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ORIGINAL PAPER

Managing the impact of climate on migration: evidence from Mexico

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Abstract
Although there is a growing literature on the impact of climate and weather-related events on migration, little is known about the mitigating effect of policies directed toward the agricultural sector, or aimed at insuring against environmental disasters. This paper uses state-level data on migration flows between Mexico and the USA from 1999 to 2012 to investigate the mitigating impact of an agricultural cash transfer program (PROCAMPO) and a disaster fund (Fonden) on the migration response to weather shocks. We find that Fonden decreases migration in response to heavy rainfall, hurricanes and droughts. Increases in PROCAMPO amounts paid to small producers play a more ambiguous role in the migration response to shocks. Changes in the distribution of PROCAMPO payments favoring more vulnerable producers in the non-irrigated *ejido* sector, however, seem to mitigate the impact of droughts on migration.

Keywords International migration · Weather shocks · Public policies · Weather variability · Natural disasters · Mexico-US migration · Inequality

JEL Classification F22 · Q54 · Q18 · 015 · J61

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1 Introduction

Among the many it consequences of weather shocks and climate on economic activity, the impact on human mobility is a key issue. Together with weather-related disasters, gradual and sustained shifts in rainfall and temperatures contribute to migration, in particular through their impact on agricultural yields (Schlenker and Roberts 2009; Feng et al. 2012). Unsurprisingly, the impact of weather shocks and variability on migration is larger in developing countries that are ex ante more vulnerable (Beine and Parsons 2015; Coniglio and Pesce 2015). This result can be partly explained by the limited capacity of governments to fund public policies that help households deal with adverse shocks. It thus seems crucial to assess the potential mitigating role of different types of pre-existing public policies that were not specifically designed to help people cope with climate variations. This article addresses the mitigating role of public policies which, though critical, has remained largely unexplored in the rapidly growing body of literature concerned with the impact of climate on migration.[1]

We explore the potentially mitigating effect of two public programs, PROCAMPO and Fonden, on Mexico-US migration in response to different types of weather shocks. The Mexican case is particularly relevant for two reasons. First, Mexico is classified as a "highly vulnerable country" with respect to climate change due to its geographic characteristics and is particularly exposed to extreme hydrometeorological events.[2] Second, Mexico is one of the top emigration countries (second behind India, according to the 2020 World Migration Report by the IOM), and Mexico-USA has been by far the world's top migration corridor in recent decades. We use unique panel data on yearly Mexico-US migrant flows from each of the 32 Mexican states during 2001 to 2012.[3] The two programs that we focus on, PROCAMPO and Fonden, although very different, are of particular relevance to our study. PROCAMPO is the largest agricultural program funded by the Mexican federal government and consists of direct payments to agricultural producers on a per-hectare basis made twice a year, while Fonden is a disaster fund aimed at providing insurance to localities hit by a natural disaster. We use satellite and land data, including high-quality data produced by the Tropical Rainfall Measuring Mission, to assess the impact of weather-related shocks. We construct measures of excess rainfalls, hurricanes, precipitation and temperature anomalies and examine the impact on Mexico-US migration flows at the federated state level.

The identification of a causal effect of those two programs relies on the assumption that changes in transfers received are not caused by changes in migration

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[1] Although our paper studies the effect of weather shocks, Hsiang (2016) refreshes the debate over the misuse of climate for weather by providing theoretical justifications for using weather variables to analyze the effect of climate.

[2] According to the World Bank's Climate Change Knowledge Portal https://climateknowledgeportal.worldbank.org/country/mexico.

[3] Migration flow data are constructed based on individual data from the Survey of Migration at the Northern Border of Mexico (*Encuesta sobre Migración en la Frontera Norte de México* or EMIF Norte), see also Chort and De La Rupelle (2016).

patterns. Regarding Fonden, previous analyses by del Valle et al. (2020) show that the program's operating rules leave no room for manipulation. Indeed, the disbursement of Fonden funds requires a declaration by the municipality that has experienced a natural disaster and a visit by a federal damage assessment committee; qualifying disasters are precisely defined using indexes, and municipality declarations are verified by a state agency based on objective data. As for PROCAMPO, the amounts per hectare paid to each producer are defined at the federal level, unconnected to any productive considerations, and, importantly, the set of eligible plots was, in theory, established in the 1990s. However, strategic manipulation of plot size declared by producers, corrupt arrangements or other non-random changes in plot characteristics may raise endogeneity concerns. Instead of using actual payments, we exploit information on individual PROCAMPO plot characteristics and construct a theoretical measure of PROCAMPO based on the characteristics of plots in 1999, before any reform took place, to which we apply the national variations in PROCAMPO payments per hectare that followed in subsequent years, especially due to the two waves of pro-poor reforms implemented in the 2000s. In addition, since the characteristics of plots themselves, such as size or irrigation, could be related to migration patterns, we exploit the discontinuity around the hectare threshold (5 ha in most states) under which plots are eligible to a bonus payment, and focus on transfers directed to plots around the threshold.

Our results suggest that Fonden has a mitigating effect on climate-induced migration. An increase in Fonden transfers to a given state tends to limit migration from that state in response to a negative weather shock. This effect is especially salient for undocumented flows, and the effect size is not negligible: a one standard deviation increase in Fonden amount per capita cuts by two-thirds the elasticity of undocumented migration to drought, offsets the impact of an additional month with rainfalls above the historical 90th percentile, and reduces undocumented migration by 13% following a hurricane. The effect of PROCAMPO is more ambiguous: an increase in PROCAMPO transfers to small producers tends to increase migration after heavy rainfall, although the effect is marginally significant. Further, PROCAMPO tends to have a mitigating effect after droughts. In addition, we explore the effect of changes in the distribution of PROCAMPO payments and find that an increased share of PROCAMPO transfers to the most vulnerable producers is generally correlated with lower weather-induced migration.

This study contributes to the growing body of literature concerned with the impact of climate and weather shocks on migration by exploring the mitigating role of public policies. There is conflicting evidence on the impact of natural disasters on migration (Mbaye and Zimmermann 2016; Cui and Feng 2020), which reflects in part the different methodological choices made by researchers (Beine and Jeusette 2018) but also emphasizes the multiple channels involved. For example, Marchiori et al. (2012) show that weather anomalies in the sub-Saharan African context generate sizable flows of both internal and international migrants through the cumulation of a direct negative impact on amenities and downward pressure on urban wages. By contrast, focusing on Tanzania, Hirvonen (2016) finds that adverse weather shocks limit internal migration due to liquidity constraints.

In the context of Mexico, a number of previous papers note the role of climatic events on international migration (Munshi 2003; Pugatch and Yang 2011; Chort 2014; Chort and De La Rupelle 2016). However, few empirical studies focus on the impact of environmental factors on Mexican international migration. Exceptions are Feng et al. (2010), who estimate the impact of decreases in crop yields due to climate change on migration. Saldaña-Zorrilla and Sandberg (2009) focus on the impact of natural disasters on international migration. Nawrotzki et al. (2013) investigate the role of drought on migration[4]. Jessoe et al. (2018) show that extreme heat leads increases both rural-to-urban migration and migration to the USA. Baez et al. (2017a) and Baez et al. (2017b) directly investigate the effect of droughts and heat on internal migration. While previous studies on the Mexican context exclusively focused on the effect of weather shocks, this paper goes further by investigating and comparing the potential mitigating impact of different public policies.

Second, our paper relates to research that analyzes the impact of public policies on migration. In the Mexican context, many studies focus on the large anti-poverty PROGRESA/*Oportunidades* program.[5] Early evaluations of PROGRESA suggest that conditional cash transfers reduce migration to the USA (Stecklov et al. 2005). Focusing on labor migration only, Angelucci (2015) finds that entitlement to the new version of the PROGRESA program (*Oportunidades*) increases migration, suggesting credit constraints and consistent with Rubalcava and Teruel (2006). These conflicting findings indicate that the same program may have heterogenous impacts on migration depending on how transfers are used. Comparing the effect of Fonden and PROCAMPO, we find that the former clearly has a mitigating effect, whereas the impact of PROCAMPO is weaker and more ambiguous. Additional results suggest, however, that a reduction in the inequality of the distribution of PROCAMPO tends to reduce migration after weather shocks.

More generally, this paper contributes to the literature on the mitigating role of public policies after a shock. The evaluation of the economic impact of the Fonden fund provided by del Valle et al. (2020) shows a positive and sustained effect of the program on local economic activity and employment, implying that Fonden may affect migration responses to climatic shocks through different channels. Previous works on PROCAMPO suggest that a basic cash transfer program may also help its beneficiaries cope with adverse economic shocks. Sadoulet et al. (2001) find an income multiplier of 1.5-2.6 for PROCAMPO beneficiaries in the *ejido* sector,[6] which indicates that the transfers received under the program help alleviate households' liquidity constraints. As such, PROCAMPO payments may affect the capacity

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[4] All these issues are also conceptually discussed in Cohen et al. (2013) but without econometric validation, while Eakin (2005) uses ethnographic data to analyze the vulnerability of rural households to climatic hazards.

[5] In particular, several studies have explored the impact of this program on children schooling outcomes (De Janvry et al. 2006). Adhvaryu et al. (2018) show that the program mitigates the negative impact of adverse weather shocks during childhood on educational attainment.

[6] The *ejido* sector characterizes communal land created by the land reform following the 1910 revolution. Members of agrarian communities were allocated land use rights, provided that they would not leave land uncultivated for more than two years.

of households to manage the effect of climatic shocks and may influence migration decisions.

The rest of the paper is organized as follows: Section 2 first describes the Mexican context and the characteristics of the PROCAMPO and Fonden programs. Section 3 presents the main expected theoretical mechanisms. The data sources and construction are described in Section 4. Section 5 presents the empirical model, and results are presented and discussed in Section 6. Section 7 concludes.

2 Context and policies

2.1 Climate and migration in Mexico

Studying the consequences of weather variability on migration in the Mexican context is particularly interesting for three reasons. First, Mexico sits astride the Tropic of Cancer and has a large diversity of climatic characteristics, although almost all parts of the country are subject to hurricanes and tropical storms in Summer and Autumn.[7]. Second, the economy of Mexican rural areas largely depends on agricultural activities.[8] Third, Mexico has a long history of migration to the USA, suggesting that moving has long been a way for Mexican households to cope with adverse economic shocks.

Climate projections for Mexico converge toward a 2.5 to 4 °C increase in temperatures and a decrease in precipitations by 2100 (Gosling et al. 2011). Projections regarding extreme phenomena such as hurricanes are less clear-cut: some studies suggest that hurricanes may become more frequent and violent (Emanuel 2013; Mendelsohn et al. 2012), but the impact of global warming on hurricanes is disputed. Although climate change is a long-term phenomenon, focusing on weather shocks in the recent period is of relevance given the dramatic acceleration of global warming in the last two decades and the observed higher frequency of natural disasters such as hurricanes or floods.

2.2 The PROCAMPO and Fonden programs

We focus in this paper on two major programs: an agricultural cash transfer program, PROCAMPO, and a disaster fund, Fonden. The PROCAMPO program is the largest agricultural program in Mexico, initially launched in 1993 to mitigate the impact of the North American Free Trade Agreement (NAFTA) on Mexican producers by

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[7] In the last decades, the most destructive episodes in Mexico were due to Hurricanes Ingrid and Manuel in September 2013, with an estimated number of directly affected people of one million and over 190 deaths, and Hurricane Norbert in 2008 striking the North Western states of Mexico and causing 25 deaths and millions of damage.

[8] Although the share of agriculture in the Mexican GDP is low (3.5% in 2010–2014) agricultural employment represents 13 % of total employment and 21% of the population live in rural areas (World Development Indicators, World Bank).

substituting direct cash payments to price support. Initially, eligibility was limited to plots planted in one of the nine identified basic crops (corn, beans, wheat, rice, sorghum, soybeans, cotton, safflower and barley) in the three year period preceding the implementation of the program. Eligible producers receive cash transfers on a per-hectare basis twice a year, for each growing season (Spring-Summer and Autumn-Winter). In an early evaluation of the program, Sadoulet et al. (2001) find a high multiplier for PROCAMPO transfers, consistent with the existence of liquidity constraints and suggesting that received amounts are massively invested by producers in agricultural inputs.

The program went through several reforms over our period of interest, in particular pro-poor reforms that increases the amount per hectare for small plots (see Chort and de la Rupelle (2022) for further details).

While average payments in real terms tend to decline over the period, the different pro-poor reforms contributed to maintain the level of transfers to small producers (less than 5 ha) to around MXN 600 in constant 1994 prices.[9] Although PROCAMPO benefits are totally unrelated to climate events, this program is interesting because it is directed at agriculture, which is expected to be particularly affected by climate shocks. The coverage of the program is high, as the number of beneficiaries of PROCAMPO was 2,471,802 in 2010, representing 63% of agricultural production units. However the population of beneficiaries of PROCAMPO is highly heterogeneous, ranging from large producers cultivating irrigated land in the Northern part of the country to small farmers cultivating rainfed crops on a few hectares, mostly found in the *ejido* sector which represents 56% of Mexican agricultural land. The *ejido* sector has been associated with economic under-development ; besides limited property rights, it has also been plagued with the historical legacy of the 16th century demographic population collapse, including coercive institutions and rampant corruption (Sellars and Alix-Garcia 2018). The *ejido* sector has undergone several changes in the 1990s leading to more individual control over *ejido* land, including a titling program initiated in 1993. Such reforms have been found to contribute to increasing migration flows to the USA.[10]

The second program, Fonden, is a disaster fund created in 1996 and operational only since 2000, aimed at providing emergency relief funds and financial support to municipalities hit by a natural disaster to fund reconstruction of federal and local government assets (World Bank 2012; del Valle et al. 2020). Following an adverse shock, the procedure is launched with a declaration of a natural disaster and is subject to the decision of a damage assessment committee. The list of natural events qualifying for the program is not closed and includes in particular the following hydro-meteorological events: severe hail, hurricane, river flooding, rain flooding, severe rain, severe snow, severe drought, tropical storm, tornado. Since the start of the program, an average of 30 declarations of natural disasters has been registered each year. An evaluation of the impact of the program on economic recovery

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[9] About USD 100 in 2010.

[10] de Janvry et al. (2015) find that when labor is no longer tied to land by land use-based property rights, migration is more likely. This finding is confirmed by Valsecchi (2014).

is provided by del Valle et al. (2020) who find a positive and sustained effect of Fonden on economic activity, associated with a large increase in employment in the construction sector. After a natural disaster, funds are delivered quickly (within days for emergency funds, to weeks or months for reconstruction funds). For this reason, in the following discussion and in the empirical analysis, we investigate the mitigating impact of the two programs (Fonden and PROCAMPO) on weather shocks occurring the same year.

State-level funds received under both programs are unlikely to be directly correlated with ex ante migration trends or, in the case of Fonden, anticipated by prospective migrants. Fonden is explicitly targeted at natural disasters that are unpredictable and exogenous to migration decisions. Although the list of natural disasters qualifying municipalities for application to Fonden is open, according to del Valle et al. (2020) who have access to disaggregated Fonden data, rainfall, flooding, and hurricanes represent 93% of the claims and over 95% of disbursed funds. A very strict verification process conditions the disbursement of Fonden benefits, involving the validation of the overrun of an objective threshold by a state agency based on observed physical parameters.[11] Nonetheless, concerns regarding a possible manipulation of Fonden rules by municipalities are taken seriously by del Valle et al. (2020). Based on municipality level data, they find no evidence of manipulation of rainfall statements by municipalities.[12]

Regarding PROCAMPO, eligibility to the program is based on plots, not on farmers, and the set of eligible plots is expected to remain stable over the period. In particular, no new plots were to become eligible after 1996. Endogeneity issues regarding PROCAMPO may however arise if the implementation of the program allowed deviations to official rules, and if plot characteristics (size or irrigation type) were strategically manipulated, as evidenced by Martínez González et al. (2017).[13] Second, a titling program, PROCEDE, aimed at the *ejido* sector, was ongoing until 2006, and could have resulted in changes in plot boundaries. Note, however, that the bulk of the program was completed before our period of interest: 80% of *ejidos* had gone through the process in 2000 (de Janvry et al. 2015). To address potential endogeneity concerns regarding PROCAMPO, we construct, for each state and year, theoretical measures of PROCAMPO transfers by combining the 1999 distribution of plot characteristics with the returns to those characteristics, defined at the federal state level and modified by several reforms over the period of our study. Theoretical

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[11] Regarding hydro-meteorological events, the threshold is set to the percentile 90 of the maximum daily historic rainfall recorded at a representative weather station, and the verification of claims made by municipalities is devolved to Conagua, which is the national weather agency and does not make public neither the threshold, nor the subset of weather stations used to compute this threshold (del Valle et al. 2020).

[12] In particular, if rainfall declaration were manipulated, they would observe excess density at the right of the threshold. They formally test and reject this assumption based on the test statistic developed by Cattaneo et al. (2019).

[13] PROCAMPO is paid on a per-hectare basis, and the payment, after the 2002–2003 reforms, depends on the size of the plots with smaller plots receiving a higher per-hectare payment. This may create an incentive for farmers to modify plot size so as to declare plots that are just below the threshold (5 ha in most states).

PROCAMPO transfers thus depend only on nationwide changes in return to plot characteristics. In particular, state-level variations of PROCAMPO amounts, or changes in inequality measures of the distribution of PROCAMPO amounts, are driven by the 1999 distribution of plots around the thresholds entitling to improved benefits, not by any strategic manipulation which could have followed the different reforms. The distribution of plot size for plots of less than 10 hectares is represented for each state in Figure 5, in Chort and de la Rupelle (2022) (Appendix 1). One might fear however that plot characteristics in 1999 may be correlated with migration trends. We address this issue, first, by including Mexican state fixed effects, that account for the impact of state time-invariant characteristics, and second, by exploiting the discontinuity in theoretical payments around the threshold entitling to a bonus per-hectare payment. We discuss further threats to our identification strategy in Section 5.2.

3 Expected effects and potential channels

We discuss in this section the impact of two different types of public programs on climate-induced migration, an unconditional cash transfer program, and a disaster fund, to mimic the characteristics of the two programs, PROCAMPO and Fonden, presented above[14]. Ideally, we would like to account for remittances received in our analysis, as their amounts are likely to contribute to explaining migration decision, especially after a shock. However, for simplicity and consistency with our data, we represent migration as an individual decision and limit our analysis of the role played by remittances to the discussion of differences between documented and undocumented migrants at the end of this section.[15]

We assume that individuals live two periods, and decide to migrate at the end of the first period. In period 1, their only source of — home (H) — income is agriculture (a), and they earn a wage $w_{Ha,i,1} = \beta_{Ha,1} x_i$ with x_{i} a measure of individual skills and $\beta H_{a,1}$ the returns to skills in the agricultural sector.[16] Their utility depends additively on their wage, and on local amenities $A_{H,1}$. Utility of individual i in period 1 is given by:

$$u_{i,1} = w_{Ha,i,1} + A_{H,1} \tag{1}$$

In period 2, their utility depends on whether they decide to migrate and, in the absence of any climatic shock, writes:

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[14] Strictly speaking, the cash transfers under PROCAMPO are not unconditional, but what matters in our study is that entitlement to the program is not affected by the migration of one household member provided that part of the household stays and maintains an agricultural activity.

[15] Remittances could not be included in the empirical analysis, for lack of state-level yearly data.

[16] In spite of the actual heterogeneity of the population of Mexican immigrants, even restricted to its unauthorized part (Hanson 2006), we focus in this discussion on individuals working in the agricultural sector as the impact of climate shocks is expected to be direct and stronger for them. However, the discussion could be extended to other sectors that are also directly or indirectly affected by climate shocks, and the empirical analysis include all migrants, whatever their status and occupation in Mexico.

$$u_{i,2} = (1 - M_i)[w_{Ha,i,2} + A_{H,2}] + M_i[w_{F,i,2} + A_{F,2} - C] \tag{2}$$

where $w_{F,i,2}$ is the foreign wage ($w_{F,i,2} = \beta_{F,2}x_i$), depending on individual skills x_i and the returns to skills abroad $\beta_{F,2}$. $A_{F,2}$ are amenities at destination, and $M_i = 0, 1$ is a choice dummy with $M_i = 1$ if individual i decides to migrate, and $M_i = 0$ if she decides to stay. Migration is assumed to be costly, with an up-front cost C. If individuals cannot borrow, they are able to migrate only if migration costs are not higher than their saving capacity. Migration is thus subject to the following feasibility constraint:

$$C \leq w_{Ha,i,1} \tag{3}$$

Under the above assumptions, the maximization problem is the following: individual i decides to migrate if $w_{F,i,2} + A_{F,2} - C \geq w_{Ha,i,2} + A_{H,2}$ provided that constraint Eq. 3 is satisfied. Such a liquidity or credit constraint implies the existence of a pool of individuals willing to migrate but who are forced to stay for lack of sufficiently high income.

We now introduce climate shocks and public policies in the model. For simplicity, we assume that climate shocks occur in period 1 only. While Cattaneo and Peri (2016) focus exclusively on the productivity channel in their model, we assume that shocks can affect both amenities, through the destruction of infrastructures for example, and wage at origin, by lowering agricultural productivity. For simplicity, we further assume that the effect of the shock is homogenous across skill levels. In the event of a negative shock (*NS*), period 1 utility u^{NS} writes:

$$u^{NS}_{i,1} = \gamma_1 w_{Ha,i,1} + \delta_1 A_{H,1} \tag{4}$$

with $0 \leq \gamma_1 \leq 1$ and $0 \leq \delta_1 \leq 1$.

In period 2, in the absence of public policies, utility of agent i writes:

$$u^{NS}_{i,2} = (1 - M_i)[\gamma_2 w_{Ha,i,2} + \delta_2 A_{H,2}] + M_i[w_{F,i,2} + A_{F,2} - C] \tag{5}$$

with $\gamma_1 \leq \gamma_2 \leq 1$ and $\delta_1 \leq \delta_2 \leq 1$, as we assume both a persistence of the impact of shocks occurred in period 1 and an attenuation between period 1 and 2. Shocks are assumed not to affect outcomes at destination.

Individual i decides to migrate if and only if:

$$w_{F,i,2} + A_{F,2} - C > \gamma_2 w_{Ha,i,2} + \delta_2 A_{H,2} \tag{6}$$

and

$$\gamma_1 w_{Ha,i,1} \geq C \tag{7}$$

In the absence of public policies, a negative climatic shock can affect migration decisions through several channels: first, through its direct impact on amenities. By lowering the value of local amenities, and thus the home utility, a negative climate shock will increase migration. Second, a negative climate shock will have an indirect negative impact on agricultural wages in period 2, which will reinforce the amenity channel. However, a third effect goes in the opposite direction: through its impact on agricultural wages in period 1, a negative climatic shock will reduce individual ability to fund migration costs and will tend to lower migration. The resulting total impact of a negative climate shock on migration is indeterminate and depends in particular on the nature and intensity of the shock which will affect the relative importance of the γ and δ parameters at each period, and on the degree of persistence of the impact over the two periods.

We now include a cash transfer program which provides an amount T at the end of each period. We assume that T can be received even when migrating, which amounts to considering an unconditional cash transfer. Amounts received at the end of period 1 can be either invested so as to mitigate the negative impact of climate shocks on agricultural wage in period 2 or used to fund migration in the second period. Individual i decides to migrate at the end of the first period provided that:

$$w_{F,i,2} + A_{F,2} - C + T > \gamma_2(\alpha_i T) w_{Ha,i,2} + \delta_2 A_{H,2} + T \tag{8}$$

and

$$\gamma_1 w_{Ha,i,1} + (1 - \alpha_i)T \geq C \tag{9}$$

with $0 \leq \alpha_i \leq 1$ the share of the amount received by individual i that is invested in agriculture. $\gamma_2(.)$ is assumed to be an increasing function of αT ($\gamma_2' > 0$), meaning that the recovery rate of agricultural productivity is increasing with the share of the first-period transfer that is invested in agriculture. The impact of the program on migration will depend on the use that is made of the payment T. If T is mostly invested in agricultural production (if α_i is close to one), we expect the program to have a mitigating impact: following a negative shock, the program will help agricultural wage to recover and increase the utility of staying. If T is mainly used to fund migration and provided that individual migration was liquidity constrained, then the program will increase migration, consistent with the assumptions made by Angelucci (2012). However, empirical evidence provided by Sadoulet et al. (2001), who focused on the *ejido* sector, suggests that PROCAMPO transfers in the first years of the program were predominantly invested by producers in agricultural inputs. The overall impact of the program on migration decisions in the event of a negative climate shock is thus indeterminate.

The disaster fund operates through different channels. Funds are transferred to localities that suffered from a negative climate shock at the end of period 1. Based on empirical evidence provided by del Valle et al. (2020), we assume that the transfers received first allow localities to reconstruct infrastructure, which we translate in the model by the fact that amenities have fully recovered in period 2. Second, the transfers generate a boom in the non-agricultural sector due to the demand for labor created by reconstruction needs. We model this effect by introducing a second income source in period 2 that can be cumulated with agricultural income. In that case, the second-period utility in the presence of a disaster fund, noted u^{DF}, writes:

$$u^{DF}_{i,2} = (1 - M_i)[\gamma_2 w_{Ha,i,2} + w_{Hna,i,2} + A_{H,2}] + M_i[w_{F,i,2} + A_{F,2} - C] \tag{10}$$

We thus expect the disaster fund to provide incentives to stay by increasing the value of the home option through its effect on amenities and on income, and thus to have a mitigating impact on migration.

In sum, while the effect of the unconditional agricultural cash transfer program on migration in response to a negative weather shock is indeterminate, the disaster fund is expected to have an unambiguous mitigating effect. Given the characteristics of the two programs studied here, we expect the impact of PROCAMPO on climate-induced migration to depend on the use that is made of cash transfers received, while Fonden is likely to reduce migration in response to an adverse shock.

4 Data

4.1 Migration flows

Migration flow data are constructed from the EMIF surveys (Encuesta sobre Migración en la Frontera Norte de México),[17] collected annually since 1993 at the Mexico-US border. The EMIF aims at providing a representative picture of migration flows between Mexico and the USA, in both directions. Individuals in transit are screened at several survey points along the border, which are regularly updated to account for changes in geographical patterns and border enforcement measures. Those identified as migrants are individually interviewed.[18] The representativeness of the EMIF data is assessed by Rendall et al. (2009), who conclude there is particularly good coverage of male flows and undocumented flows.[19] The comparison of migration flows computed using EMIF to the figures obtained using data from surveys with a more traditional design is particularly difficult. We provide in Table 3 (in the Appendix) the estimated number of migrants based on the ENADID 2009 (*Encuesta Nacional de la Dinámica Demográfica*) (Instituto Nacional de Estadística and Geografía (Mexico) and Consejo Nacional de Población (Mexico) 2011) and the EMIF, for the 2005–2009 period. Unsurprisingly, figures are systematically higher for flows computed from the EMIF. ENADID is a household survey that provides measures of migration based on retrospective data on the previous five years. As is the case of any household survey conducted in the country of origin, the design of ENADID does not allow to capture migration of individuals who migrated to the USA and left no one behind them (ie those who lived alone in Mexico, or left with their entire household, or those whose household in Mexico split after they left

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[17] http://www.colef.net/emif/

[18] The survey design is described in detail in each yearly report provided by the EMIF team, available at: http://www.colef.mx/emif/publicacionesnte.php and additional information on the survey design and the computation of the sampling weights are provided on the website of the EMIF (http://www.colef.net/emif/diseniometodologico.php).

[19] The advantages and drawbacks of using the EMIF data to analyze Mexico-US migration flows are also extensively discussed in Chort and De La Rupelle (2016)

(Bertoli et al. 2020). Moreover, migrants captured in the ENADID may be counted several times in the EMIF if they made repeated trips to the USA.[20]

To further evaluate the geographic representativeness of the EMIF, we compare the weighted state-level migration data from the EMIF to migration data from the ENADID. Table 4 in the Appendix compares, for the top ten Mexican states of origin over the period 2004–2009, the shares of each state in total emigration flows according to the two data sources (EMIF and ENADID). Rankings and contributions of most states are very similar in both cases, with the notable exception of Chiapas. Indeed, Chiapas appears as a major state of origin in the EMIF, whereas its contribution to total emigration flows is much lower in the ENADID. However, studies pointing to the incredibly high amount of remittances received by Chiapas with regard to its number of international migrants (as measured by traditional household surveys) suggest that the data from the EMIF provide a more accurate estimate of the actual size of migration flows from Chiapas (Solís and Aguilar 2006).

We focus in this study on the module of the EMIF intended to measure migration flows from Mexico to the USA. Interviews are conducted on the Mexican side of the Mexico-US border, close to main points of entry on the US territory that were previously identified. We consider as migrants only those individuals who declare that they have the intention to cross the border and enter the USA.[21] Using the survey sampling weights and information on surveyed migrants' state of origin, we construct a database of yearly migration flows for the 31 Mexican states of origin plus the Federal district. The migration database used in this article exploits 14 waves of the EMIF survey that could be matched with climatic data covering the 1999–2012 period.[22] We focus on male flows since, according to Rendall et al. (2009), the EMIF tends to under-represent migrant women. We use information on the possession of documents and the type of documents potential migrants have to construct documented and undocumented migration flows. We define as undocumented migrants those individuals who declare having no document to cross the border nor to work in the USA.

The distinction between documented and undocumented migrant flows is motivated by the fact that they are likely to differ along many dimensions, and in particular as regards their networks: documented migrants are likely to rely on stronger networks at the destination than undocumented ones. Indeed, family reunification has been by far the primary motive for obtaining a legal residence permit in the USA (Hanson 2006). In the EMIF data, family reunification is the main reason given by

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[20] The limits of the ENADID design as regards the quantification of migration flows is explicitly stated in the methodological document that describes the 2009 survey, available here: https://www.inegi.org.mx/contenidos/productos/prod_serv/contenidos/espanol/bvinegi/productos/metodologias/ENADID/2009/met_y_tab_enadid09.pdf Estimates of migrant flows based on the ENADID can be considered a lower bound, and those based on the EMIF an upper bound of actual migration flows over the period.

[21] Note that due to the peculiar design of this flow survey our definition of migrants is indeed a proxy for actual migration as we have no guarantee that those who declare their intention to cross will actually succeed. By contrast, by surveying potential migrants on the Mexican side of the border, the EMIF survey is more likely to better capture undocumented migration.

[22] Since Fonden data are available since 2000, our main model is estimated over the period 2001–2012.

surveyed individuals who declare they have legal border-crossing documents. Networks may impact migration cost, making migration cheaper for those who have contacts at destination. On the other hand, potential migrants with large networks are likely to receive more remittances (unobserved in our data), providing informal insurance against shocks.

Descriptive statistics are provided in Table 5. Male migrants account for 0.5% on average of the total population of their state of origin, and most of them (64% on average over 1999–2012) are undocumented.

4.2 Weather shocks, economic variables, and public programs

We use satellite data from the "Tropical Rainfall Measuring Mission" (TRMM) and monthly gridded time series provided by the Department of Geography of the University of Delaware to construct state-level variables capturing deviations in precipitation and air temperatures from long-term averages. The TRMM is a joint project between the NASA and the Japanese Aerospace Exploration Agency that was launched in 1997 to study tropical rainfall and is therefore well adapted to the Mexican context. Moreover, various technological innovations (including a precipitation radar, flying for the first time on an earth-orbiting satellite) and the low flying altitude of the satellite increase the accuracy of the climatic measures. The TRMM products combine satellite measures with monthly terrestrial rain gauge data. The measures are provided for 0.25 × 0.25 degree grid squares (around 25 km × 25 km), which allows us to construct very precise climatic variables.[23] We construct rainfall and temperature state-level variables for the two main meteorological seasons in Mexico, the rainy season (spanning from May to October) and the dry season.[24] Following Beine and Parsons (2015), we create state-level normalized rainfall and air temperature variables (z-scores). However, we construct those measures of weather anomalies at the seasonal level as seasonal variables are more relevant and precise than yearly indicators (Hsiang 2010; Coniglio and Pesce 2015).[25]

A description of the state-level variability of the constructed measures of weather anomalies is provided in figures 6 to 9 in Chort and de la Rupelle (2022) (Appendix 1). These graphs show that, within each state, we observe substantial

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[23] Alternative measures of climate shocks such as the Palmer Drought Severity Index (PDSI) or the Standardized Precipitation-Evapotranspiration Index (SPEI) are less suitable to our analysis as their resolution is lower (2.5 × 2.5 degree for the PDSI, 0.5 x 0.5 degree for the SPEI).

[24] We also investigate the impact of yearly shocks, but find no significant effect on migration (results available upon request).

[25] To construct seasonal z-scores, we first assign grid points to states based on latitude and longitude coordinates, then compute state-level total precipitations or average temperatures for each season, state-level long-term seasonal averages and state-level seasonal standard deviations. Long-term averages are obtained by combining the land and satellite data sources described above. The normalized variable is the state-level rainfall or temperature value minus the state-level long-run mean, divided by the state-level standard deviation over the observation period. For example, a positive value for the rainfall z-score for year t and season s in state i means that for year t, season s has been an especially rainy season in state i. Conversely, a negative value means that precipitation has been lower than the (long-term) average in state i and season s of year t.

variation in the different z-scores. To account for the potential damaging impact of tropical rainfall, and consistent with operating rules of Fonden disbursements, we complement these measures of weather variability with a variable capturing intense precipitation episodes at the infra-seasonal level. We use the number of months in the year with precipitation exceeding the 90th percentile of the long-term distribution for each Mexican state. With this measure, we intend to construct a proxy for the threshold set by Fonden rules to claim funds after heavy rainfall, flooding and hurricanes. Our heavy rainfall measure is constructed at the state level, based on the number of months where the state experienced rainfall above the percentile 90 of monthly rainfall. However, Fonden sets the threshold to the 90th percentile of maximum historic daily rainfall experienced by a municipality during the month when the event took place. We assume that our state-level measure is correlated with heavy rainfalls experienced by municipalities, but we expect this proxy to be noisy. Typically, localized rainfall will not be captured by our measure. This should downward bias the estimated impact of the disbursement of Fonden following heavy rainfall.

In addition, we construct a state-level data set of hurricanes affecting Mexico between 1999 and 2012, from the Historical Hurricane Track tool developed by the U.S. National Oceanic and Atmospheric Administration (NOAA).[26] We gather information on the number and intensity of hurricanes and storms affecting each Mexican state and create two yearly state-level variables: a dummy variable equal to one if at least one hurricane or storm hit the state at a given year, and the maximum storm intensity registered in the year. Findings by Pajaron and Vasquez (2020) in the case of the Philippines suggest that higher storm intensities are associated with a lower migration response. Some of these weather-related variables may be correlated: this is what we check in Chort and de la Rupelle (2022) (Table 6, Appendix 1). This should be kept in mind when interpreting the regression results as the inclusion of several weather shocks implies larger standard errors.

We do not have a variable that allows us to directly measure flooding, but flooding is potentially captured by several weather variables: excess rainfall, hurricanes and droughts, as dry soils facilitate water runoff even after moderate rainfall.[27]

State-level data on PROCAMPO payments were aggregated based on individual data provided by the Mexican ministry of agriculture (SAGARPA). Aggregate data on total annual amounts distributed at the state level under the Fonden program come from the open data Mexican government's website.[28]

Additional data on income, population, agriculture and crime used to test the robustness of our main results to the inclusion of state-level controls come from the Mexican Instituto Nacional de Estadística y Geografía (INEGI).[29]

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[26] http://www.csc.noaa.gov/hurricanes/

[27] We discuss further this mechanism below, in Section 6.

[28] https://datos.gob.mx/

[29] Some of our variables taken from the census, and in particular Mexican population at the state level, are linearly extrapolated for the years in which they are not available.

5 Empirical strategy

5.1 Estimated equation

In our main model, we estimate the effect of weather shocks and their interactions with public policies on migration. All regressions are panel regressions with origin and year fixed effects and are estimated with OLS. As common or idiosyncratic unobserved characteristics of states may induce serial and spatial correlation or error terms, we provide non-parametric estimates of the variance of the coefficients following Conley and Ligon (2002).[30]

The estimated equation is the following:

$$\begin{aligned} MIGR_{i,t} =& \beta_1 CLIM_{i,t-1} + \beta_2 CLIM_{i,t-1} \times POL_{i,t} + \beta_3 POL_{i,t} \\ & + D_i + D_t + \epsilon_{i,t} \end{aligned}$$

with $MIGR_{i,t}$ is the migration rate from Mexican origin state i at time t (per 10,000 population), $CLIM_{i,t-1}$ a set of climatic variables measured in origin state i and year $t-1$, and $POL_{i,t-1}$ represents our measures of Fonden and PROCAMPO.

D_i and D_t are state and year fixed effects.[31] To avoid endogeneity issues, we follow Dallmann and Millock (2016), Cai et al. (2016) and Cattaneo and Peri (2016), and choose not to include additional controls in our main specification. We test the robustness of our results when controlling for GDP per capita, unemployment rate, and the share of homicides, all of them with a lag of one period (see Chort and de la Rupelle (2022), Section 6.3).

We exploit the information contained in the micro-data used to construct aggregate flows to estimate the above equation for documented and undocumented flows separately.

For a relatively small number of observations, we observe zero total and/or undocumented flows (5 state-year cells for total flows representing 1% of observations, and 12 state-year cells for undocumented flows representing 2.5% of the total

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[30] The code for STATA developed by Hsiang (2010), based on Conley (1999) is available at http://www.fight-entropy.com/2010/06/standard-error-adjustment-ols-for.html. We modified it in order to account for fixed effects and we corrected for the subsequent loss of degree of freedom. Parameters are estimated by OLS, and standard errors are corrected accounting for serial correlation over 1 period and for spatial correlation up to a distance cutoff set at 500 km. The cutoff has been chosen after examining the Moran's I index (for male migration rate) using different distance thresholds. Moran's I is significant up to a cutoff of 1600km, and decreases from 0.4 to 0.01 as the distance cutoff increases from 200 to 1600 km, respectively. Small cutoffs might however reduce the number of observations impacted by the correction, given the size of some Mexican states. Interestingly, a jump is visible when considering a cutoff of 500 km (Moran's I amounts to 0.25) instead of 600 km (Moran's I amounts to 0.09). A cutoff of 500 km only excludes one state (Baja California, for which the distance to the closest neighboring state is higher than 500 km). 500 km is also the median value of the distance between the capital city of each state and Mexico city. All results are robust to allowing for autocorrelation over 2 periods and to a 800 km distance cutoff, representing the mean value of the distance between the capital cities of all pairs of Mexican states.

[31] In Appendix 1, we report additional estimation results documenting the impact of weather shocks on migration with measures of weather shocks interacted with quartiles of agricultural production, and depending on the sign of the shock.

sample). As a high share of migrant flows are undocumented, the proportion of zero flows is larger for documented flows (9.5% of state-year observations). Zero cells are not expected to be qualitatively different from non-zero ones, but rather result from migration flows that are too small to be captured by the EMIF surveys. To deal with this issue, we use an inverse hyperbolic sine transformation of the dependent variables which is approximately similar to the log transformation and allows retaining zero values.[32] We estimate our model with OLS.[33]

5.2 Identification issues

PROCAMPO As discussed in Section 2.2, variations in PROCAMPO payments, net of state fixed effects, are theoretically exogenous to migration. However, concerns regarding potentially endogenous changes in plot characteristics as well as biased measurement errors (if for instance the management of administrative data varies with political parties in power) could threaten our identification strategy. We thus use PROCAMPO plot-level data on 36.9 million claims to compute an exogenous measure of transfers for each year and state using the 1999 distribution of characteristics in each state. We categorize all plots depending on the growing season, irrigation status and total area cultivated by the producer. We then rely on administrative sources to retrieve the nationwide evolution of per-hectare payment. We combine this information with the distribution of plot characteristics in 1999, and then re-aggregate the obtained results at the state level. This provides us with state-level variables for PROCAMPO amounts or distribution whose variation are exogenous to changes in plot characteristics. In what follows, these variables are labelled “theoretical” PROCAMPO variables. It is important to note that the variation in theoretical PROCAMPO payments for a given state is driven by both the national reforms in the per-hectare amount and the distribution of plots around the relevant thresholds in 1999 (1 hectare and 5 hectares, for the bottom of the distribution which is of relevance to us in our main specification).[34] Since states with different distributions of plot size may have dissimilar migration trajectories, we exploit the discontinuity introduced by the nationally defined 5 hectare threshold that determines different per-hectare payments. More specifically, we define our variable of interest as the state-level theoretical amount of PROCAMPO payments — computed using plot size distribution in 1999 and subsequent evolutions of per-hectare payments for plots under the 5-hectare threshold — theoretically paid to plots around this 5-hectare threshold. As noted above, the 5-hectare threshold holds for the majority of Mexican states, and for them, we consider amounts paid to plots between 4 and 6 hectares. For the 11 states from the Northern part of the country that benefited from

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[32] We test the robustness of our results to alternative transformations, such as the log and the cube root, see (Chort and de la Rupelle 2022), Section 6.3.

[33] Alternative methods may seem more adequate to dealing with zero values of the dependent variable, such as the Poisson pseudo-maximum likelihood (PPML) estimator. However, the advantages of the PPML estimator, limited given the relatively small proportion of zeros in our data, are outbalanced by the fact that it does not allow to correct for spatial and serial correlation of error terms.

[34] Additional results using the full distribution of PROCAMPO also account for reforms limiting payments for plots larger than 100 ha.

an exemption from 2003 to 2009 and were assigned a different threshold conferring entitlement to a bonus payment, we consider amount paid to plots between 1 hectare below and 1 hectare above the threshold. With this definition of the PROCAMPO variable, we are rather confident that we are not capturing time-varying characteristics of Mexican states that could explain migration trends.

Fonden We have already stressed that the disbursement of Fonden was arguably not manipulated by local governments, as established by del Valle et al. (2020) and del Valle (2021). The identification of the effect of the variable of interest, namely the interaction term between Fonden and weather-related variables, requires that conditional on state fixed effect, year fixed effects, and control variables, effects on migration are linear. Even if Fonden is indexed on a running variable that cannot be manipulated, we do not limit our analysis to events occurring close by the threshold conditioning the disbursement of Fonden. Correctly identifying our effect of interest requires that the effect of Fonden should be similar for all municipalities, whatever their distance to the threshold; the effect should be likely to remain stable whatever the intensity of the experienced event.

del Valle et al. (2020) assess the external validity of their estimated effect for Fonden and find no evidence that the effect of Fonden was not stable or was likely to change considerably for lower or for heavier rainfall. Investigating the derivative of Fonden treatment effect, they show that it was locally constant. They thus provide evidence that in municipalities which are away from the threshold and experience much lower or much higher rainfall, Fonden was likely to have effects of similar magnitudes on their outcome of interest. Even though their outcome variable (night lights) is different from ours, their findings support the hypothesis that the effect of Fonden would not have been substantially different for different shock intensity.

Additionally, we need to ensure that the effect of the different weather variables on migration is relatively linear, conditional on other control variables which include weather events of various intensities , so that their estimated effect in places where Fonden was not disbursed correctly control for their expected impacts in places where Fonden has been disbursed. To check that this is the case, we add to the sample the years 1999 and 2000, so that lagged weather shocks occur in 1998 and 1999, before Fonden became fully operational. Reassuringly, results for Fonden are unaffected when including the years 1999 and 2000 (see Table 8, in Appendix).

As noted in the introduction, past migration, in particular through remittances, could have an indirect role on the impact of disasters and may thus be correlated to amounts of Fonden received. Indeed, remittances are expected to increase the capacity of communities to face adverse shocks. In that case, past migration would limit the need for Fonden support. In our regressions, differences in migration history to the USA, as well as historical migrant networks, are captured by Mexican state fixed effects. However, year-to-year variations in migration flows may affect financial transfers to home communities and thus modify their vulnerability to shocks. To test this assumption, we regress the amount of Fonden received in t on migration flows in $t-1$, controlling for lagged and contemporaneous weather shock variables. We provide the same test for our different measures of PROCAMPO. Results are reported in Table 9 in Appendix. Reassuringly, they show no significant correlation between lagged migration and measures of Fonden or PROCAMPO.

6 Results

6.1 Mitigating impact of public policies

In Table 1, we explore the effects of PROCAMPO and Fonden on climate-driven migration. Regarding PROCAMPO, our variable of interest is the log theoretical per capita amount paid to plots around (± 1 hectare) the threshold conferring entitlement to an increased per-hectare payment.[35]

Since the Fonden program is a disaster fund, amounts received are conditioned upon the occurrence of a shock. As a consequence, the proportion of state-year cells with zero registered amounts is high (43% of our observations). We use the inverse hyperbolic sine transformation of the yearly per capita amounts received, but our results are robust to alternative choices (see Section 6.3).

Table 1 shows regression estimates with interactions between weather and policy variables for total, documented, and undocumented flows respectively.

Column (1) suggests than an increase in PROCAMPO amounts increases migration following heavy rainfalls. Estimated coefficients imply that the effect of heavy rainfalls is negative when PROCAMPO is at its lowest value, consistent with the existence of credit constraints.[36] An increase by one standard deviation in PROCAMPO (1.3 log points) implies an increase in the total migration rate by 7%. Note that the effect within a given state is likely to be much smaller. Standard deviations of PROCAMPO within states are of 5% on average; a 5% increase in PROCAMPO implies a change in the total migration rate by 0.34%. An increase in PROCAMPO transfers may allow the migration of individuals which would have been otherwise trapped by heavy rainfalls. This effect is however small and barely significant. As shown in Section 6.3 below, the significance of the coefficient on the interaction between PROCAMPO and heavy rainfall vanishes in most alternative specifications.

As appears in column (3), the interaction of the measures of weather shocks with Fonden suggests a mitigating effect of the Fonden program, especially for undocumented flows: a concurrent increase in the Fonden variable limits or even outbalances the effect of a hurricane or a drought. Additional results, shown in Appendix 1, help us to interpret the coefficients on the interaction between Fonden and rainfall shock variables. Indeed, according to Table 6, column (9), in Appendix 1, the impact of rainfall shocks during the dry season appears to be driven by negative rainfall shocks, which are found to increase migration, especially undocumented. The negative coefficient on the rain deviation variable for the dry season must be interpreted as a *positive* effect of droughts on migration flows. By contrast, the positive coefficient on the rain deviation variable interacted with Fonden suggests that Fonden *reduces* the undocumented migration response to negative rainfall shocks. A similar mitigating effect of Fonden is found for documented flows after (negative) rainfall shocks during the rainy season. Note that Table 6, column (6) does not allow

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[35] We center the variable so that the effects of shocks are estimated when the log of PROCAMPO is at its mean.

[36] When log PROCAMPO is at its sample minimum, i.e., -5.5 log points below the sample average, the elasticity of migration to heavy rainfalls is -0.25 ($0.041+0.053 \times (-5.5)$).

to unambiguously determine wether the effect of rainfall shocks on migration during the rainy season is driven by positive or negative shocks, since both coefficients are negative and comparable in size[37]. We report in Table 7 the full set of interactions between our measures of PROCAMPO and Fonden and separate variables for negative and positive shocks. Results from Table 7 suggest that negative rainfall deviations significantly *increase* documented and total migration, and that Fonden tends to have a mitigating effect. Note, in addition, that Table 7 reveals that PROCAMPO also has mitigating effects, but less significant than those of Fonden, on total flows after negative rainfall shocks during the dry season, but seems to increase documented migration after negative rainfall shocks during the rainy season.

We find consistent results for the impact of Fonden after hurricanes on undocumented flows. The coefficient on the hurricane dummy is positive (although not significant for total flows only, see column (2)), but the sign of the coefficient on the hurricane dummy interacted with Fonden is reversed for undocumented flows, pointing again to the mitigating effect of Fonden. In addition, evidence of a mitigating effect of Fonden is also found for the measure of abnormal concentration of precipitations: a greater number of months in the year with rainfall above the 90th percentile tends to increase documented flows (column (4)), but the effect is alleviated by higher amounts of Fonden.

As regards the size of estimated effects, one additional month with heavy rainfall leads to an increase in the documented migration rate by 13.3%. An increase by one standard deviation of Fonden amount per capita almost offsets the effect of heavy rainfalls on documented migration: the documented migration rate decreases by 9.4% (2.4 × 0.039).

When a state experiences a hurricane, an increase by one standard deviation in Fonden transfers reduces undocumented migration by 13.4% (2.4 × 0.056). As for droughts, again, Mexico’s disaster fund contributes to a severe decrease in the elasticity of migration rate to drought. While the elasticity of undocumented migration to rainfall deviations during the dry season is equal to 12.9%, one standard deviation in the per capita amount of Fonden implies a decrease by 9.2 % (2.4 × 0.038) of the undocumented migration rate, reducing the overall elasticity of undocumented migration to drought by more than two-thirds. The elasticity of documented migration to drought during the rainy season is equal to 26%, and a one standard deviation increase in Fonden amounts lead to a 10.3% decrease of the documented migration rate.

The mitigating effect of Fonden following abnormally low precipitations deserves further explanation. Indeed, the program is primarily intended at the reconstruction of damaged low-income housing and infrastructures (del Valle et al. 2020) and droughts are expected to have both a direct damaging impact on infrastructures through clay shrinkage, in particular on roads, buildings, and water and sewer lines (Corti et al. 2011; Combs 2012), and a further indirect effect on infrastructures linked to wildfires or soil absorption capacity. With regard to the latter issue, droughts are likely to be correlated with flooding although we cannot directly measure such a correlation for lack of disaggregate data on the type of disasters on which Fonden amounts are spent. Water runoff

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[37] The coefficient on negative rain deviations during the rainy season is significant at 12%

Table 1 Climatic factors and Mexico-US migration flows: impact of public policies, 2001–2012

Inverse hyperbolic sine dependent variable	Total male flows	Documented male flows	Undocumented male flows
	(1)	(2)	(3)
Hurricane $_{t-1}$	0.232	0.047	0.077
	(0.195)	(0.231)	(0.173)
Hurricane max intensity $_{t-1}$	−0.021	−0.060	0.032
	(0.066)	(0.076)	(0.059)
Number of months rain > 90th ptile $_{t-1}$	0.041	0.133**	0.008
	(0.046)	(0.056)	(0.049)
Rain deviations rainy season $_{t-1}$	-0.120*	-0.257***	−0.059
	(0.068)	(0.074)	(0.077)
Rain deviations dry season $_{t-1}$	-0.114**	0.000	-0.129**
	(0.050)	(0.069)	(0.059)
Temp deviations rainy season $_{t-1}$	0.048	0.011	−0.011
	(0.064)	(0.079)	(0.072)
Temp deviations dry season $_{t-1}$	−0.087	−0.131	0.004
	(0.072)	(0.102)	(0.068)
Log PROCAMPO around threshold ± 1 ha per capita centered $_{t-1}$	0.968	1.065	0.068
	(0.754)	(0.942)	(0.754)
Hurricane $_{t-1}$ × Log PROC. thresh. ± 1 ha pcap $_{t-1}$	−0.022	0.028	0.087
	(0.121)	(0.160)	(0.102)
Nb of months rain> 90ptile $_{t-1}$ × Log PROC. thresh.+/- 1 ha pcap $_{t-1}$	0.053	0.028	0.009
	(0.033)	(0.041)	(0.034)
Rain deviation rainy season $_{t-1}$ +/-Log PROC. thresh. ± 1 ha pcap $_{t-1}$	0.018	−0.010	−0.013
	(0.032)	(0.039)	(0.033)
Rain deviation dry season $_{t-1}$ ×Log PROC. thresh. ± 1 ha pcap $_{t-1}$	0.043	−0.010	0.063
	(0.036)	(0.040)	(0.045)
Temp deviation rainy season $_{t-1}$ ×Log PROC. thresh. ± 1 ha pcap $_{t-1}$	0.026	−0.002	−0.006
	(0.030)	(0.035)	(0.032)
Temp deviation dry season $_{t-1}$ ×Log PROC. thresh. ± 1 ha pcap $_{t-1}$	0.044	−0.068	0.061
	(0.050)	(0.057)	(0.049)
Inverse hyperbolic sine Fonden per capita $_{t-1}$	0.035*	0.064*	−0.003
	(0.020)	(0.038)	(0.024)
Hurricane $_{t-1}$ ×Inv. hyperb. sine Fonden pcap $_{t-1}$	−0.034	0.026	-0.056*
	(0.033)	(0.045)	(0.031)
Nb of months rain> 90ptile $_{t-1}$ ×Inv. hyperb. sine Fonden pcap $_{t-1}$	-0.023**	-0.039**	−0.008
	(0.011)	(0.018)	(0.013)

Table 1 (continued)

Inverse hyperbolic sine dependent variable	Total male flows (1)	Documented male flows (2)	Undocumented male flows (3)
Rain deviation rainy season $_{t-1}$ ×Inv. hyperb. sine Fonden pcap $_{t-1}$	0.025*	0.043**	0.015
	(0.013)	(0.019)	(0.015)
Rain deviation dry season $_{t-1}$ ×Inv. hyperb. sine Fonden pcap $_{t-1}$	0.032***	0.007	0.038***
	(0.011)	(0.016)	(0.011)
Temp deviation rainy season $_{t-1}$ ×Inv. hyperb. sine Fonden pcap $_{t-1}$	0.024	0.036	0.013
	(0.016)	(0.025)	(0.014)
Temp deviation dry season $_{t-1}$ ×Inv. hyperb. sine Fonden pcap $_{t-1}$	0.013	−0.000	0.010
	(0.015)	(0.017)	(0.014)
N	384	384	384

Standard errors corrected for autocorrelation and spatial correlation in parentheses

* p>0.10, **p>0.05, ***p>0.01

are intensified after periods of drought because the water holding capacity of crusted soils is low (Horton 1933). Experimental evidence in the case of Northern Mexico show that very small amounts of rainfall can cause Hortonian runoff (Descroix et al. 2007).[38] As a consequence, normal rainfall may result in runoff and flooding with potential devastating consequences if they occur after a period of drought. Note that drought induced Hortonian runoff accelerate soil degradation, which in turn decreases the water holding capacity of soils. These different mechanisms may explain why we find a mitigating impact of Fonden during drier than average periods.

6.2 Group fixed effects estimations

Economic and agroecological conditions differ across Mexican regions, and may influence both migration patterns and vulnerability or adaptation to shocks. For example, as explained in Section 2, 11 Mexican states from the Northern part of the country benefited from marginal adaptations of the PROCAMPO national rules due to their specific climatic and agricultural characteristics. In order to account for unobserved heterogeneity patterns shared by groups of states, we test the robustness of our main results by applying to the analysis of migration flows the estimator developed by Bonhomme and Manresa (2015). This estimator is particularly relevant to the empirical study of migration. While we might know the destination of migrants, we usually do not know all other alternative destinations they might have considered. These alternative destinations might be shared by groups of migrants, or group of states of origin in our analysis, who for instance have

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[38] “Runoff can occur after 1 or 2 mm rainfall in crusted soils in the Western Sierra Madre” (Descroix et al. 2007), p.156.

connected migration networks. As a result, groups of states sharing the same migration networks and thus the same pool of potential destinations, might both face similar shocks at origin and experience changes in their set of potential destinations. The latter change might thus be wrongly attributed to variations in the conditions at origin. Correcting for spatial autocorrelation is a first way of dealing with this issue, yet usual methods treat all units within a given perimeter in the same way, and assume time-invariant patterns of unobserved heterogeneity. This estimator allows group membership to be endogenously determined following a minimization criteria — groups are formed of states with similar time profile, net of the effects of the covariates included in the model.

We use the grouped fixed effects (GFE) estimator and replicate models from Table 1 with the number of groups varying from 2 to 7.

Figures 1, 2, 3, and 4 display the coefficients obtained with the GFE estimator for the subsamples and interactions of interest, namely the interactions between Fonden and weather variables, depending on the number of groups. Standard errors are obtained after a blockbootstrap of 1000 replications. Figure 1 suggests that the mitigating effect of Fonden after a hurricane is not significant at conventional levels in most specifications. By contrast, as shown in Figs. 2, 3, and 4, the mitigating effect of Fonden after heavy rainfall and rainfall shocks during the rainy season (on documented flows), and after rainfall shocks during the dry season (on total flows, but also on undocumented flows although not shown) are robust to considering different number of groups. The effect of PROCAMPO after heavy rainfall which was significant at 11% is not significant with GFE estimations whatever the number of groups (figure not shown).

6.3 Additional robustness checks

We test the robustness or our results to using different transformations of our dependent and explanatory variables. All robustness tables are shown in Chort and de la Rupelle (2022) (Appendix 1). We first re-estimate our model with a cube root transformation of the dependent variables (Table 11 in Chort and de la Rupelle (2022)), which is a relevant alternative to the inverse hyperbolic sine in presence of zeros, and also allows to relax the assumption of constant elasticity of migration to shocks.[39] Results on the impact of Fonden are very similar to those reported in Table 1. As for PROCAMPO, we observe some differences in column (1). Although the signs of the coefficients are unchanged, the estimated coefficient on the number of months with rainfall above the 90th percentile is smaller and becomes non-significant with cube root transformed dependent variables compared to our main specification, while the opposite is observed for the interaction between PROCAMPO and rain deviations during the rainy season. This suggests that the results obtained for PROCAMPO may be altered by a change in the transformation of the dependent variables and should not be over-interpreted.

Coefficients are likely to be more precisely estimated, which is of particular concern given that weather variables are correlated.

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[39] Note, moreover, that the cube root transformation, although less standard in the literature, seems to perform better than the inverse hyperbolic sine to ensure a normal distribution of errors, as suggested by a quantile-to-quantile analysis.

In Table 12 in Chort and de la Rupelle (2022) (Appendix 1), we report estimation results with a log transformation of the dependent variables.[40] Again, results regarding Fonden appear to be robust, except the mitigating effect after hurricanes. Note that the mitigating effect of Fonden after heavy rainfall and rain deviations during the rainy season, which appeared to be driven by documented flows, is significant only for total flows. There is no longer any significant mitigating effect of PROCAMPO.

In addition, Table 13 in Chort and de la Rupelle (2022) (Appendix 1) shows that estimating separate regressions for PROCAMPO and Fonden does not affect our results.

We also re-estimate our main equation with standard errors simply clustered at the state level (Table 14 in Chort and de la Rupelle (2022), Appendix 1). The effect of PROCAMPO interacted with heavy rainfall is not significant. As regards Fonden, results reported in our main table remain significant with the exception of the coefficients on the interaction between Fonden on the one hand, and the heavy rainfall and rain deviations during the rainy season on the other hand, for documented flows, which are no longer significant when spatial correlation in the error terms is not accounted for. The difference between the two tables thus suggests that there is a negative correlation in the error terms across adjacent regions. Heavy rains may be more concentrated geographically than other weather variables.

Additionally, we test the robustness of our main results to the inclusion of a set of lagged economic and social controls at the Mexican federated state level, namely the GDP per capita, the unemployment rate and the rate of homicides (Table 14 in Chort and de la Rupelle (2022), Appendix 1). We obtain results that are very similar to those reported in Table 1, both for PROCAMPO and Fonden. In addition, our results for Fonden are robust to dropping observations for the year 2010 in order to remove the effect of the exceptional drought of 2009 (Table 16 in Chort and de la Rupelle (2022), Appendix 1).

Last, as small migration flows are likely to be less precisely estimated in the EMIF scheme, this may result in artificial variation of our aggregate measures of migration for those states with little emigration to the USA. We test the robustness of our main results by excluding observations corresponding to the bottom 5% of the distribution of migration flows from our regression sample. The results are shown in Table 17 in Chort and de la Rupelle (2022) (Appendix 1). There is no longer any evidence of a mitigating effect of Fonden after a hurricane or heavy rainfall, but the mitigating effect of Fonden remains after droughts and the coefficients on the interaction between rain deviations and Fonden are similar in size and significance to those reported in Table 1.

6.4 Distributional effects

In this section, we provide an alternative exploration of the impact of the different pro-poor reforms of PROCAMPO that were implemented in the 2000s. Instead of investigating the impact of total amounts paid to small plots around the 5 hectare threshold, we focus on changes in the entire distribution of PROCAMPO. Indeed, the different reforms of

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[40] We use the log of the dependent variable to which we add 0.01 (which is lower than the lowest observed value for the variable in the sample) and add to the set of controls a binary indicator for zero flows.

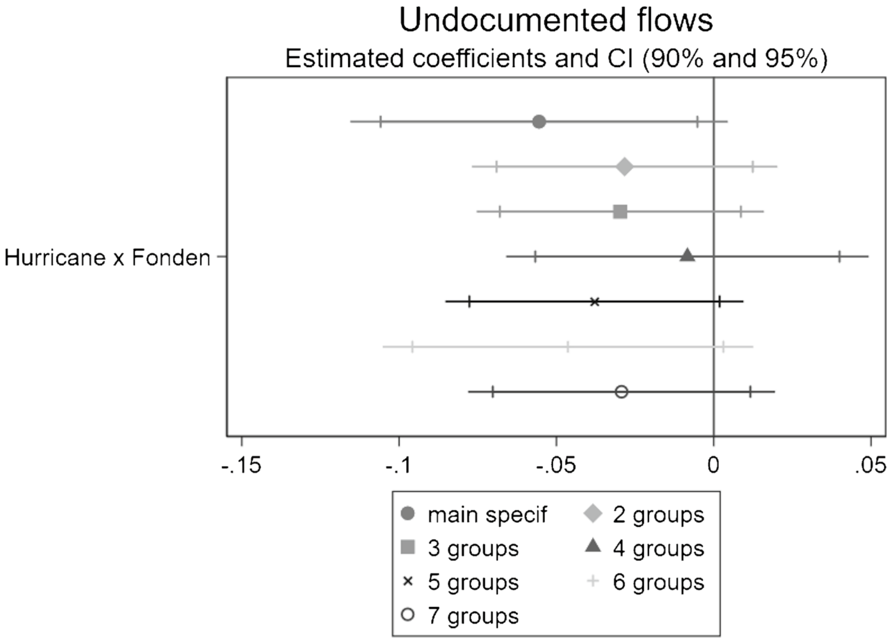

Fig. 1 GFE coefficients for Fonden × hurricanes, undocumented flows. The figure displays the coefficients estimated by the grouped fixed effect estimator, for different numbers of groups, and the confidence intervals at 90 and 95%, obtained after a blockbootstrap of 1000 replications. The label "Main specif" refers to the specification presented in Table 1 (not GFE)

PROCAMPO, by increasing in particular the amounts received by the smallest producers, have contributed to reduce inequalities. Table 2 presents the estimation results of equation 11 in which the amount of PROCAMPO is replaced by two different measures of inequality in its distribution.

The first one is the share of PROCAMPO transfers allocated to non-irrigated plots in the *ejido* sector. The *ejido* sector concentrates many vulnerable producers, and non-irrigated plots are likely to suffer more from climate shocks. Indeed, irrigation is expected to reduce the impact of climate shocks on migration (Benonnier et al. 2018). The second one is the Gini coefficient for the transfers received by producers. As explained in Section 5, to avoid endogeneity issues, both measures are based on theoretical PROCAMPO amounts: they combine the distribution of plots in 1999 with the yearly evolutions of the PROCAMPO benefits they were theoretically entitled to in the subsequent years. To facilitate the reading of the table, both measures are constructed such that an increase in the variable represents a more redistributive program.

An increase in the share of PROCAMPO received by producers in the non-irrigated *ejido* sector is associated with a lower migration response to rain deviation during the dry season (column (1)), which is consistent with our main findings presented in Table 1. As regard hurricane, an increase in the share of PROCAMPO amounts paid to the non-irrigated *ejido* sector is found to have

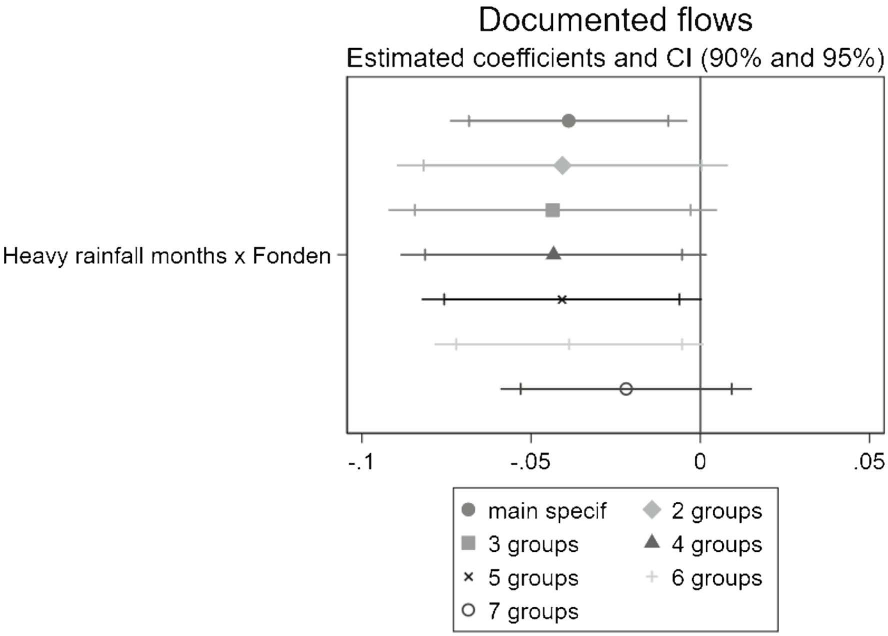

Fig. 2 GFE coefficients for Fonden × heavy rainfall, documented flows. The figure displays the coefficients estimated by the grouped fixed effect estimator, for different numbers of groups, and the confidence intervals at 90 and 95%, obtained after a blockbootstrap of 1000 replications. The label "Main specif" refers to the specification presented in Table 1 (not GFE)

a mitigating effect since the sign of the coefficient on the interaction is the opposite of the main effect of hurricanes (columns (3) and (5)). The overall impact on migration is more ambiguous since hurricanes have opposite effects on documented and undocumented flows. Although we cannot directly test it, this finding is consistent with the fact that potential documented migrants have larger networks and may receive greater amounts of remittances when affected by a hurricane. However, variations in the share of PROCAMPO amounts paid to the non-irrigated *ejido* sector are driven by the initial distribution of such type of land in the different states, which could also be related to subsequent migration patterns. Unlike our preferred measure of PROCAMPO which exploits variations around the 5 hectare threshold, this measure is likely to capture the impact of characteristics of states that could be related to migration trends. We are thus careful not to overinterpret these results.

Inequality in the distribution of PROCAMPO measured by the Gini has no significant effect on migration in response to any shock except temperature deviations during the dry season (columns (2) and (6)). Note that this effect could be driven either by positive or negative variation in temperatures, as the effect of temperature on migration is not driven by positive rather than negative variations (see Table 6). But interestingly, a reduction of inequality has a mitigating role. Negative (resp. positive) temperature shocks during the dry season increase (resp. decrease) migration flows, but less so when inequality is lower.

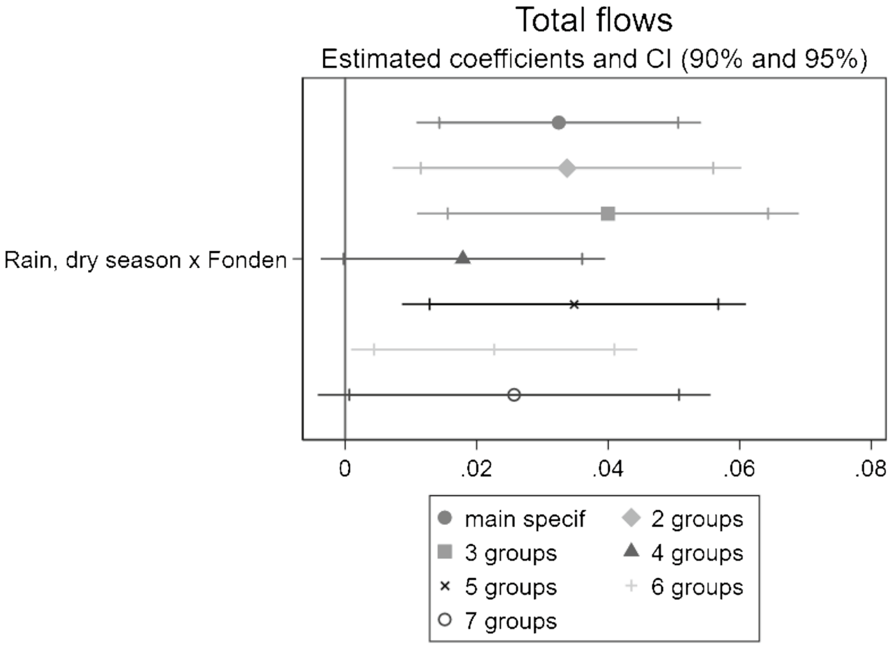

Fig. 3 GFE coefficients for Fonden × rain deviations (dry season), total flows. The figure displays the coefficients estimated by the grouped fixed effect estimator, for different numbers of groups, and the confidence intervals at 90 and 95%, obtained after a blockbootstrap of 1000 replications. The label "Main specif" refers to the specification presented in Table 1 (not GFE)

7 Conclusion

Using unique panel data documenting migration flows from Mexican states to the USA over the 1995–2009 period, we explore the impact of rainfall and temperature shocks on migration rates to the USA and the mitigating role of two public programs, an agricultural cash transfer program (PROCAMPO) and a disaster fund (Fonden). We exploit the panel dimension of our data to control for origin and year fixed effects and account for spatial and serial correlation. In addition, our state-level data being constructed from an individual survey, we are able to separately analyze documented and undocumented flows.

We find evidence that public policies may mitigate the impact of weather shocks on migration. Our results highlight the importance of a disaster fund, Fonden, in lowering the migration response to weather shocks. An increase in amounts transferred under Fonden limits the migration response to hurricanes, heavy rainfall, and abnormally low rainfall during the dry season. The effect of Fonden is sizable and particularly important on undocumented migrant flows. An increase in Fonden payments by one standard deviation for an average state decreases the migration response to a negative weather shock by 9 to 13%. The impact of the agricultural cash transfer program is more ambiguous: an increase in the amounts received by small producers tends to increase migration after heavy rainfall, although this result is weakly significant, whereas it tends to limit migration after drought episodes during the dry season, consistent with the effect of Fonden. In

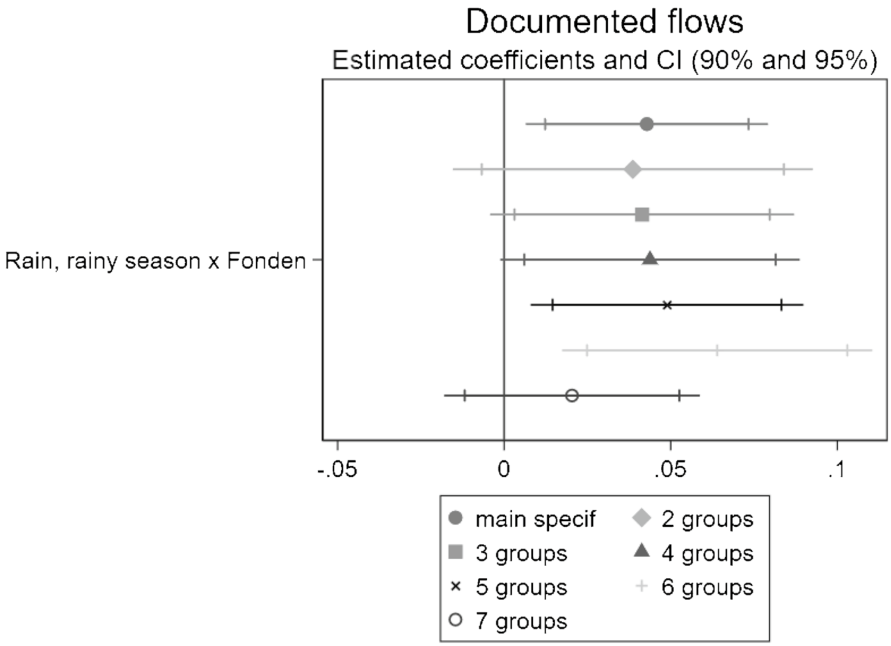

Fig. 4 GFE coefficients for Fonden × rain deviations (rainy season), documented flows. The figure displays the coefficients estimated by the grouped fixed effect estimator, for different numbers of groups, and the confidence intervals at 90 and 95%, obtained after a blockbootstrap of 1000 replications. The label "Main specif" refers to the specification presented in Table 1 (not GFE)

addition, an increase in the redistributive attributes of PROCAMPO — more specifically a larger share received by farmers in the *ejido* sector for non-irrigated land — seems to have a mitigating effect after hurricanes and tends to reduce undocumented migration after some weather shocks, and particularly rain deviations during the dry season.

Our results on Fonden are consistent with del Valle et al. (2020), who find that the economic activity generated by Fonden is 1.4 times larger than the cost of the program, and that in municipalities just above the cutoff, nighttime lights increase by up to 50 %. Their results point to a significant increase in working opportunities at home, and we show that this translates into lower incentives to migrate after a negative weather shock.

As weather variability is believed to increase as a consequence of climate change, recurring droughts episodes or more frequent hurricanes are expected to contribute to increase migration flows from Mexican states. Consistent with del Valle et al. (2020), this paper highlights the impact of well targeted public policies such as disaster funds on climate-induced migration. This paper also suggests that reducing income inequality in the agricultural sector might lower climate-induced migration. Our findings suggest that the tailoring of existing programs may prove an efficient and cost-effective way to limit the impact of climate change on migration. However, we must bear in mind that, as evidenced by Deryugina and Molitor (2018) after Hurricane Katrina, shock-induced mobility may prove beneficial for displaced individuals.

Table 2 Impact of PROCAMPO distribution, 2001–2012

Inverse hyperbolic sine dependent variable	Total male flows		Documented male flows		Undocumented male flows	
	(1)	(2)	(3)	(4)	(5)	(6)
Hurricane $_{t-1}$	0.067	0.155	0.539	0.866	-0.517*	−0.583
	(0.299)	(0.683)	(0.330)	(0.592)	(0.289)	(0.629)
Hurricane max intensity $_{t-1}$	−0.028	−0.042	−0.004	0.001	0.003	−0.012
	(0.050)	(0.053)	(0.062)	(0.068)	(0.046)	(0.046)
Number of months rain > 90th ptile $_{t-1}$	−0.094	−0.245	−0.100	−0.320	0.002	0.024
	(0.079)	(0.192)	(0.107)	(0.238)	(0.089)	(0.203)
Rain deviations rainy season $_{t-1}$	0.022	0.139	−0.028	0.022	0.086	0.134
	(0.125)	(0.263)	(0.139)	(0.388)	(0.143)	(0.281)
Rain deviations dry season $_{t-1}$	-0.281**	−0.377	−0.112	−0.101	-0.294*	-0.475*
	(0.129)	(0.245)	(0.156)	(0.321)	(0.176)	(0.266)
Temp deviations rainy season $_{t-1}$	−0.004	0.231	−0.082	0.119	0.054	0.119
	(0.120)	(0.344)	(0.163)	(0.472)	(0.126)	(0.354)
Temp deviations dry season $_{t-1}$	-0.369**	-1.049***	−0.221	-0.726*	-0.327**	-0.923***
	(0.164)	(0.334)	(0.212)	(0.438)	(0.153)	(0.305)
Predicted share of PROCAMPO for non-irrigated *ejidos* $_{t-1}$	−4.152		−4.552		−5.227	
	(5.284)		(7.691)		(4.663)	
Hurricane $_{t-1}$ ×PROC. sh non irrig. *ej*.$_{t-1}$	0.086		-0.731*		0.697**	
	(0.395)		(0.415)		(0.340)	
Nb of months rain> 90ptile $_{t-1}$ ×PROC. sh non irrig. *ej*. $_{t-1}$	0.122		0.203		−0.029	
	(0.111)		(0.145)		(0.120)	
Rain deviation rainy season $_{t-1}$ ×PROC. sh non irrig. *ej*.$_{t-1}$	−0.097		−0.189		−0.148	
	(0.159)		(0.187)		(0.193)	
Rain deviation dry season $_{t-1}$ ×PROC. sh non irrig. *ej*.$_{t-1}$	0.333**		0.184		0.345	
	(0.163)		(0.200)		(0.216)	

Table 2 (continued)

Inverse hyperbolic sine dependent variable	Total male flows		Documented male flows		Undocumented male flows	
	(1)	(2)	(3)	(4)	(5)	(6)
Temp deviation rainy season $_{t-1}$ ×PROC. sh non irrig. $ej._{t-1}$	0.158		0.238		−0.060	
	(0.152)		(0.205)		(0.169)	
Temp deviation dry season $_{t-1}$ ×PROC. sh non irrig. $ej._{t-1}$	0.431**		0.131		0.465**	
	(0.198)		(0.251)		(0.187)	
(1-PROCAMPO gini) $_{t-1}$		−3.620		−1.939		−2.954
		(2.444)		(3.686)		(2.088)
Hurricane $_{t-1}$ × (1-PROCAMPO gini) $_{t-1}$		0.070		−1.580		1.181
		(1.324)		(1.124)		(1.176)
Number of months rain> 90th ptile $_{t-1}$ × (1-PROCAMPO gini) $_{t-1}$		0.430		0.681		−0.088
		(0.370)		(0.446)		(0.388)
Rain deviation rainy season $_{t-1}$ × (1-PROCAMPO gini) $_{t-1}$		−0.363		−0.337		−0.305
		(0.468)		(0.707)		(0.530)
Rain deviation dry season $_{t-1}$ × (1-PROCAMPO gini) $_{t-1}$		0.628		0.216		0.803*
		(0.436)		(0.572)		(0.477)
Temp deviation rainy season $_{t-1}$ × (1-PROCAMPO gini) $_{t-1}$		−0.268		−0.092		−0.202
		(0.628)		(0.847)		(0.682)
Temp deviation dry season $_{t-1}$ × (1-PROCAMPO gini) $_{t-1}$		1.838***		1.109		1.709***
		(0.590)		(0.750)		(0.547)
N	384	384	384	384	384	384

Standard errors corrected for autocorrelation and spatial correlation in parentheses

* p>0.10, ** p>0.05, *** p>0.01

Appendix A. Descriptive statistics tables and figures

Table 3 Estimates of Mexican migration to the US (2004-2009 — top ten states of origin according to ENADID): comparison between data from EMIF and ENADID

	ENADID	EMIF
Michoacan	179,498	306,693
Guanajuato	142,691	476,388
Veracruz	141,174	230,246
Jalisco	129,966	221,504
Oaxaca	83,386	211,733
Puebla	82,130	128,158
Hidalgo	81,961	120,947
Guerrero	79,742	136,630
Chiapas	67,826	397,502
Mexico	66,954	166,915
Other states	584,486	1,212,941

EMIF 2004–2009 (authors' calculations), INEGI, ENADID 2009

Table 4 Contribution of Mexicans states to total Mexico-US migration flows (2004–2009 — top ten states of origin): comparison between data from EMIF and ENADID

EMIF		ENADID	
Guanajuato	13.2	Michoacán	10.3
Chiapas	10.5	Veracruz	8.6
Michoacan	8.8	Guanajuato	8.3
Jalisco	6.4	Jalisco	8.0
Veracruz	6.0	Puebla[a]	5.1
Oaxaca	5.8	Oaxaca	5.0
Sonora	4.8	Hidalgo[b]	4.8
Mexico	4.7	Guerrero	4.8
Sinaloa	4.0	México	4.2
Guerrero	3.7	Chiapas	4.1

EMIF 2004–2009 (authors' calculations), INEGI, ENADID 2009

[a] Based on EMIF data, Puebla is ranked 11th with 3.6% of total flows

[b] Based on EMIF data, Hidalgo is ranked 12th with 3.4% of total flows

Table 5 Summary statistics

Variable	Mean	Std. Dev.
Male migration rate (per 10 000 inhab.)	48.868	46.395
Male documented migration rate (per 10 000 inhab.)	15.562	24.59
Male undocumented migration rate (per 10 000 inhab.)	33.306	36.131
Inverse hyperbolic sine male migration rate (per 10 000 inhab.)	4.084	1.135
Inverse hyperbolic sine male documented migration rate (per 10 000 inhab.)	2.598	1.436
Inverse hyperbolic sine male undocumented migration rate (per 10 000 inhab.)	3.593	1.247
Cube root male migration rate (per 10 000 inhab.)	3.298	1.143
Cube root male documented migration rate (per 10 000 inhab.)	2.013	1.088
Cube root male undocumented migration rate (per 10 000 inhab.)	2.824	1.119
Ln male migration rate (per 10 000 inhab.)	3.267	2.035
Ln male documented migration raet (per 10 000 inhab.)	1.294	2.868
Ln undocumented male migration rate (per 10 000 inhab.)	2.566	2.967
Log PROCAMPO around threshold ± 1 ha per capita centered $_{t-1}$	0.004	1.294
Inverse hyperbolic sine Fonden per capita $_{t-1}$	2.232	2.418
(1-PROCAMPO gini) $_{t-1}$	0.539	0.089
Predicted share of PROCAMPO for non irrig. {ejidos} $_{t-1}$	0.715	0.287
Hurricane $_{t-1}$	0.167	0.373
Hurricane max intensity $_{t-1}$	0.552	1.225
Number of months rain > 90th ptile $_{t-1}$	1.576	1.224
Rain deviation rainy season $_{t-1}$	0.449	1.064
Rain deviation dry season $_{t-1}$	0.156	1.015
Temp deviation rainy season $_{t-1}$	0.498	0.908
Temp deviation dry season $_{t-1}$	0.268	0.927
Number of observations	384	

Appendix B. Impact of rainfall and temperatures

Table 6 shows the results of the estimation of the impact of climate shocks on migration, for total male flows (columns (1) to (3)), and then separately for documented male flows (columns (4) to (6)) and undocumented male flows (columns (7) to (9)). All specifications include state of origin and year fixed effects and standards errors are corrected for serial and spatial correlation. The dependent variable is the cube root of the migration rate at the Mexican state level (per 10,000 inhabitants).

As suggested by estimation results reported in columns (1) to (3), hurricanes tend to increase migration. However the effect of hurricane intensity is not significant in most specifications.

We find a negative and significant coefficient on the precipitation z-score during the dry season and a positive and significant coefficient on the temperature z-score during the rainy season (column (1)).

Columns (3), (6) and (9) allow us to go further in the interpretation of our results by exploring separately the impact of positive and negative deviations from long-term averages in rainfall and temperatures, that is, for each type of climate anomaly, the specifications disentangle positive and negative z-scores.

Documented migration increases when the rainfall are larger than average during the rainy season. Undocumented migration increases following negative rain shocks during the dry season.

Since by construction all negative deviations variables take negative or zero values, the negative and significant coefficient on the negative rain deviations variable in column (6) suggests that precipitation shortage during the rainy season tends to increase documented migration. Similarly, droughts (negative rainfall deviations) during the dry season are found to increase undocumented migration (column (9)). Our findings are consistent with previous evidence of drought driven migration in the Mexican context (Pugatch and Yang 2011; Chort 2014; Chort and De La Rupelle 2016; Nawrotzki et al. 2013).

As for temperatures, results in column (3) suggest that total flows are negatively affected by negative deviations during the rainy season.

Table 6 Climatic factors and Mexico-US migration flows — 1999–2012

Inverse hyperbolic sine dependent variable	Total male flows			Documented male flows			Undocumented male flows		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Hurricane $_{t-1}$	0.168	0.194	0.148	0.008	0.094	−0.004	0.041	0.039	0.029
	(0.193)	(0.192)	(0.197)	(0.172)	(0.163)	(0.176)	(0.184)	(0.184)	(0.185)
Hurricane max intensity $_{t-1}$	−0.026	−0.036	−0.025	0.009	−0.031	0.009	−0.010	−0.007	−0.008
	(0.062)	(0.060)	(0.063)	(0.064)	(0.058)	(0.065)	(0.056)	(0.055)	(0.056)
Number of months rain > 90th ptile $_{t-1}$	−0.020	−0.057*	−0.019	0.041	−0.016	0.049	−0.027	−0.040	−0.029
	(0.037)	(0.033)	(0.037)	(0.047)	(0.038)	(0.047)	(0.033)	(0.029)	(0.033)
Rain deviations rainy season $_{t-1}$	−0.064			−0.173***			−0.004		
	(0.054)			(0.057)			(0.051)		
Rain deviations dry season $_{t-1}$	−0.063			0.004			−0.047		
	(0.047)			(0.053)			(0.046)		
Temp deviations rainy season $_{t-1}$	0.103	0.113*		0.042	0.078		0.073	0.071	
	(0.065)	(0.064)		(0.075)	(0.075)		(0.055)	(0.053)	
Temp deviations dry season $_{t-1}$	−0.023	−0.016		−0.086	−0.099		0.039	0.047	
	(0.046)	(0.047)		(0.064)	(0.065)		(0.042)	(0.042)	
Positive rain deviations $_{t-1}$ — rainy season			−0.058			−0.155**			-0.013
			(0.065)			(0.062)			(0.059)
Negative rain deviations $_{t-1}$ — rainy season			−0.071			−0.205			0.017
			(0.085)			(0.135)			(0.089)
Positive rain deviations $_{t-1}$ — dry season			0.018			0.038			0.028
			(0.043)			(0.061)			(0.044)
Negative rain deviations $_{t-1}$ — dry season			−0.248**			−0.056			−0.221**
			(0.106)			(0.118)			(0.100)

Table 6 (continued)

Inverse hyperbolic sine dependent variable	Total male flows			Documented male flows			Undocumented male flows		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Positive temp deviations $_{t-1}$ — rainy season			0.065			0.001			0.077
			(0.076)			(0.090)			(0.071)
Negative temp deviations $_{t-1}$ — rainy season			0.218**			0.209			0.062
			(0.100)			(0.141)			(0.086)
Positive temp deviations $_{t-1}$ — dry season			−0.020			−0.146			0.029
			(0.070)			(0.091)			(0.063)
Negative temp deviations $_{t-1}$ — dry season			−0.041			−0.015			0.055
			(0.061)			(0.096)			(0.048)
N	448	448	448	448	448	448	448	448	448

Standard errors corrected for autocorrelation and spatial correlation in parentheses

$^{*}\ p < 0.10$, $^{**}\ p < 0.05$, $^{***}\ p < 0.01$

Table 7 Climatic factors and Mexico-US migration flows, 2001–2012 — decomposition of shocks

Inverse hyperbolic sine dependent variable	Total male flows		Documented male flows		Undocumented male flows	
	(1)	(2)	(3)	(4)	(5)	(6)
Hurricane $_{t-1}$	0.135	0.273	0.030	0.170	−0.026	0.085
	(0.166)	(0.197)	(0.162)	(0.228)	(0.142)	(0.180)
Hurricane max intensity $_{t-1}$	−0.022	−0.027	0.006	−0.092	0.011	0.028
	(0.057)	(0.062)	(0.064)	(0.074)	(0.051)	(0.058)
Number of months rain > 90th ptile $_{t-1}$	−0.030	0.020	0.027	0.125*	−0.025	−0.003
	(0.036)	(0.052)	(0.049)	(0.066)	(0.035)	(0.056)
Positive rain dev. rainy season $_{t}$	0.003	−0.021	−0.092	−0.121	−0.003	−0.012
	(0.067)	(0.099)	(0.066)	(0.096)	(0.066)	(0.098)
Negative rain dev. rainy season $_{t}$	−0.097	−0.294***	−0.224*	−0.513***	−0.020	−0.111
	(0.078)	(0.102)	(0.129)	(0.168)	(0.097)	(0.124)
Positive rain dev. dry season $_{t}$	0.018	-0.013	0.029	0.082	0.022	−0.053
	(0.042)	(0.068)	(0.060)	(0.104)	(0.044)	(0.080)
Negative rain dev. dry season $_{t}$	−0.042	−0.149	0.096	0.065	−0.075	−0.204
	(0.103)	(0.102)	(0.123)	(0.143)	(0.099)	(0.137)
Positive temp dev. season $_{t}$	0.077	0.036	0.075	0.000	0.006	−0.021
	(0.072)	(0.078)	(0.094)	(0.087)	(0.071)	(0.100)
Negative temp dev. rainy season $_{t}$	0.204**	0.183	0.159	0.159	0.083	0.053
	(0.101)	(0.123)	(0.137)	(0.158)	(0.086)	(0.124)
Positive temp dev. dry season $_{t}$	-0.047	−0.197**	−0.179*	−0.321**	−0.003	−0.084
	(0.077)	(0.098)	(0.108)	(0.130)	(0.073)	(0.100)
Negative temp dev. dry season $_{t}$	-0.027	0.075	−0.045	0.148	0.069	0.139
	(0.056)	(0.109)	(0.096)	(0.159)	(0.049)	(0.088)
Log PROCAMPO around threshold ± 1 ha per capita centered $_{t-1}$		0.822		1.183		0.033
		(0.758)		(0.947)		(0.808)

Table 7 (continued)

Inverse hyperbolic sine dependent variable	Total male flows		Documented male flows		Undocumented male flows	
	(1)	(2)	(3)	(4)	(5)	(6)
Hurricane $_{t-1}$ × Log PROC. thresh. ± 1 ha pcap $_{t-1}$		−0.035		0.023		0.090
		(0.120)		(0.157)		(0.108)
Number of months rain> 90ptile $_{t-1}$ ×Log PROC. thresh. ± 1 ha pcap $_{t-1}$		0.047		−0.011		0.041
		(0.034)		(0.047)		(0.035)
Positive rain dev. rainy season $_t$ ×PROC. thresh ± 1 ha pcap $_{t-1}$		0.058		0.085		−0.062
		(0.051)		(0.068)		(0.056)
Negative rain dev. rainy season $_t$ ×PROC. thresh ± 1 ha pcap $_{t-1}$		−0.008		−0.088*		0.002
		(0.042)		(0.047)		(0.048)
Positive rain dev. dry season $_t$ ×PROC. thresh ± 1 ha pcap $_{t-1}$		−0.015		0.085		−0.018
		(0.043)		(0.075)		(0.054)
Negative rain dev. dry season $_t$ ×PROC. thresh ± 1 ha pcap $_{t-1}$		0.125*		−0.039		0.105
		(0.075)		(0.080)		(0.075)
Positive temp dev. season $_t$ ×PROC. thresh ± 1 ha pcap $_{t-1}$		0.027		0.000		−0.054
		(0.055)		(0.060)		(0.064)
Negative temp dev. rainy season $_t$ ×PROC. thresh ± 1 ha pcap $_{t-1}$		−0.015		−0.052		0.070
		(0.056)		(0.074)		(0.072)
Positive temp dev. dry season $_t$ ×PROC. thresh ± 1 ha pcap $_{t-1}$		0.121*		−0.063		0.112
		(0.063)		(0.087)		(0.074)
Negative temp dev. dry season $_t$ ×PROC. thresh ± 1 ha pcap $_{t-1}$		−0.091		−0.070		−0.048
		(0.082)		(0.089)		(0.070)
Inverse hyperbolic sine Fonden per capita $_{t-1}$		0.050*		0.100**		−0.004
		(0.027)		(0.046)		(0.033)
Hurricane $_{t-1}$ ×Inv. hyperb. sine Fonden pcap $_{t-1}$		−0.034		0.028		−0.055*

Table 7 (continued)

Inverse hyperbolic sine dependent variable	Total male flows		Documented male flows		Undocumented male flows	
	(1)	(2)	(3)	(4)	(5)	(6)
		(0.032)		(0.044)		(0.031)
Number of months rain> 90ptile $_{t-1}$ ×Inv. hyperb. sine Fonden pcap $_{t-1}$		-0.021		-0.039^{*}		−0.008
		(0.013)		(0.020)		(0.013)
Positive rain dev. rainy season $_t$ × Fonden pcap $_{t-1}$		−0.002		−0.001		0.004
		(0.019)		(0.023)		(0.018)
Negative rain dev. rainy season $_t$ × Fonden pcap $_{t-1}$		0.090^{***}		0.150^{**}		0.047
		(0.027)		(0.060)		(0.030)
Positive rain dev. dry season $_t$ × Fonden pcap $_{t-1}$		0.007		−0.037		0.026
		(0.021)		(0.030)		(0.023)
Negative rain dev. dry season $_t$ × Fonden pcap $_{t-1}$		0.044^{**}		0.026		0.044
		(0.022)		(0.034)		(0.030)
Positive temp dev. season $_t$ × Fonden pcap $_{t-1}$		0.021		0.047		0.011
		(0.025)		(0.039)		(0.024)
Negative temp dev. rainy season $_t$ × Fonden pcap $_{t-1}$		0.009		−0.007		0.009
		(0.035)		(0.037)		(0.034)
Positive temp dev. dry season $_t$ × Fonden pcap $_{t-1}$		0.049		0.040		0.035
		(0.031)		(0.040)		(0.031)
Negative temp dev. dry season $_t$ × Fonden pcap $_{t-1}$		-0.025		−0.046		−0.016
		(0.027)		(0.031)		(0.023)
N	384	384	384	384	384	384

Standard errors corrected for autocorrelation and spatial correlation in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Appendix C. Robustness checks

Table 8 Climatic factors and Mexico-US migration flows: 1999–2012

Inv. hyp. sine dependent variable	Total male flows (1)	Documented male flows (2)	Undocumented male flows (3)
Hurricane $_{t-1}$	0.235	0.067	0.112
	(0.219)	(0.217)	(0.209)
Hurricane max intensity $_{t-1}$	−0.035	−0.076	0.025
	(0.067)	(0.072)	(0.060)
Nb of months rain > 90th ptile $_{t-1}$	0.043	0.123**	0.008
	(0.048)	(0.050)	(0.046)
Rain deviations rainy season $_{t-1}$	−0.146**	−0.280***	−0.055
	(0.062)	(0.067)	(0.065)
Rain deviations dry season $_{t-1}$	−0.203***	−0.025	−0.196***
	(0.064)	(0.072)	(0.060)
Temp deviations rainy season $_{t-1}$	0.038	−0.030	0.042
	(0.064)	(0.075)	(0.063)
Temp deviations dry season $_{t-1}$	−0.077	−0.107	0.011
	(0.056)	(0.079)	(0.052)
Log PROCAMPO around threshold ± 1 ha per capita centered $_{t-1}$	1.154*	1.308	0.111
	(0.627)	(0.797)	(0.662)
Hurricane $_{t-1}$ ×Log PROC. thresh. ± 1 ha pcap $_{t-1}$	−0.029	0.024	0.000
	(0.101)	(0.131)	(0.126)
Nb of months rain> 90ptile $_{t-1}$ ×Log PROC. thresh. ± 1 ha pcap $_{t-1}$	0.042	0.021	0.004
	(0.032)	(0.039)	(0.032)
Rain deviation rainy season $_{t-1}$ ×Log PROC. thresh. ± 1 ha pcap $_{t-1}$	0.022	0.013	0.008
	(0.030)	(0.035)	(0.034)
Rain deviation dry season $_{t-1}$ ×Log PROC. thresh. ± 1 ha pcap $_{t-1}$	0.073**	0.024	0.075*
	(0.034)	(0.036)	(0.042)
Temp deviation rainy season $_{t-1}$ ×Log PROC. thresh. ± 1 ha pcap $_{t-1}$	0.008	0.005	−0.007
	(0.024)	(0.025)	(0.023)
Temp deviation dry season $_{t-1}$ ×Log PROC. thresh. ± 1 ha pcap $_{t-1}$	0.035	-0.054	0.047
	(0.040)	(0.046)	(0.040)
Inverse hyperbolic sine Fonden per capita $_{t-1}$	0.019	0.050	−0.009
	(0.021)	(0.035)	(0.024)
Hurricane $_{t-1}$ ×Inv. hyperb. sine Fonden pcap $_{t-1}$	-0.031	0.029	−0.062
	(0.040)	(0.045)	(0.044)

Table 8 (continued)

Inv. hyp. sine dependent variable	Total male flows (1)	Documented male flows (2)	Undocumented male flows (3)
Nb of months rain> 90ptile $_{t-1}$ ×Inv. hyperb. sine Fonden pcap $_{t-1}$	-0.020^{*}	-0.034^{**}	-0.008
	(0.011)	(0.016)	(0.012)
Rain deviation rainy season $_{t-1}$ ×Inv. hyperb. sine Fonden pcap $_{t-1}$	0.030^{**}	0.047^{***}	0.019
	(0.013)	(0.018)	(0.014)
Rain deviation dry season $_{t-1}$ ×Inv. hyperb. sine Fonden pcap $_{t-1}$	0.048^{***}	0.008	0.051^{***}
	(0.013)	(0.016)	(0.012)
Temp deviation rainy season $_{t-1}$ ×Inv. hyperb. sine Fonden pcap $_{t-1}$	0.031^{*}	0.045^{*}	0.010
	(0.016)	(0.024)	(0.014)
Temp deviation dry season $_{t-1}$ ×Inv. hyperb. sine Fonden pcap $_{t-1}$	0.021	0.002	0.016
	(0.015)	(0.016)	(0.014)
N	448	448	448

Standard errors corrected for autocorrelation and spatial correlation in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 9 Public policies and past migration, 2000–2012

	Fonden	PROCAMPO		
	Inv. hyp. sine amount per capita (1)	Log PROC around threshold per capita (2)	Share non irrig. *Ej* (3)	1-Gini (4)
Male migration (inv. hyp. sine) in $_{t-1}$	−0.085	0.008	0.000	−0.000
	(0.192)	(0.005)	(0.001)	(0.001)
Hurricane $_t$	-1.521^{***}	0.005	0.002	0.005
	(0.557)	(0.014)	(0.002)	(0.004)
Hurricane max intensity $_t$	0.923^{***}	−0.001	−0.000	-0.002^{*}
	(0.151)	(0.006)	(0.001)	(0.001)
Number of months rain >90th ptile $_t$	0.064	0.001	−0.000	−0.001
	(0.134)	(0.003)	(0.000)	(0.001)
Rain deviation rainy season $_t$	0.392^{**}	−0.004	−0.000	−0.001
	(0.171)	(0.005)	(0.001)	(0.001)
Rain deviation dry season $_t$	0.052	-0.008^{*}	0.000	−0.000
	(0.157)	(0.004)	(0.001)	(0.001)
Temp deviation rainy season $_t$	−0.005	0.005	−0.000	−0.000
	(0.219)	(0.006)	(0.001)	(0.001)
Temp deviation dry season $_t$	0.406^{**}	−0.000	−0.000	0.000
	(0.183)	(0.005)	(0.001)	(0.001)
Hurricane $_{t-1}$	−0.959	0.017	0.005^{*}	0.004
	(0.673)	(0.015)	(0.003)	(0.004)
Number of months rain > 90th ptile $_{t-1}$	0.071	0.001	−0.000	−0.000
	(0.131)	(0.004)	(0.000)	(0.001)
Hurricane max intensity $_{t-1}$	0.779^{***}	−0.008	-0.001^{*}	−0.002
	(0.188)	(0.005)	(0.001)	(0.001)
Rain deviations rainy season $_{t-1}$	−0.184	0.002	0.000	-0.001^{*}
	(0.176)	(0.004)	(0.001)	(0.001)
Rain deviations dry season $_{t-1}$	-0.294^{*}	−0.002	−0.000	−0.000
	(0.151)	(0.003)	(0.001)	(0.001)
Temp deviations rainy season $_{t-1}$	0.155	0.011	−0.001	−0.003
	(0.198)	(0.007)	(0.001)	(0.002)
Temp deviations dry season $_{t-1}$	−0.063	0.011^{*}	−0.001	0.001
	(0.207)	(0.006)	(0.001)	(0.002)
N	416	416	416	416

Standard errors corrected for autocorrelation and spatial correlation in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

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Declarations

Conflicts of interest The authors declare no competing interests.

References

Adhvaryu A, Nyshadham A, Molina T, Tamayo J (2018) Helping children catch up: Early life shocks and the progresa experiment. Technical report, National Bureau of Economic Research

Angelucci M (2012) US border enforcement and the net flow of Mexican illegal migration. Econ Dev Cult Change 60(2):311–357

Angelucci M (2015) Migration and financial constraints: Evidence from Mexico. Rev Econ Stat 97(1):224–228

Baez J, Caruso G, Mueller V, Niu C (2017) Droughts augment youth migration in Northern Latin America and the Caribbean. Climatic Change 140(3):423–425

Baez J, Caruso G, Mueller V, Niu C (2017) Heat exposure and youth migration in Central America and the Caribbean. Am Econ Rev 107(5):446–450

Beine M, Parsons C (2015) Climatic factors as determinants of international migration. Scandinavian J Econ 117(2):723–767

Beine MA, Jeusette L (2018) A meta-analysis of the literature on climate change and migration

Benonnier T, Millock K, Taraz V (2018) Climate change, migration and irrigation. Working Paper

Bertoli S, Gautrain E, Murard E (2020) Left behind, but not alone: Changes in living arrangements and the effects of migration and remittances in mexico

Bonhomme S, Manresa E (2015) Grouped patterns of heterogeneity in panel data. Econometrica 83(3):1147–1184

Cai R, Feng S, Oppenheimer M, Pytlikova M (2016) Climate variability and international migration: The importance of the agricultural linkage. J Environ Econ Manage 79:135–151

Cattaneo C, Peri G (2016) The migration response to increasing temperatures. J Dev Econ 122:127–146

Cattaneo MD, Jansson M, Ma X (2019) Simple local polynomial density estimators. J Am Stat Asso (just-accepted):1–11

Chort I (2014) Mexican migrants to the US: what do unrealized migration intentions tell us about gender inequalities? World Dev 59:535–552

Chort I, De La Rupelle M (2016) Determinants of Mexico-US outward and return migration flows: a state-level panel data analysis. Demography 53(5):1453–1476

Chort, I. and de la Rupelle, M. (2022). Managing the impact of climate on migration: evidence from mexico. GLO Discussion Paper Series, (1040)

Cohen IS, Spring ÚO, Padilla GD, Paredes JC, Inzunza Ibarra MA, López RL, Díaz JV (2013) Forced migration, climate change, mitigation and adaptive policies in Mexico: Some functional relationships. Int Migration 51(4):53–72

Combs S (2012) The impact of the 2011 drought and beyond. Texas Comptroller of Public Accounts Special Rep., Publ, 96(1704):16

Coniglio ND, Pesce G (2015) Climate variability and international migration: an empirical analysis. Environ Dev Econ 20(4):434–468

Conley TG (1999) GMM estimation with cross sectional dependence. J Econ 92(1):1–45

Conley TG, Ligon E (2002) Economic distance and cross-country spillovers. J Econ Growth 7(2):157–187

Corti T, Wüest M, Bresch D, Seneviratne SI (2011) Drought-induced building damages from simulations at regional scale. Nat Hazards Earth Sys Sci 11(12):3335–3342

Cui X, Feng S (2020) Climate change and migration. Handbook of Labor, Human Resources and Population Economics, pp 1–15

Dallmann I, Millock K (2016) Climate variability and internal migration: a test on Indian inter-state migration. Document de travail du Centre d'Economie de la Sorbonne

de Janvry A, Emerick K, Gonzalez-Navarro M, Sadoulet E (2015) Delinking land rights from land use: certification and migration in mexico. Am Econ Rev 105(10):3125–49

De Janvry A, Finan F, Sadoulet E, Vakis R (2006) Can conditional cash transfer programs serve as safety nets in keeping children at school and from working when exposed to shocks? J Dev Econ 79(2):349–373

del Valle A (2021) Saving lives with pre-financed rules-based disaster aid: Evidence from mexico

del Valle A, de Janvry A, Sadoulet E (2020) Rules for recovery: Impact of indexed disaster funds on shock coping in mexico. Am Econ J App Econ 12(4):164–95

Deryugina T, Molitor D (2018) Does when you die depend on where you live? evidence from hurricane katrina. Technical report, National Bureau of Economic Research

Descroix L, Viramontes D, Estrada J, Barrios J-LG, Asseline J (2007) Investigating the spatial and temporal boundaries of Hortonian and Hewlettian runoff in Northern Mexico. J Hydrol 346(3):144–158

Eakin H (2005) Institutional change, climate risk, and rural vulnerability: Cases from Central Mexico. World Dev 33(11):1923-1938X

Emanuel KA (2013) Downscaling CMIP5 climate models shows increased tropical cyclone activity over the 21st century. Proceedings of the National Academy of Sciences 110(30):12219–12224

Feng S, Krueger AB, Oppenheimer M (2010) Linkages among climate change, crop yields and Mexico-US cross-border migration. Proceedings of the National Academy of Sciences 107(32):14257–14262

Feng S, Oppenheimer M, Schlenker W (2012) Climate change, crop yields, and internal migration in the United States. Technical report, National Bureau of Economic Research

Gosling SN, Dunn R, Carrol F, Christidis N, Fullwood J, Gusmao DD, Golding N, Good L, Hall T, Kendon L, et al (2011) Climate: Observations, projections and impacts

Hanson GH (2006) Illegal migration from Mexico to the United States. J Econ Lit 44(4):869–924

Hirvonen K (2016) Temperature changes, household consumption, and internal migration: Evidence from tanzania. Am J Agri Econ 98(4):1230–1249

Horton RE (1933) The role of infiltration in the hydrologic cycle. Eos Transact Am Geophys Union 14(1):446–460

Hsiang S (2016) Climate econometrics. Annual Rev Res Econ 8:43–75

Hsiang SM (2010) Temperatures and cyclones strongly associated with economic production in the Caribbean and Central America. Proceedings of the National Academy of Sciences 107(35):15367–15372

Instituto Nacional de Estadística and Geografía (Mexico) and Consejo Nacional de Población (Mexico) (2011). Encuesta nacional de la dinámica demográfica 2009: panorama sociodemográfico de Mexico: principales resultados. INEGI

Jessoe K, Manning DT, Taylor JE (2018) Climate change and labour allocation in rural mexico: Evidence from annual fluctuations in weather. Econ J 128(608):230–261

Marchiori L, Maystadt J-F, Schumacher I (2012) The impact of weather anomalies on migration in sub-saharan africa. J Environ Econ Manage 63(3):355–374

Martínez González A, Plakias Z, Partridge M (2017) The Mexican PROCAMPO farmland subsidy and its effectiveness as a rural anti-poor program. working paper, Department of Agricultural, Environmental and Development Economics, The Ohio State University

Mbaye L, Zimmermann KF (2016) Natural disasters and human mobility. ZEF-Center for Development Research, University of Bonn, Working Paper, 151

Mendelsohn R, Emanuel K, Chonabayashi S, Bakkensen L (2012) The impact of climate change on global tropical cyclone damage. Nat Climate Change 2(3):205–209

Munshi, K. (2003). Networks in the modern economy: Mexican migrants in the U. S. labor market. Quart J Econ 118(2):549–599

Nawrotzki R, Riosmena F, Hunter L (2013) Do rainfall deficits predict U.S.-bound migration from rural Mexico? evidence from the Mexican census. Population Res Policy Rev 32(1):129–158

Pajaron MC, Vasquez GNA (2020) Weathering the storm: weather shocks and international labor migration from the philippines. J Population Econ 33(4):1419–1461

Pugatch T, Yang D (2011) The impact of Mexican immigration on U.S. labor markets: Evidence from migrant flows driven by rainfall shocks. Technical report

Rendall MS, Aguila E, Basurto-Dávila R, Handcock MS (2009) Migration between Mexico and the US estimated from a border survey. In: Annual meeting of the Population Association of America

Rubalcava L, Teruel G (2006) Conditional public transfers and living arrangements in rural Mexico. California Center for Population Research

Sadoulet E, De Janvry A, Davis B (2001) Cash transfer programs with income multipliers: PROCAMPO in Mexico. World Dev 29(6):1043–1056

Saldaña-Zorrilla SO, Sandberg K (2009) Impact of climate-related disasters on human migration in Mexico: a spatial model. Climatic Change 96(1–2):97–118

Schlenker W, Roberts MJ (2009) Nonlinear temperature effects indicate severe damages to US crop yields under climate change. Proceedings of the National Academy of sciences 106(37):15594–15598

Sellars EA, Alix-Garcia J (2018) Labor scarcity, land tenure, and historical legacy: Evidence from Mexico. J Dev Econ 135(C):504–516

Solís DV, Aguilar M (2006) Crisis rural y migraciones en Chiapas. Migración y Desarrollo 6:102–130

Stecklov G, Winters P, Stampini M, Davis B (2005) Do conditional cash transfers influence migration? A study using experimental data from the Mexican PROGRESA program. Demography 42(4):769–790

Valsecchi M (2014) Land property rights and international migration: Evidence from Mexico. J Dev Econ 110:276–290

World Bank (2012) Fonden : Mexico's natural disaster fund - a review. World Bank, Washington DC