Western Africa, whereas it seems to be less important in other time periods and parts of the world.

While Abel et al. (2019) focused on forced migration across countries, in this contribution we apply their approach to analyze internal migration between different areas within a given country. Our aim is to advance the research on this topic by providing a rigorous empirical quantification of the causal mechanisms linking environmental shocks to internal population mobility via the effect such shocks have on the probability of violent conflict. In particular, we concentrate on the assessment of internal migration patterns in Colombia between 2000 and 2005. For this case study we use municipality-level migration data based on Siraj et al. (2020), and combine them with information on conflicts and battle deaths from the Uppsala Conflict Data Program (UCDP), and with climate data based on the Standardised Precipitation-Evapotranspiration Index (SPEI). In addition, we employ a set of socioeconomic variables from the National Administrative Department of Statistics of Colombia (DANE) and the Integrated Public Use Microdata Series (IPUMS), as well as other controls. To test for a causal link between climatic shocks, conflict and internal migration in Colombia, we apply a gravity model that takes into account the potential lack of exogeneity in both the outbreak of conflict and the existence of non-zero migration flows between individual municipalities. Based on the method proposed by Kim (2006) and also employed by Abel et al. (2019), we have set up a sample selection model composed of three equations that are estimated in two steps. First, we estimate the impact of the climate on the probability of conflict. Second, we analyze how conflicts affect internal migration, while taking into account whether there is a non-zero flow of migrants, as well as the size of the flow. Thus, the analysis goes beyond the identification of partial correlation structures across these three variables (as was partly done for Colombia by Camargo et al., 2020) and instead concentrates on improving our understanding of the causal mechanisms linking environmental shocks to internal migration through changes in the occurrence of conflict.

Our novel results imply the existence of a significant positive effect both of the severity of droughts and the likelihood of conflicts and between conflicts and internal migration, revealing an indirect effect of environmental shocks on internal migration in Colombia.

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These results contribute to a better understanding of the linkages between climate, conflicts and migration at the subnational level and provide novel empirical evidence for migration and climate policy.

The remainder of this paper is structured as follows. First, we provide an overview of the empirical literature on the connections between climatic shocks, conflicts and migration, and review the existing work on the case of Colombia. Next, we describe the data employed in the analysis and the corresponding sources. We then provide information on our econometric framework and estimation method, and present the main results as well as the findings from our robustness checks. We close the paper with a discussion of our conclusions.

## Review of literature

The academic debate concerning the role played by environmental shocks (and, to the extent that it affects their probability of occurrence and their size, by climate change) as a driver of conflict that can, in turn, lead to migration is not new. The discussion has gained momentum in the context of the conflicts leading to the Arab Spring and the start of the civil war in Syria in 2011 (Friedman, 2013). Empirically, this channel has been found to provide a partial explanation for the differences in migration rates between countries and subnational regions. The meta-analysis of the effect of environmental shocks on migration by Hoffmann et al. (2020) concluded that climatic shocks tend to affect human mobility more systematically in countries that have experienced adverse sociopolitical conditions and violent conflict. Similarly, Koubi (2019) reviewed recent scientific publications to examine the consensus on the climate-conflict link, and found that the existing evidence points to environmental change being one of the contributing factors to the emergence of conflicts. Droughts, natural hazards, sea level rise and the melting of glaciers are expected to have the biggest effects on climate change-induced migration in Latin America in the future (Kaenzig and Piguet, 2014).

Notwithstanding the problems associated with the measurement of the variables involved in the pathway leading from environmental change to migration through the channel of an increased likelihood of conflict, theoretical complexities can arise when conceptualizing the linkages between these phenomena. The climate system, natural resources, violent conflict and human mobility interact with each other in ways that make the empirical assessment of causal narratives particularly challenging (see, for instance, the analytical framework provided Scheffran et al., 2012). The complicated interactions arising in the climate-migration link (independently of whether conflict acts as an intermediate mechanism or not) have led to conceptualizations based on the existence of context-specific thresholds that make adaptation responses to climatic shocks inadequate (see the work by McLeman, 2018 or McLeman et al., 2021).

From a theoretical perspective, the vulnerability of populations to climatic extremes can be considered a function of their dependence on natural resources, the sensitivity of these resources to environmental change and the adaptive capacity particular human groups possess (see Barnett and Adger, 2007 or Von Uexkull et al., 2016). Adaptive capacity, in turn, is determined by socioeconomic development (which expands the set of potential

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income-generating activities) and past conflict experiences. Thus populations who are dependent on natural capital are more sensitive to climatic shocks that may affect their source of income generation.

In this context, several theoretical mechanisms linking climatic shocks to conflict events have been put forward in the literature. Koubi (2019) categorized the main climatic factors contributing to the emergence of conflicts as related to (a) direct effects and resource scarcity, and (b) indirect effects having to do with economic outcomes and migration. The direct effects include increased hostility and violent conflict following temperature anomalies due to physiological and psychological factors, a channel that has been widely disputed and discussed in the recent empirical literature (see Hsiang et al., 2013 or Buhaug et al., 2014, for instance). An additional direct mechanism is related to resource scarcity driven by negative environmental shocks. In the framework of agriculture-based economies, this situation would increase competition, thus leading to conflict and violence. Such a theoretical argument, the importance of which is reinforced by the relevance of the agricultural sector and the natural resources in the economy, is put forward by Homer-Dixon (2010), among others. In addition to this direct effect of climatic shocks on the likelihood of violence via competition over natural resources, there is a potential indirect mechanism through the negative income shocks associated with reductions in agricultural output caused by adverse environmental conditions (Dell et al., 2014). After outbreaks of violent conflict, migration emerges as a natural adaptation mechanism. Acknowledging the multidimensionality of human mobility phenomena, the relative importance of violence as a cause of migration flows (compared to that of mobility driven by environmental change and food security) is explored in Morales-Muñoz et al. (2020).

The complex interactions between environmental phenomena, conflict and migration flows make it particularly difficult to empirically identify causal mechanisms. Abel et al. (2019) examined whether - and, if so, to what degree - environmental change might fuel regional conflicts, and thus result in an increase in forced international migration. Their work analyzed data on asylum applications from 2006 to 2015 for 157 countries, and focused on the identification of causal effects. The results in Abel et al. (2019) confirm that only a few conflicts leading to an increase in forced migration can be causally linked to environmental shocks, particularly in Northern Africa and Western Asia between 2010 and 2012 (and then only for certain countries). These findings imply that climatic shocks do not affect conflicts and thus migration in the same ways or to a similar degree all over the world. It thus appears that climatic shocks related to climate change, and the governmental responses to such shocks, may fuel existing conflicts, particularly in countries that undergo socioeconomic and political changes like those we have seen in Syria over the last decade.

In contrast to the focus on international migration by Abel et al. (2019), Ash and Obradovich (2020) examined the impact that the stress caused by droughts and environmental changes had on conflicts within Syria. Their findings indicate that climate change had at least an indirect effect on these conflicts, which resulted in increased internal migration that itself fueled conflicts. The primary indirect effect in this context was the contribution of environmental change to harvest outcomes and agricultural yields, which highlights the indirect role of income shocks as a driver of violent conflict in agricultural societies. Changes in agriculture and progressive urbanization can add to already subliminal conflicts

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within countries. Ash and Obradovich (2020) found that the risk of protests increased not only due to drought conditions, but also in response to additional precipitation in relatively cooler districts. In their study they focused on the effects of environmental change anomalies in certain subdistricts of the country. As no migration data were available for the time period under study, with the biggest drought occurring between 2006 and 2010, Ash and Obradovich (2020) used nighttime light intensity data to measure changes in population.

As laid out by Abel et al. (2019) and Ash and Obradovich (2020), it appears that there are certain underlying circumstances in which climatic changes are likely to ignite and feed conflicts. This risk is especially high in regions that have large agricultural sectors, and are thus dependent on harvests and efficient agriculture, as well as in regions characterized by political instability and/or low levels of economic development (Koubi, 2019). These results are also in line with those reported in the meta-analysis by Hoffmann et al. (2020).

Most of the empirical literature linking climatic shocks to migration relies on the use of high frequency data on temperature and precipitation anomalies, droughts and floods. However, the potential effects of climate change on conflict and migration may be of a long-term nature, and could therefore remain hidden when only short-term horizons are investigated. Furthermore, the lack of a consistent definition of the term "migrant" or "conflict" throughout these studies is a common criticism of the existing empirical literature. As there are several different types of conflicts (including interpersonal conflict, inter-group conflict, civil conflict, inter-communal violence, low-intensity conflict, social conflict and political repression), not all results seem comparable or interpretable in the same manner (Koubi, 2019). Brzoska and Fröhlich (2016) criticized the lack of empirical evidence to support the simplistic assumption that climatic shocks lead to resource scarcity, which, in turn, leads to conflict and migration.

In our analysis, we employ the methods used in Abel et al. (2019) to analyse the causal links between drought, conflict and internal migration for the case of Colombia. Given the long history of low-intensity violent conflict in the country, the focus on this particular country offers us insights into the potential role of environmental shocks in causing outbreaks of violence in a context of latent insecurity. The existing literature on internal migration in Colombia has emphasized the role of conflict as a push factor for human mobility, and has concluded that migrants are more willing to relocate to distant locations when confronted with extreme violence (Lozano-Gracia et al., 2010). In addition, Ibáñez and Vélez (2008) found that very sizeable welfare losses are associated with such forced migration flows. Engel and Ibáñez (2007) presented a conceptual theoretical framework for the empirical assessment of the determinants of migration decisions and applied it to data for Colombian households. The results of the study show that while economic incentives are important for explaining mobility decisions, violence affects the relevance of economic factors. Ibáñez et al. (2019) found that the economic impact of weather shocks in Colombia can lead to migration, and that the mobility response is modulated by the existence of particular wartime institutions in the origin location.

Our contribution expands this body of empirical work for Colombia by providing evidence on the causal link between environmental shocks and migration, which is mediated by the emergence of conflict. While other contributions assessing the role of climatic shocks in conflict and migration have relied on information on population density changes to

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identify mobility (see Ash and Obradovich, 2020, for instance), we employ in our analysis actual migration flow estimates that have recently been developed by Siraj et al. (2020). The use of these data allows us to directly assess the role played by conflict as a transmission mechanism of the effect of environmental events on mobility, without the need for the (potentially unrealistic) assumptions regarding population dynamics that are required to interpret variation in population density as migration changes. In contrast to the analysis in Ibáñez and Vélez (2008), which concentrated on quantifying the welfare losses associated with forced displacement in Colombia, our study focuses on the particular role played by drought risks as a causal determinant of conflict, and thus of internal migration flows in the country. In addition, the particular methodological framework used in our analysis, which aims at providing a rigorous empirical identification of the causal linkages in the hypothesized theoretical mechanisms, has not been used in the context of internal migration until now.

## Data

### Migration data

Internal migration data including information on migrant flows between all 1,122 municipalities of Colombia from 2000 to 2005, are sourced from Siraj et al. (2020), who estimated 5-year internal migration on the admin2 level using census-based microdata on the admin1 level and a novel approach for modeling spatial interactions. The original sources in Siraj et al. (2020) are census microdata available through the Integrated Public Use Microdata Series-International (IPUMSI) database, which are combined with additional information to obtain estimates for bilateral migration flows across municipalities. The estimation approach is based on previously identified economic, sociodemographic and geographic factors, including regional productivity, population size and shares of people living in urban areas, as well as the geographic contiguity of and the distances between regions. The flows created have been validated by making use of migration flows at the department level from the 2005 census. Figure 1 visualizes the total municipality-level internal migration (in-migration and out-migration) level in Colombia by district from 2000 to 2005. The central role of the district of Bogotá as both an origin and destination region for internal migration is clearly visible in Figure 1. Migration into other large economically relevant municipalities, such as Cali and Medellin, also appears to be important. In addition, at the municipality level, smaller but regionally relevant urban centers, such as Pereira (Risaralda) or Neiva (Huila), are also able to attract a relatively large number of migrants. It should be noted that these migration estimates include total numbers of migrants between pairs of municipalities, but do not differentiate between forced and voluntary migration.[1]

1 To the best of our knowledge, no data for migration in Colombia that include this distinction are available on the admin2 level. Further studies might expand this area of research by differentiating between different types of migration if the information becomes available.

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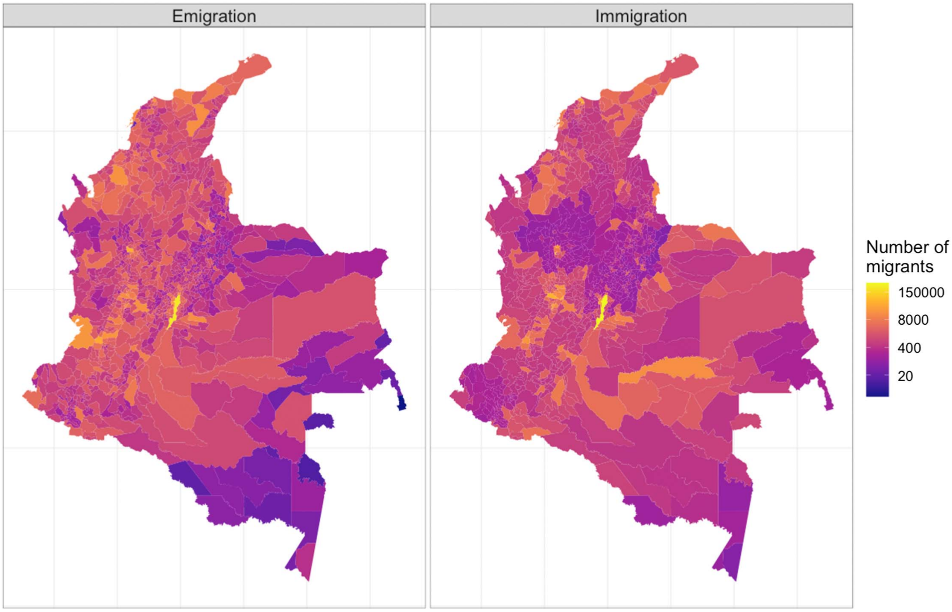
**Figure 1** Internal migration levels by municipality, Colombia 2000–2005.




## Conflict data

Data on conflicts and battle deaths are sourced from the Uppsala Conflict Data Program (UCDP), the main provider of global information on armed conflicts and organized violence (UCDP, 2021). The UCDP has global coverage and provides yearly data, which are continuously updated. In addition to the number of battle deaths, information on different aspects of armed conflict, like conflict dynamics and conflict resolution, is offered. As well as drawing on information on conflicts in our period of interest, 2000 to 2005, data from preceding years (the number of battle deaths in the years 1995 to 1999), we construct variables based on information about the time since the last conflict evaluated in the year 2000, and a dummy variable measuring whether any conflict happened in the period 1995 to 1999. It should be noted that we employ the term "conflict" to refer to individual violent events leading to casualties (battle deaths), although the Colombian internal conflict was already ongoing decades before the period considered in this analysis. As such, our model exploits the spatial variation in the intensity and the frequency of violent events in the years under scrutiny, against the background of more structural long-term conflict.

## Climate data

As our basic climatic variable, we use the Standardised Precipitation-Evapotranspiration Index (SPEI). This index measures the severity of droughts based on their intensity and

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duration. It identifies the onset and the end of drought episodes, allows for a comparison of drought severity through time and space, and provides meaningful information for a wide range of different climates (Beguería et al., 2010). In addition, the SPEI facilitates the identification of different types of droughts and the assessment of their impact in the context of global warming. The index is measured on an intensity scale, with negative values being linked to droughts and positive values indicating wet conditions. In the categorization of dry conditions, the index can be used to identify the subcategories of mild, moderate, severe and extreme droughts (Paulo and Pereira, 2006).

An advantage of the SPEI compared to other climatic or drought indices is that in addition to capturing information on temperature and precipitation, it also measures the effects temperature has on evaporation and transpiration (Vicente-Serrano et al., 2010). Global data on the SPEI are available at a monthly level starting in January 1901, and are provided at a spatial resolution of 0.5°, which is equivalent to roughly 5.5 kilometers at the equator (Beguería et al., 2010). Its use of potential evapotranspiration based on climatic water balance and its multiscalar nature make the SPEI a more precise measure of drought than indices based exclusively on the use of precipitation and temperature information. The existing literature on the identification of drought periods has often reported differences in the identification of droughts depending on whether information on evapotranspiration is exploited (see Vicente-Serrano et al., 2012 or Tirivarombo et al., 2018, for instance), and has highlighted the importance of incorporating the water balance in drought indices, particularly in the context of climate change trends.

To analyze the potential effects of droughts and extreme climatic conditions on conflict and internal migration in Colombia, we compute the mean level of the SPEI from 1995 to 1999 for each municipality in Colombia, which is then used as the control variable of interest in our model. The period under study is not characterized by extremely large environmental shocks, such as the floods in 2010 and 2011 or the historic droughts in 2015 (that extend back to 2012 in some regions of the country such as La Guaji). These shocks led to large-scale damage to crops and infrastructure, and are held directly responsible for the displacement of populations (see, for example, World Bank, 2021).

## Socioeconomic data

As control variables, we employ a set of socioeconomic and geographic variables in our statistical model. The socioeconomic data are based on surveys that are sourced from the National Administrative Department of Statistics of Colombia (DANE) and the Integrated Public Use Microdata Series (IPUMS).

We have obtained data on the municipality-level GDP per capita, as well as on its growth rate, from DANE. Since municipality-level GDP data are only available from 2011 onward, we apply the distribution of GDP over municipalities from 2011 to department-level data from the year 2000. Additionally, we include department-level information on the shares of agriculture and mining in total GDP as well as municipality-level population data. These variables are complemented by information on the shares of black and indigenous persons in every municipality. This information is sourced from the IPUMS, and is evaluated for the

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year 2005. These variables provide controls for push and pull factors related to employability, income and other economic characteristics at the municipality level.

### Geographic data

Our set of input data are completed with three geographic variables, including the distances between municipality centroids, a dummy variable for common borders, and a dummy variable for municipalities belonging to the same department.

## Method

Our method is based on Abel et al. (2019), and uses a gravity equation model to assess the determinants of internal migration in Colombia. This setting builds on the work of Cohen et al. (2008), and integrates an estimation technique developed by Kim (2006) to additionally address the statistical issues of endogenous selection and non-random treatment in conflict occurrence. In particular, it considers potential biases that might be introduced by a lack of randomness in the selection of municipalities affected by conflict and municipalities with non-zero migration flows. Since conflict affects both the existence of migration flows and their size, the method appears to be particularly adequate for the research question at hand. In addition, the emergence of conflict is potentially endogenous and might depend on climatic conditions (and other factors). In contrast to Abel et al. (2019), where the target variable was forced international displacement, in our application we assess the response in terms of internal migration.

Using the model setting in Kim (2006), we set up a sample selection model consisting of three equations, which are estimated in two steps. First, we analyze the impact of climate on conflict occurrence in Colombia. In the remaining equations of the specification, we estimate how conflicts affect internal migration, considering both a model for the existence of non-zero flows of migrants and another model for the size of the flow, conditional on its existence. The specification used is thus given by

$$c_i^* = Z_{c,i}\gamma_1 + \epsilon_{c,i}, \;\; c_i = I(c_i^* > 0) \tag{1}$$

$$s_{ij}^* = Z_{s,ij}\gamma_2 + c_i\beta_2 + \epsilon_{s,ij}, \;\; s_{ij} = I(s_{ij}^* > 0) \tag{2}$$

$$a_{ij}^* = Z_{a,ij}\gamma_3 + c_i\beta_3 + \epsilon_{a,ij}, \;\; a_{ij} = a_{ij}^* s_i \tag{3}$$

where the indicator function $I(x)$ takes a value of one if $x$ is true, and a value of zero otherwise. Equation (1) describes the occurrence of conflict ($c_i = 1$) in municipality $i$ in the period of interest (2000 to 2005). Equation (2) specifies whether a non-zero flow of migrants can be observed from origin municipality $i$ to destination municipality $j$ ($s_{ij} = 1$), and equation (3) addresses the size of the observed flow of migrants in logs ($a_{ij}$) from municipality $i$ to municipality $j$ for origin-destination pairs with non-zero flows. Because of the lack of

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exogenous randomness in the selection of municipalities with non-zero outflows of migrants, we assume the error terms $\epsilon_{c,i}$, $\epsilon_{s,ij}$ and $\epsilon_{a,ij}$ to be jointly multivariate normally distributed and potentially correlated.

The vectors $Z_{c,i}$, $Z_{s,ij}$ and $Z_{a,ij}$ contain the control variables for each of the equations, which are chosen based on existing models for migration and conflict. In order to account for the persistence of past conflict, as well as for the potential effect of environmental shocks, which is at the center of our analysis, $Z_{c,i}$ includes information on the number of battle deaths in the corresponding municipality from 1995 to 1999, the number of conflicts and the average level of the SPEI in the same period. If conflict is long-lived and geographically concentrated, the effect of the first two variables on the probability of subsequent conflict is expected to be positive. Furthermore, $Z_{c,i}$ also contains a variable measuring the shares of black and indigenous persons in the total population (to control for ethnic fractionalization, which is often found to affect the likelihood of armed conflict), the shares of agriculture and mining in total GDP (to control for the sectoral composition of the region), as well as the number of years that have passed since the last conflict (as of the year 2000), which allows us to account for recurring conflicts. $Z_{s,ij}$ contains variables measuring the distance between the municipalities of origin and destination, and the distance squared and two dummy variables, with one indicating whether origin and destination share a common border and the other indicating whether they are located in the same department. These variables are routinely used as covariates in gravity models for migration, and are thus assumed to affect the existence of positive migration flows across pairs of municipalities. Finally, $Z_{a,ij}$ contains all variables included in $Z_{s,ij}$ as well as information on total population, GDP per capita and its growth rate, and the shares of agriculture and mining in both origin and destination. As such, this set of controls is typical of gravity models of migration (see Cohen et al., 2008 or Abel et al., 2019). In this setting, we assume that the equation-specific covariates included only in $Z_{c,i}$ do not to affect our main dependent variable directly, but rather through the mediating conflict variable, which allows us to interpret the links between climate, conflicts, and migration in a causal manner.

As proposed by Kim (2006), this sample selection model is estimated as a combination of the bivariate probit and the type II tobit model, which contains the endogenous conflict indicator in both the selection equation and the final equation on the number of migrants. Hence, we control for the endogeneity of $c_i$ and the bias caused by the non-random selection of $s_{ij}$. Following Kim (2006), we first estimate equations (1) and (2) as a bivariate probit model. Next, we estimate the outcome equation by applying a Generalized Method of Moments (GMM) estimator. This enables us to obtain estimates of the parameters of the model as if it was a type II tobit model with a bivariate selection and parameter restrictions.

## Results

### Main results

Table 1 gives an overview of the parameter estimates of equations (1)–(3) based on the method proposed in the previous section. The first part of Table 1 presents the results

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**Table 1** Parameter estimates for conflict, selection for migration and migration flow size

| | | Estimate | Std. Error | $z$ value | Pr(>\|$z$\|) | |
|---|---|---|---|---|---|---|
| Conflict | (Intercept) | 0.99 | 0.01 | 115.88 | 0.000 | *** |
| | Battle deaths in preceding period | −0.11 | 0.00 | −40.57 | 0.000 | *** |
| | Level of SPEI in preceding period | −1.20 | 0.01 | −124.11 | 0.000 | *** |
| | Share of black persons | 0.25 | 0.01 | 39.59 | 0.000 | *** |
| | Share of indigenous persons | 0.79 | 0.01 | 86.49 | 0.000 | *** |
| | Share of agriculture in GDP of origin | −0.44 | 0.02 | −22.34 | 0.000 | *** |
| | Share of mining in GDP of origin | 0.91 | 0.01 | 93.18 | 0.000 | *** |
| | Number of conflicts in preceding period | 0.89 | 0.01 | 141.12 | 0.000 | *** |
| | Years since last conflict | −0.08 | 0.00 | −52.65 | 0.000 | *** |
| Selection | (Intercept) | −0.01 | 0.01 | −1.67 | 0.096 | |
| | Distance between origin and destination | −3.37 | 0.02 | −154.24 | 0.000 | *** |
| | Dist. btw. origin and destination squared | 1.23 | 0.02 | 53.54 | 0.000 | *** |
| | Common border | 2.01 | 0.03 | 60.80 | 0.000 | *** |
| | Same department | −0.29 | 0.01 | −50.87 | 0.000 | *** |
| | Conflict | 0.75 | 0.01 | 129.21 | 0.000 | *** |
| Flow size | (Intercept) | −5.97 | 0.06 | −102.07 | 0.000 | *** |
| | Distance between origin and destination | −5.82 | 0.16 | −36.17 | 0.000 | *** |
| | Dist. btw. origin and destination squared | 2.10 | 0.05 | 39.49 | 0.000 | *** |
| | Common border | 2.81 | 0.05 | 54.33 | 0.000 | *** |
| | Same department | −0.47 | 0.01 | −31.98 | 0.000 | *** |
| | Population size of origin | 0.25 | 0.02 | 14.75 | 0.000 | *** |
| | Population size of destination | 0.24 | 0.02 | 14.67 | 0.000 | *** |
| | GDP per capita in origin | −0.10 | 0.01 | −9.84 | 0.000 | *** |
| | GDP per capita in destination | −0.09 | 0.01 | −9.38 | 0.000 | *** |
| | GDP growth in origin | −0.81 | 0.03 | −29.08 | 0.000 | *** |
| | GDP growth in destination | −1.27 | 0.02 | −60.18 | 0.000 | *** |
| | Share of agriculture in GDP of origin | 0.06 | 0.03 | 2.26 | 0.024 | * |
| | Share of agric. in GDP of destination | −1.24 | 0.02 | −49.59 | 0.000 | *** |
| | Share of mining in GDP of origin | −0.07 | 0.01 | −4.81 | 0.000 | *** |
| | Share of mining in GDP of destination | −0.03 | 0.01 | −2.97 | 0.003 | ** |
| | Conflict | 1.11 | 0.03 | 32.60 | 0.000 | *** |

*(table continues)*

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**Table 1** (*continued*)

| | | Estimate | Std. Error | $z$ value | Pr(>\|$z$\|) | |
|---|---|---|---|---|---|---|
| Control terms | $\rho_{120}$ | −0.21 | 0.01 | −27.11 | 0.000 | *** |
| | $\rho_{121}$ | −0.40 | 0.00 | −86.65 | 0.000 | *** |
| | $\mu_{11}$ | −0.56 | 0.02 | −27.14 | 0.000 | *** |
| | $\mu_{12}$ | 1.54 | 0.07 | 21.84 | 0.000 | *** |
| | $\mu_{01}$ | −0.33 | 0.01 | −23.76 | 0.000 | *** |
| | $\mu_{02}$ | 1.59 | 0.07 | 24.13 | 0.000 | *** |

***, **, * indicate the significance at the 1%, 5% and 10% level, respectively.

for equation (1) with conflict as the binary dependent variable. The results show a statistically significant connection between droughts and the occurrence of conflicts in Colombia in the time period analyzed, with more droughts being related to a higher probability of conflict. Moreover, we can see that municipalities with a higher number of conflicts in the past and a smaller number of years since the last conflict tend to be more prone to witnessing further violent conflict events. Conflicts involving a large number of casualties, however, tend to be less persistent than those with a relatively smaller casualty count. Such a result indicates that armed conflict in Colombia tends to have a high degree of spatial-temporal persistence at the municipality level, in line with the results of the econometric analysis carried out by Sánchez et al. (2005) for homicides and other types of violence at the departmental level. It appears that both higher shares of black and indigenous persons in the population and a higher share of mining in total GDP are positively correlated with the probability of conflict. This suggests that some violent episodes in Colombia might involve a competition for resources at the subnational level. Such a conclusion is supported by existing work on the military strategies of Colombian guerrillas. Echandia-Castilla (2008) showed that the expansion of conflict in the country follows a pattern that correlates with the socioeconomic characteristics of the territories occupied by the guerrillas. The results of Echandia-Castilla (2008) were refined in Dufort (2014), which conceptualized the dual role of violence in the Colombian conflict as a force of resource extraction and of military control. Our results lend support to such an interpretation of the dynamics of conflict in the country.

Under the header *Selection*, Table 1 provides the estimation results for equation (2), which describes the selection of municipalities for non-zero migration outflows. The results show that conflicts have a significant positive relationship with the selection for migration flows. Furthermore, it reveals that people tend to migrate to neighboring municipalities, but not necessarily to other municipalities in the same department. The distance between origin and destination has a non-linear relationship with the likelihood of migration flows. When the distance between two municipalities increases, the probability of selection first decreases and then increases again. The relationship between the selection for migration and droughts is captured through the treatment variable conflict. Building on the positive

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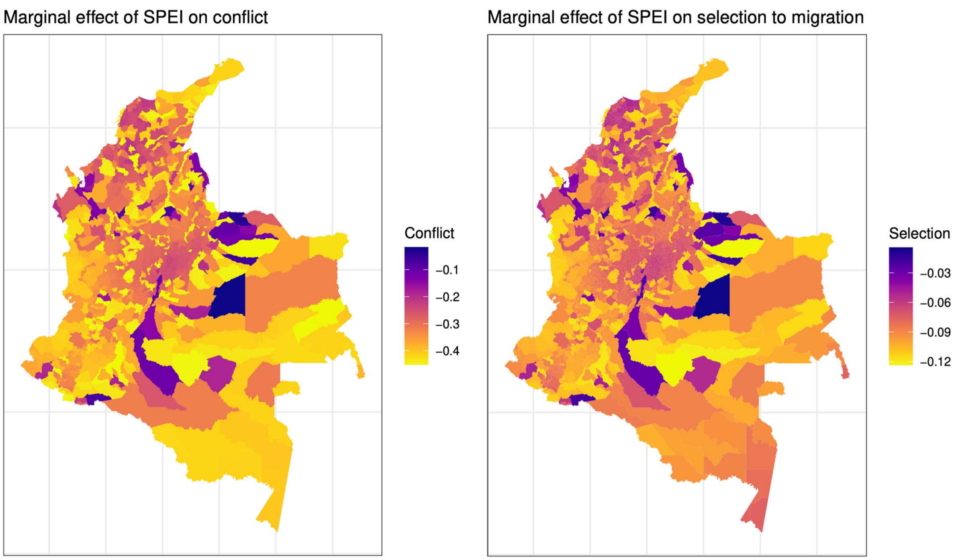
relation between conflict and selection, we can observe an indirect positive correlation linking the drought indicator to the existence of migration.

To give a better picture of the effects of changes in the SPEI on conflicts and selection for migration, Figure 2 illustrates the marginal effects of an increase in the SPEI of one standard deviation on both variables. The effect of changes in drought risk on selection is driven by its role as a determinant of conflict. As negative SPEI values are linked to droughts and positive values indicate wet conditions, the effects of the increase of the variable plotted in Figure 2 corresponds to a reduction in droughts. Figure 2 shows that an increase in the SPEI leads to a reduction in the probability of conflict and of selection in all municipalities. Since the scope of this effect is related to the value of other variables included in the model, the sizes of the marginal effects vary in different parts of the country. On average, an increase in the SPEI of one standard deviation leads to a decrease of 0.32 in the probability of conflict and a decrease of 0.08 in the probability of selection for migration (via its effect on the probability of conflict).

The third part of Table 1 shows the parameter estimates for the size of migration flows. In line with their effect on selection, conflicts also have a significant positive correlation with the number of migrants. Similarly, in the estimates referring to the effect of distance between origin and destination, municipalities with a common border and municipalities within the same department qualitatively match the corresponding estimates explaining the selection for migration. GDP per capita and its growth rate are negatively correlated with the size of both migration inflows and migration outflows. In addition, people appear to migrate from areas with higher shares of agriculture in GDP to areas where this sector is less

**Figure 2** Marginal effects of SPEI on conflict and selection to internal migration in Colombia from 2000 to 2005.

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important, while mining seems to be negatively related to the numbers of both out-migrants and in-migrants.[2]

Overall, our results support the existence of a causal linkage between climate, conflicts and migration. While this link is probably limited to certain years and regions of the world, our analysis suggests that it has at least played a role in the internal flows of migration in Colombia in the 2000–2005 period. Our results imply that droughts might have contributed to the outbreak of conflicts in Colombia in this period, leading to increased numbers of people migrating to other municipalities inside the country.

## Robustness checks

Our main results suggest the existence of a causal relationship between droughts, conflicts and internal migration for Colombia. To check the robustness of these findings, we investigate three alternative model specifications: changing the definition of the conflict variable, restricting the considered area to different subsets and including department fixed effects to control for time-invariant differences in conflict and migration patterns across more aggregated subnational units than the municipality level. For the first robustness check we adjust the definition of a conflict so that it is based on different numbers of battle-related deaths: 10 or 20 instead of one. In an additional robustness check, we split the municipalities into two subsets, one without any conflicts between 1995 and 1999, which precedes our observation period for migration, and one with at least one conflict in the same period.

Tables 2 and 3 show the original results next to the alternative versions of the specification based on different definitions of conflict and of the sample of municipalities considered. The SPEI variable has a significant negative effect in all of our specifications for the conflict equation, which suggests that the evidence that droughts promote conflict is robust to considering larger conflicts or subsets of municipalities with different conflict histories. The size of the parameter estimate varies considerably across specifications based on the definition of conflict. Setting the threshold for conflict to a larger number of battle deaths leads to a decrease in the estimated effect, which suggests that droughts tend to be more closely related to smaller conflicts, and that the effect is quantitatively smaller for conflicts with a relatively large number of casualties. This result is supported by the findings of Abel et al. (2019), who drew a similar conclusion regarding the correlation between droughts and conflicts of different intensities at the country level. Moreover, Table 3 shows that the effect of drought on the probability of violent conflict is larger in areas that have not witnessed another conflict in previous years, although the effect of conflict on migration tends to be smaller in these regions.

Finally, Table 4 presents the results that include department origin and destination fixed effects in the gravity specification, and thus concentrate on the effects of environmental

2 Reliance on agricultural output and mining has significant effects on both the probability of conflict and the size and the direction of migration flows. Such effects may be exclusive to the case of Colombia, due to the asymmetric distribution of guerrilla forces across rural and urban areas. Unfortunately, given the lack of data on the share of agricultural and mining output at the municipality level, a more detailed analysis of such potential interaction effects is not possible.

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**Table 2** Parameter estimates of robustness checks on the number of battle deaths

| | | Baseline model | 10 battle deaths | 20 battle deaths |
|---|---|---|---|---|
| Conflict | (Intercept) | 0.99*** | −1.06*** | −0.93*** |
| | Battle deaths in preceding period | −0.11*** | 0.41*** | 0.35*** |
| | Level of SPEI in preceding period | −1.20*** | −0.56*** | −0.93*** |
| | Share of black persons | 0.25*** | 0.49*** | 0.69*** |
| | Share of indigenous persons | 0.79*** | 1.12*** | 0.79*** |
| | Share of agriculture in GDP of origin | −0.44*** | −1.20*** | −1.08*** |
| | Share of mining in GDP of origin | 0.91*** | 1.01*** | −0.35*** |
| | Number of conflicts in preceding period | 0.89*** | 0.14*** | −0.20*** |
| | Years since last conflict | −0.08*** | 0.09*** | −0.07*** |
| Selection | (Intercept) | −0.01 | 0.09*** | 0.15*** |
| | Distance between origin and destination | −3.37*** | −3.42*** | −3.33*** |
| | Dist. btw. origin and destination squared | 1.23*** | 1.24*** | 1.19*** |
| | Common border | 2.01*** | 2.01*** | 1.9*** |
| | Same department | −0.29*** | −0.30*** | −0.30*** |
| | Conflict | 0.75*** | 0.72*** | 0.82*** |
| Flow size | (Intercept) | −5.97*** | −5.57*** | −5.17*** |
| | Distance between origin and destination | −5.82*** | −5.25*** | −4.00*** |
| | Dist. btw. origin and destination squared | 2.10*** | 1.98*** | 1.63*** |
| | Common border | 2.81*** | 2.60*** | 2.13*** |
| | Same department | −0.47*** | −0.42*** | −0.32*** |
| | Population size of origin | 0.25*** | 0.24*** | 0.24*** |
| | Population size of destination | 0.24*** | 0.24*** | 0.24*** |
| | GDP per capita in origin | −0.10*** | −0.09*** | −0.10*** |
| | GDP per capita in destination | −0.09*** | −0.09*** | −0.09*** |
| | GDP growth in origin | −0.81*** | −0.80*** | −0.82*** |
| | GDP growth in destination | −1.27*** | −1.27*** | −1.27*** |
| | Share of agriculture in GDP of origin | 0.06* | 0.09*** | 0.07** |
| | Share of agric. in GDP of destination | −1.24*** | −1.23*** | −1.23*** |
| | Share of mining in GDP of origin | −0.07*** | −0.06*** | 0.05*** |
| | Share of mining in GDP of destination | −0.03** | −0.03** | −0.03** |
| | Conflict | 1.11*** | 1.03*** | 0.87*** |

*(table continues)*

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**Table 2** (*continued*)

| | | Baseline model | 10 battle deaths | 20 battle deaths |
|---|---|---|---|---|
| Control terms | $\rho_{120}$ | −0.21*** | −0.32*** | −0.91*** |
| | $\rho_{121}$ | −0.40*** | −0.17*** | −0.13*** |
| | $\mu_{11}$ | −0.56*** | −0.24*** | −0.10*** |
| | $\mu_{12}$ | 1.54*** | 1.20*** | 0.59*** |
| | $\mu_{01}$ | −0.33*** | −0.39*** | −1.32*** |
| | $\mu_{02}$ | 1.59*** | 1.32*** | 0.79*** |

***, **, * indicate the significance at the 1%, 5% and 10% level, respectively.

shocks and conflicts on migration flows within departments. This specification results in similar effects of conflicts on migration flows as those obtained without department fixed effects, which appears to indicate that the results from our main specification are driven by migration flows within departments, as would be expected if the mobility observed in the

**Table 3** Parameter estimates of robustness checks: Subsamples by existence of conflict

| | | Baseline model | 10 battle deaths | No previous conflicts | Previous conflicts |
|---|---|---|---|---|---|
| Conflict | (Intercept) | 0.99*** | −1.06*** | | 0.75*** |
| | Battle deaths in preceding period | −0.11*** | 0.41*** | | −0.19*** |
| | Level of SPEI in preceding period | −1.20*** | −0.56*** | −1.31*** | −0.92*** |
| | Share of black persons | 0.25*** | 0.49*** | 0.33*** | −0.07*** |
| | Share of indigenous persons | 0.79*** | 1.12*** | 0.66*** | 1.81*** |
| | Share of agriculture in GDP of origin | −0.44*** | −1.20*** | −0.67*** | 0.29*** |
| | Share of mining in GDP of origin | 0.91*** | 1.01*** | 0.87*** | 0.99*** |
| | Number of conflicts in preceding period | 0.89*** | 0.14*** | | 0.88*** |
| | Years since last conflict | −0.08*** | 0.09*** | | 0.05*** |
| Selection | (Intercept) | −0.01 | 0.09*** | 0.07*** | −0.13*** |
| | Distance between origin and destination | −3.37*** | −3.42*** | −3.32*** | −3.55*** |
| | Dist. btw. origin and destination squared | 1.23*** | 1.24*** | 1.17*** | 1.40*** |
| | Common border | 2.01*** | 2.01*** | 2.02*** | 2.07*** |
| | Same department | −0.29*** | −0.30*** | −0.30*** | −0.25*** |
| | Conflict | 0.75*** | 0.72*** | 0.62*** | 0.90*** |

*(table continues)*

**Table 3** (*continued*)

| | | Baseline model | 10 battle deaths | No previous conflicts | Previous conflicts |
|---|---|---|---|---|---|
| Flow size | (Intercept) | −5.97*** | −5.57*** | −4.56*** | −7.28*** |
| | Distance between origin and destination | −5.82*** | −5.25*** | −4.25*** | −4.4*** |
| | Dist. btw. origin and destination squared | 2.10*** | 1.98*** | 1.61*** | 1.92*** |
| | Common border | 2.81*** | 2.60*** | 2.32*** | 2.32*** |
| | Same department | −0.47*** | −0.42*** | −0.34*** | −0.31*** |
| | Population size of origin | 0.25*** | 0.24*** | 0.18*** | 0.40*** |
| | Population size of destination | 0.24*** | 0.24*** | 0.23*** | 0.27*** |
| | GDP per capita in origin | −0.10*** | −0.09*** | −0.10*** | −0.06*** |
| | GDP per capita in destination | −0.09*** | −0.09*** | −0.08*** | −0.12*** |
| | GDP growth in origin | −0.81*** | −0.80*** | −0.80*** | −0.42*** |
| | GDP growth in destination | −1.27*** | −1.27*** | −1.21*** | −1.53*** |
| | Share of agriculture in GDP of origin | 0.06* | 0.09*** | 0.10** | −0.16** |
| | Share of agric. in GDP of destination | −1.24*** | −1.23*** | −1.28*** | −1.14*** |
| | Share of mining in GDP of origin | −0.07*** | −0.06*** | 0.32*** | −0.25*** |
| | Share of mining in GDP of destination | −0.03** | −0.03** | −0.12*** | 0.13*** |
| | Conflict | 1.11*** | 1.03*** | 0.33*** | 0.96*** |
| Control terms | $\rho_{120}$ | −0.21*** | −0.32*** | −0.04** | −0.33*** |
| | $\rho_{121}$ | −0.40*** | −0.17*** | −0.35*** | −0.44*** |
| | $\mu_{11}$ | −0.56*** | −0.24*** | −0.14*** | −0.37*** |
| | $\mu_{12}$ | 1.54*** | 1.20*** | 0.91*** | 0.63*** |
| | $\mu_{01}$ | −0.33*** | −0.39*** | 0.16*** | −0.40*** |
| | $\mu_{02}$ | 1.59*** | 1.32*** | 0.99*** | 0.84*** |

***, **, * indicate the significance at the 1%, 5% and 10% level, respectively.

data tends to be over relatively short distances. In addition, the estimated reactions of migration flows to GDP growth in the specification with origin and destination fixed effects at the department level are much larger than those in the model without them, which points to the existence of more pronounced push and pull effects via economic developments within departments than at the between-department level.

In summary, these checks suggest that there is a robust correlation between climate, conflicts and internal migration in Colombia for the period under study. The variation in the size of the estimated effect of environmental change on conflict gives a hint of the circumstances in which this dynamic might be most relevant. In particular, droughts seem to be more closely related to smaller conflicts and to have a bigger effect in regions that have not experienced a conflict in recent years.

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**Table 4** Parameter estimates: Specification with department fixed effects

| | | Baseline model | Department fixed effects |
|---|---|---|---|
| Conflict | (Intercept) | 0.99*** | 0.99*** |
| | Battle deaths in preceding period | −0.11*** | −0.11*** |
| | Level of SPEI in preceding period | −1.20*** | −1.20*** |
| | Share of black persons | 0.25*** | 0.25*** |
| | Share of indigenous persons | 0.79*** | 0.79*** |
| | Share of agriculture in GDP of origin | −0.44*** | −0.44*** |
| | Share of mining in GDP of origin | 0.91*** | 0.91*** |
| | Number of conflicts in preceding period | 0.89*** | 0.89*** |
| | Years since last conflict | −0.08*** | −0.08*** |
| Selection | (Intercept) | −0.01 | −0.01 |
| | Distance between origin and destination | −3.37*** | −3.37*** |
| | Dist. btw. origin and destination squared | 1.23*** | 1.23*** |
| | Common border | 2.01*** | 2.01*** |
| | Same department | −0.29*** | −0.29*** |
| | Conflict | 0.75*** | 0.75*** |
| Flow size | (Intercept) | −5.97*** | 0.47*** |
| | Distance between origin and destination | −5.82*** | −5.37*** |
| | Dist. btw. origin and destination squared | 2.10*** | 1.07*** |
| | Common border | 2.81*** | 2.63*** |
| | Same department | −0.47*** | −0.26*** |
| | Population size of origin | 0.25*** | 0.26*** |
| | Population size of destination | 0.24*** | 0.25*** |
| | GDP per capita in origin | −0.10*** | −0.09*** |
| | GDP per capita in destination | −0.09*** | −0.04*** |
| | GDP growth in origin | −0.81*** | −3.40*** |
| | GDP growth in destination | −1.27*** | −2.44*** |
| | Share of agriculture in GDP of origin | 0.06* | |
| | Share of agriculture in GDP of destination | −1.24*** | |
| | Share of mining in GDP of origin | −0.07*** | |
| | Share of mining in GDP of destination | −0.03** | |
| | Conflict | 1.11*** | 1.01*** |

*(table continues)*

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**Table 4** (*continued*)

| | | Baseline model | Department fixed effects |
|---|---|---|---|
| Control terms | $\rho_{120}$ | −0.21*** | −0.21*** |
| | $\rho_{121}$ | −0.40*** | −0.40*** |
| | $\mu_{11}$ | −0.56*** | −0.48*** |
| | $\mu_{12}$ | 1.54*** | 1.36*** |
| | $\mu_{01}$ | −0.33*** | −0.34*** |
| | $\mu_{02}$ | 1.59*** | 1.38*** |

***, **, * indicate the significance at the 1%, 5% and 10% level, respectively.

## Conclusion

Environmental factors are generally seen as being among main causes of migration. Together with economic, political, social and demographic drivers, these factors are considered in a large number of studies analyzing the triggers of migration flows. In many of these studies, the effects of different causes are evaluated simultaneously, without taking into account the potential causal linkages between them.

Following the methodological setting used in Abel et al. (2019), this paper focused on the interaction between environmental and political factors, and on how this correlation can affect internal migration. In particular, our aim was to make this connection in the context of internal migration in Colombia in the years 2000 to 2005. To establish a causal linkage between climate, conflicts and migration dynamics on the municipality level, we used a sample selection model proposed by Kim (2006). This gravity model considered the issue of endogenous selection regarding the probability of observing a conflict, and regarding the likelihood of non-zero migration flows.

We found a significant positive link between droughts and conflicts, as well as between conflicts and migration, indicating the existence of a causal linkage between climate, conflicts and internal migration in Colombia. Our robustness checks confirmed these results and revealed further details about the observed effects. First, we found that droughts tend to be more closely related to smaller conflicts for which the number of battle-related deaths is below 10. Second, we showed that the effect of drought on the emergence of conflict tends be larger in areas that have not witnessed another conflict in previous years. Our analysis advances the literature by making use of a novel dataset on internal migration flows in the country, which was recently developed by Siraj et al. (2020). The results of our analysis complement the existing results for international migration (see Abel et al., 2019, for example), and confirm that in countries that have experienced violent conflict, human mobility, is more prone to react to environmental shocks than it is in countries with a stable political setting (Hoffmann et al., 2020). In addition, our results provide estimates that can be used to inform estimates of the potential welfare losses from climatic shocks within climate scenarios that incorporate migration (building, for instance, upon the work of Ibáñez and Vélez, 2008).

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Providing empirical evidence for one of the pathways through which climatic change can affect migration may be expected to support the design of evidence-based policy measures aimed at mitigating the negative consequences of environmental change trends in the future. Unfortunately, the existing data did not allow us to discern the actual reason for migration, and further data collection efforts should concentrate on improving the information quality of internal mobility data for the country. This is particularly important for differentiating conflict migrants from migration driven exclusively by climate hazards and thus for refining the predictive power of econometric models such as the one employed in this study.

Our analysis leaves room for future research focusing on other countries and different periods of time. Additional evidence might then allow the community to gain an even better understanding of the linkages between climate, conflicts and migration and could make it easier to assess the scope of these dynamics in different parts of the world. Measuring the actual contribution of anthropogenic climate change to changes in the probability of drought episodes in Colombia would require a full-fledged climate attribution study (see Simpson et al., 2021 or van Oldenborgh et al., 2021, for example). This exercise is beyond the scope of the current contribution, but future research that combines the results of attribution studies with the quantitative insights of causal inference models will prove particularly important. Such an interdisciplinary effort would provide extremely valuable insights that can be used to obtain reliable predictions of future migratory pressures.

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