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Managing the Impact of Climate on Migration: Evidence from Mexico*

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Abstract

While there is a growing literature on the impact of climate and weather-related events on migration, little is known about the mitigating effect of different policies directed to the agricultural sector, or aimed at insuring against environmental disasters. This paper uses state-level data on migration flows between Mexico and the U.S. 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 are found to play a more ambiguous role on the migration response to shocks. Changes in the distribution of PROCAMPO 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-U.S. migration; Inequality

JEL classification : F22; Q54; Q18 ; 015; J61

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1 Introduction

Among the many consequences of weather shocks and climate on economic activity, its impact on human mobility is a key issue. Together with weather-related disasters, gradual and sustained shifts in rainfall and temperatures also contribute to drive 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 found to be 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 helping households to face 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 by the impact of climate on migration ¹.

We focus in this article on Mexico, and 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 hydro meteorological 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-US is by far the top migration corridor. Our unit of analysis is the Mexican state (32 entities) and we use unique panel data on yearly Mexico-US migrant flows from each Mexican state, from 2001 to 2012³. The two programs that we focus on, PROCAMPO and Fonden,

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

²According to the World Bank’s Climate Change Knowledge Portal <https://climateknowledgeportal.worldbank.org/country/mexico>.

³Migration flow data are constructed based on individual data from the Survey of Migration at the

though of very different nature, are of particular relevance to our study. PROCAMPO is the largest agricultural program funded by the Mexican federal government and consists in 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. Finally, in order to assess the impact of weather related shocks, we use satellite and land data, including the high quality data produced by the Tropical Rainfall Measuring Mission, to construct measures of excess rainfalls, hurricanes, precipitation and temperature anomalies on Mexico-US migration flows at the federated state level.

The identification of a causal effect of those two programs relies in particular on the assumption that changes in transfers received are not caused by changes in migration patterns. Regarding Fonden, previous analyses by [del Valle et al. \(2020\)](#) have shown that the operating rule of the program leave no room for manipulation. Indeed, the disbursement of Fonden funds requires a declaration by the municipality which has experienced a natural disaster and the visit of 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 has been established in theory once and for all in the 1990s. However, strategic manipulation of plot size declared by producers, corruption 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 which followed in the 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

Northern Border of Mexico (*Encuesta sobre Migración en la Frontera Norte de México* or EMIF Norte), see also [Chort and De La Rupelle \(2016\)](#)

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.

Estimation results suggest that Fonden has a mitigating effect on climate-induced migration in the sense that an increase in Fonden transfers to a given state tends to limit migration from this state in response to a negative weather shock. This effect is especially salient for undocumented flows, and its size is not negligible: 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 appears to be more ambiguous: an increase in PROCAMPO transfers to small producers tends to increase migration after heavy rainfall, although the effect is barely significant, and on the contrary, PROCAMPO tends to have a mitigating effect after negative rainfall shocks. In addition, we explore the effect of changes in the distribution of PROCAMPO, 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 contrasted evidence in the literature 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 a 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 have incidentally stressed 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 have specifically focused 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, based on state level data for the periods 1995-2000 and 2000-2005. Saldaña-Zorrilla and Sandberg (2009) use data from the 1990 and 2000 Mexican censuses and focus on the impact of natural disasters on international migration. Nawrotzki et al. (2013) investigate the role of drought on migration based on the 2000 Mexican census⁴. Jessoe et al. (2018) show that extreme heat leads increases both rural-to-urban migration and migration to the US. Baez et al. (2017a) and Baez et al. (2017b) directly investigate the effect of droughts and heat on migration but their scope is limited to internal mobility. 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 previous research that has analyzed the impact of public policies on migration. In the Mexican context, many studies have focused on the large anti-poverty PROGRESA/*Oportunidades* program⁵. Early evaluations of PROGRESA suggest that conditional cash-transfers reduce migration to the U.S. (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, suggestive of the existence of 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 the use that is made of transfers received. Comparing the effect of Fonden and PROCAMPO, we find that while the former clearly has a mitigating effect, the impact of PROCAMPO is weaker and more ambiguous. Additional results

⁴All 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.

⁵In 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.

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 to cope with adverse economic shocks. [Sadoulet et al. \(2001\)](#) find an income multiplier of 1.5-2.6 for PROCAMPO beneficiaries in the *ejido* sector⁶, which indicates that the transfers received under the program contribute to alleviating households' liquidity constraints. As such, PROCAMPO payments may affect the capacity of households to manage the effect of climatic shocks and 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 different 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

⁶The *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.

country are subject to hurricanes and tropical storms in Summer and Autumn⁷. Second, the economy of Mexican rural areas largely depends on agricultural activities⁸. Third, Mexico has a long history of migration to the United States, suggesting that moving has long been a way for Mexican households to cope with adverse economic shocks.

Climate projections for Mexico converge towards 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 vastest agricultural program in Mexico, initially launched in 1993 to mitigate the impact of the North American Free Trade Agreement (NAFTA) on Mexican producers by 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,

⁷In 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 damages.

⁸Although 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, The World Bank).

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 Appendix D 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 prices⁹. 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 U.S. 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

⁹About USD 100 in 2010.

¹⁰de 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).

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 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 parameters¹¹. 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 municipalities¹².

¹¹Regarding 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](#)).

¹²In particular, if rainfall declaration were manipulated, they would observe excess density at the right

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 had been 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 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 Appendix. 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.

of the threshold. They formally test and reject this assumption based on the test statistic developed by [Cattaneo et al. \(2019\)](#).

¹³PROCAMPO 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).

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 above¹⁴. 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 $\beta_{Ha,1}$ 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:

$$u_{i,1} = w_{Ha,i,1} + A_{H,1} \quad (1)$$

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

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

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

¹⁴Strictly 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.

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

¹⁶In 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.

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 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:

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

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:

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

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:

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

and

$$\gamma_1 w_{Ha,i,1} \geq C \quad (7)$$

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:

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

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. $\gamma_2(\cdot)$ 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 to reconstruct infrastructures, 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 which can be cumulated with agricultural income. In that case, the second period utility in presence

of a disaster fund, noted u^{DF} , writes:

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

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 US, 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 interviewed¹⁸. The representativeness of the EMIF data is assessed by [Rendall et al.](#)

¹⁷<http://www.colef.net/emif/>

¹⁸The 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>).

(2009) who conclude to the particularly good coverage of male flows and undocumented flows¹⁹. 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 Appendix, Table 3, 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 US 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 (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 US²⁰.

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 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 according to the ENADID. However, studies pointing to the incredibly high amount of remittances received by Chiapas with regard to its number of international migrants

¹⁹The 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)

²⁰The 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.

(as measured by traditional household surveys) tend to 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 at measuring migration flows from Mexico to the US. 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 US²¹. Using the survey sampling weights, and information on the state of origin of surveyed migrants, 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 period²². 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 individuals who declare having no document to cross the border nor to work in the US.

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 destination than undocumented ones. Indeed, family reunification has been by far the primary motive for obtaining a legal residence permit in the U.S (Hanson, 2006). In the EMIF data, family reunification is the main reason given by surveyed individuals who declare having legal documents to cross the border. Networks may impact migration cost, making migration cheaper for those who have contacts at destination. On the other hand

²¹Note 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.

²²Fonden data being available since 2000, our main model is estimated over the period 2001-2012

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 precipitations and air temperatures from long-term averages. The TRMM is a joint project between the NASA and the Japanese Aerospace Exploration Agency which has been launched in 1997 to study tropical rainfalls, 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. Interestingly enough, the TRMM products combine satellite measures with monthly terrestrial rain gauge data. Last, the measures are provided for 0.25 x 0.25 degree grid squares (around 25 km X 25 km), which allows us to construct very precise climatic variables²³. 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 season²⁴. 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 have been found to be more relevant and precise than yearly indicators

²³Alternative 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 x 2.5 degree for the PDSI, 0.5 x 0.5 degree for the SPEI).

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

(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 Appendix. These graphs show that, within each state, we observe substantial 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 precipitations 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 rainfalls above the percentile 90 of monthly rainfalls. 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 rainfalls 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

²⁵To 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 precipitations have been lower than (long-term) average in state i and season s of year t .

²⁶<http://www.csc.noaa.gov/hurricanes/>

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 indeed 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 [Table 6](#), in Appendix. One will have to keep this in mind when interpreting the regression results, as the inclusion of several weather shocks implies higher standard errors.

We have no variable allowing us to directly measure flooding, but flooding is potentially captured by several weather variables : excess rainfall, hurricanes, but also 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 website²⁸.

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.

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](#)

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

²⁸<https://datos.gob.mx/>

²⁹Some 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.

(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 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

³⁰The 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 km 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.

³¹In Appendix B, 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.

state-year cells for undocumented flows representing 2.5% of the total 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, PROCAMPO variations, net of state fixed effect, 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 nation-wide 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

³²We test the robustness of our results to alternative transformations, such as the log and the cube root, see Section 6.3.

³³Alternative 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.

“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 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 which cannot be manipulated, we do not limit our analysis to events occurring close by the threshold conditioning the disbursement of

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

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. \(2020\)](#) have assessed the external validity of their estimated effect for Fonden and found 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 have shown that it was locally constant. They have thus provided 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 years 1999 and 2000 (see [Table 9](#), 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 U.S., 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 10](#) 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 the two public programs presented in Section 2, 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

The Fonden program being 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 choose to consider 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 that 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

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

³⁶When 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 ($0.041 + 0.053 * (-5.5)$).

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

Inv. hyp. sine dependent variable	Total male flows (1)	Documented male flows (2)	Undocumented male flows (3)
Hurricane in t_{-1}	0.232 (0.19)	0.047 (0.23)	0.077 (0.17)
Hurricane max intensity t_{-1}	-0.021 (0.07)	-0.060 (0.08)	0.032 (0.06)
Nb months rain >90th ptile t_{-1}	0.041 (0.05)	0.133** (0.06)	0.008 (0.05)
Rain deviation rainy s. t_{-1}	-0.120* (0.07)	-0.257*** (0.07)	-0.059 (0.08)
Rain deviation dry s. t_{-1}	-0.114** (0.05)	0.000 (0.07)	-0.129** (0.06)
Temp deviation rainy s. t_{-1}	0.048 (0.06)	0.011 (0.08)	-0.011 (0.07)
Temp deviation dry s. t_{-1}	-0.087 (0.07)	-0.131 (0.10)	0.004 (0.07)
Log PROCAMPO around threshold +/- 1ha per capita t_{-1} - centered	0.968 (0.75)	1.065 (0.94)	0.068 (0.75)
Hurricane in t_{-1} XLog PROC. thresh.+/- 1ha pcap t_{-1}	-0.022 (0.12)	0.028 (0.16)	0.087 (0.10)
Nb months rain >90th ptile t_{-1} XLog PROC. thresh.+/- 1ha pcap t_{-1}	0.053 [†] (0.03)	0.028 (0.04)	0.009 (0.03)
Rain deviation rainy s. t_{-1} XLog PROC. thresh.+/- 1ha pcap t_{-1}	0.018 (0.03)	-0.010 (0.04)	-0.013 (0.03)
Rain deviation dry s. t_{-1} XLog PROC. thresh.+/- 1ha pcap t_{-1}	0.043 (0.04)	-0.010 (0.04)	0.063 (0.05)
Temp deviation rainy s. t_{-1} XLog PROC. thresh.+/- 1ha pcap t_{-1}	0.026 (0.03)	-0.002 (0.04)	-0.006 (0.03)
Temp deviation dry s. t_{-1} XLog PROC. thresh.+/- 1ha pcap t_{-1}	0.044 (0.05)	-0.068 (0.06)	0.061 (0.05)
Inverse hyperbolic sine Fonden per capita t_{-1}	0.035* (0.02)	0.064* (0.04)	-0.003 (0.02)
Hurricane in t_{-1} XInv. hyperb. sine Fonden pcap t_{-1}	-0.034 (0.03)	0.026 (0.04)	-0.056* (0.03)
Nb months rain >90th ptile t_{-1} XInv. hyperb. sine Fonden pcap t_{-1}	-0.023** (0.01)	-0.039** (0.02)	-0.008 (0.01)
Rain deviation rainy s. t_{-1} XInv. hyperb. sine Fonden pcap t_{-1}	0.025* (0.01)	0.043** (0.02)	0.015 (0.01)
Rain deviation dry s. t_{-1} XInv. hyperb. sine Fonden pcap t_{-1}	0.032*** (0.01)	0.007 (0.02)	0.038*** (0.01)
Temp deviation rainy s. t_{-1} XInv. hyperb. sine Fonden pcap t_{-1}	0.024 (0.02)	0.036 (0.03)	0.013 (0.01)
Temp deviation dry s. t_{-1} XInv. hyperb. sine Fonden pcap t_{-1}	0.013 (0.01)	-0.000 (0.02)	0.010 (0.01)
N	384	384	384

[†] Standard errors corrected for autocorrelation and spatial correlation in parentheses

[†] $p < 0.11$, * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

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 B, help us to interpret the coefficients on the interaction between Fonden and rainfall shock variables. Indeed, according to Table 7, column (9), in Appendix B, 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 7, column (6) does not allow to unambiguously determine whether 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 size³⁷. We report in Table 8 the full set of interactions between our measures of PROCAMPO and Fonden and separate variables for negative and positive shocks. Results from Table 8 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 8 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

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

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 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 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

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

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.

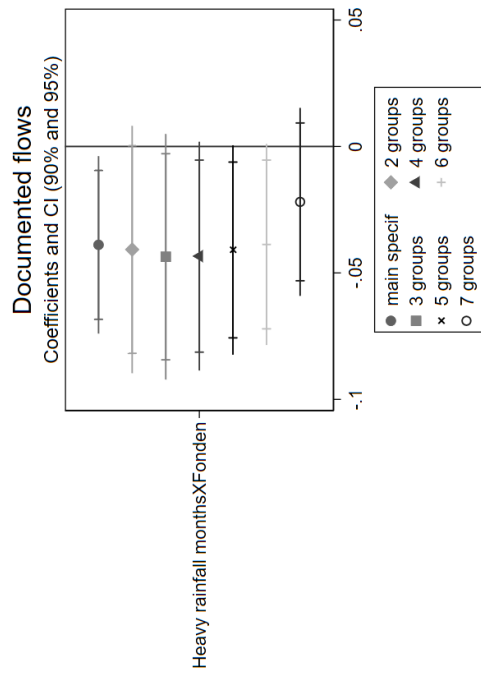


Figure 1: GFE coefficients for Fonden X hurricanes, undocumented flows

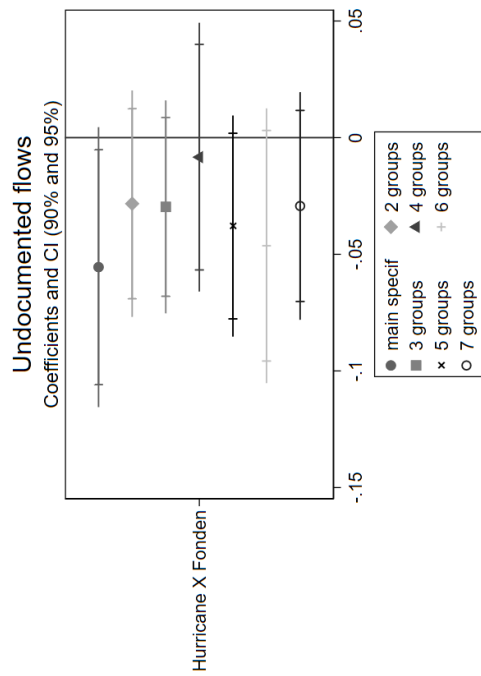


Figure 2: GFE coefficients for Fonden X heavy rainfall, documented flows

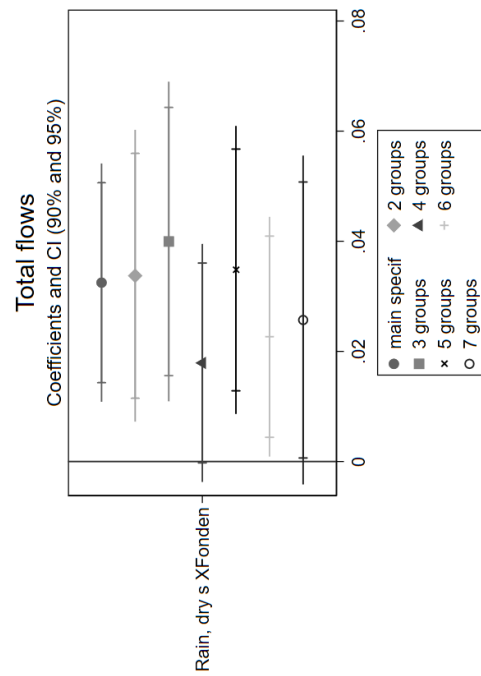


Figure 3: GFE coefficients for Fonden X rain deviations (dry season), total flows

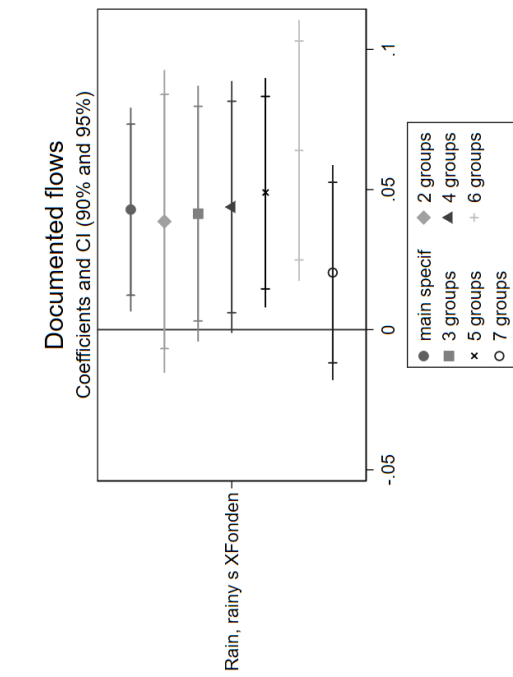


Figure 4: GFE coefficients for Fonden X rain deviations (rainy season), documented flows

The figures display 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 specification" refers to the specification presented in Table 1 (not GFE).

Figures 1 to 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 block-bootstrap of 1000 replications. Graph 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 graphs 2 to 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 of our results to using different transformations of our dependent and explanatory variables. We first re-estimate our model with a cube root transformation of the dependent variables (Table 11 in Appendix), 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 in Table 11 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.

³⁹Note, 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.

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

In [Table 12](#) (in Appendix), 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](#) 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](#)). 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 (see [Table 15](#) in Appendix). 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 Appendix).

⁴⁰We 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.

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 US. 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 Appendix. 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 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 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 7](#)). 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.

Table 2: Impact of PROCAMPO distribution, 2001-2012

Inv. hyperbol. sine dependent variable	Total male flows		Documented male flows		Undocumented male flows	
	(1)	(2)	(3)	(4)	(5)	(6)
Hurricane in $t-1$	0.067 (0.30)	0.155 (0.68)	0.539 [†] (0.33)	0.866 (0.59)	-0.517* (0.29)	-0.583 (0.63)
Hurricane max intensity $t-1$	-0.028 (0.05)	-0.042 (0.05)	-0.004 (0.06)	0.001 (0.07)	0.003 (0.05)	-0.012 (0.05)
Nb months rain >90th ptile $t-1$	-0.094 (0.08)	-0.245 (0.19)	-0.100 (0.11)	-0.320 (0.24)	0.002 (0.09)	0.024 (0.20)
Rain deviation rainy s. $t-1$	0.022 (0.12)	0.139 (0.26)	-0.028 (0.14)	0.022 (0.39)	0.086 (0.14)	0.134 (0.28)
Rain deviation dry s. $t-1$	-0.281** (0.13)	-0.377 [†] (0.25)	-0.112 (0.16)	-0.101 (0.32)	-0.294* (0.18)	-0.475* (0.27)
Temp deviation rainy s. $t-1$	-0.004 (0.12)	0.231 (0.34)	-0.082 (0.16)	0.119 (0.47)	0.054 (0.13)	0.119 (0.35)
Temp deviation dry s. $t-1$	-0.369** (0.16)	-1.049*** (0.33)	-0.221 (0.21)	-0.726* (0.44)	-0.327** (0.15)	-0.923*** (0.31)
Predicted share of PROCAMPO for non irr <i>ejidos</i> $t-1$	-4.152 (5.28)		-4.552 (7.69)		-5.227 (4.66)	
Hurricane in $t-1$ XPROC. sh no irrig $Ej.t-1$	0.086 (0.40)		-0.731* (0.41)		0.697** (0.34)	
Nb months rain >90th ptile $t-1$ XPROC. sh no irrig $Ej.t-1$	0.122 (0.11)		0.203 (0.14)		-0.029 (0.12)	
Rain deviation rainy s. $t-1$ XPROC. sh no irrig $Ej.t-1$	-0.097 (0.16)		-0.189 (0.19)		-0.148 (0.19)	
Rain deviation dry s. $t-1$ XPROC. sh no irrig $Ej.t-1$	0.333** (0.16)		0.184 (0.20)		0.345 [†] (0.22)	
Temp deviation rainy s. $t-1$ XPROC. sh no irrig $Ej.t-1$	0.158 (0.15)		0.238 (0.21)		-0.060 (0.17)	
Temp deviation dry s. $t-1$ XPROC. sh no irrig $Ej.t-1$	0.431** (0.20)		0.131 (0.25)		0.465** (0.19)	
(1-PROCAMPO gini) $t-1$		-3.620 (2.44)		-1.939 (3.69)		-2.954 (2.09)
Hurricane in $t-1$ X (1-PROCAMPO gini) $t-1$		0.070 (1.32)		-1.580 (1.12)		1.181 (1.18)
Nb months rain >90th ptile $t-1$ X (1-PROCAMPO gini) $t-1$		0.430 (0.37)		0.681 [†] (0.45)		-0.088 (0.39)
Rain deviation rainy s. $t-1$ X (1-PROCAMPO gini) $t-1$		-0.363 (0.47)		-0.337 (0.71)		-0.305 (0.53)
Rain deviation dry s. $t-1$ X (1-PROCAMPO gini) $t-1$		0.628 (0.44)		0.216 (0.57)		0.803* (0.48)
Temp deviation rainy s. $t-1$ X (1-PROCAMPO gini) $t-1$		-0.268 (0.63)		-0.092 (0.85)		-0.202 (0.68)
Temp deviation dry s. $t-1$ X (1-PROCAMPO gini) $t-1$		1.838*** (0.59)		1.109 (0.75)		1.709*** (0.55)
N	384	384	384	384	384	384

Standard errors corrected for autocorrelation and spatial correlation in parentheses

[†] $p < 0.13$, * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

7 Conclusion

Using unique panel data documenting migration flows from Mexican states to the US over the 1995-2009 period, we explore the impact of rainfall and temperature shocks on migration rates to the US 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 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.

Statements and Declarations

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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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

Sources : 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 ¹	5.1
Oaxaca	5.8	Oaxaca	5.0
Sonora	4.8	Hidalgo ²	4.8
Mexico	4.7	Guerrero	4.8
Sinaloa	4.0	México	4.2
Guerrero	3.7	Chiapas	4.1

Sources : EMIF 2004-2009 (authors' calculations), INEGI, ENADID 2009

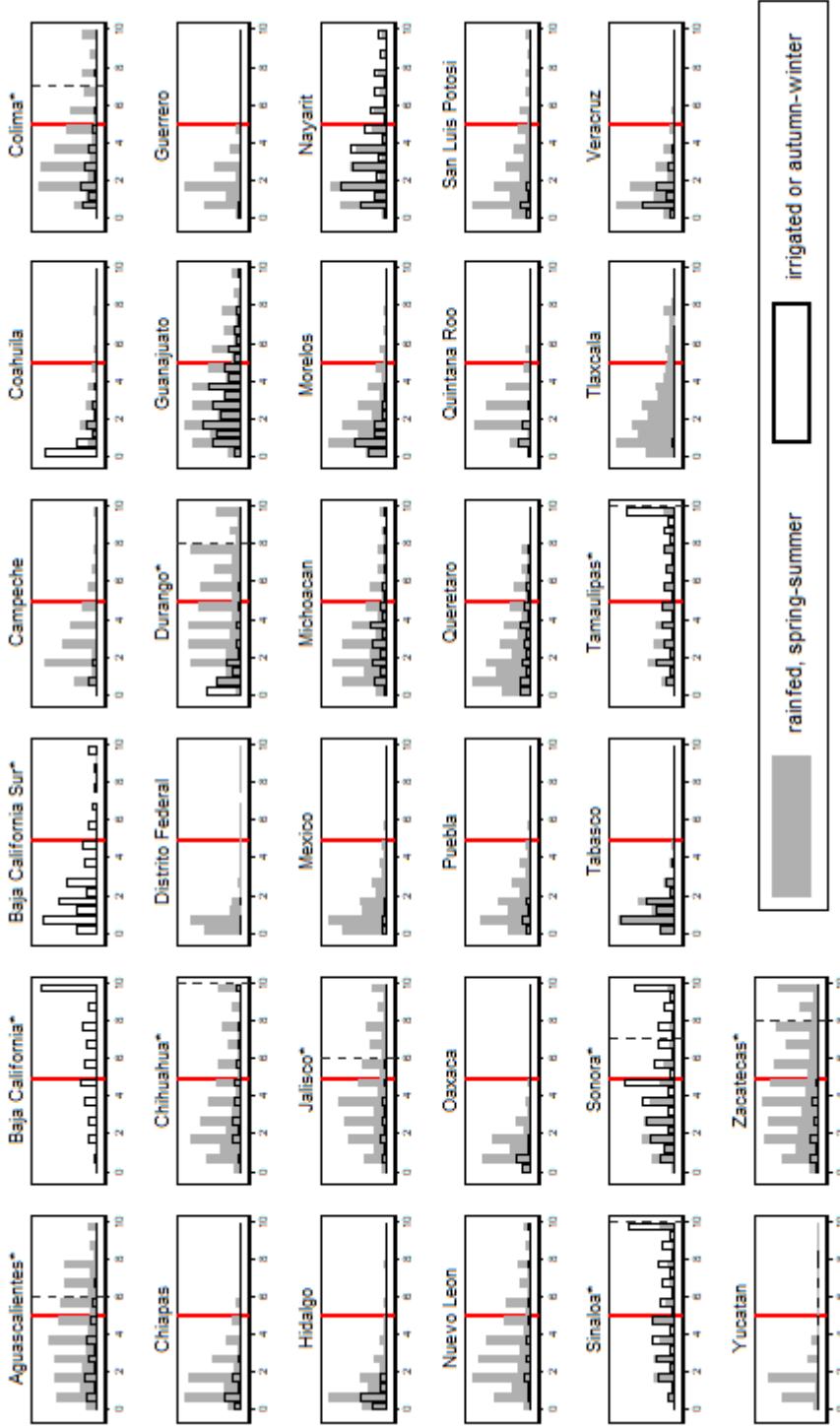
¹ Based on EMIF data, Puebla is ranked 11th with 3.6% of total flows

² 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
Inv hyperbolic sine male migration rate (per 10 000 inhab.)	4.084	1.135
Inv hyperbolic sine male documented migration rate (per 10 000 inhab.)	2.598	1.436
Inv 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 +- 1ha per capita t_{-1} - centered	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 irr \ emph{ejidos} t_{-1}	0.715	0.287
Hurricane in t_{-1}	0.167	0.373
Hurricane max intensity t_{-1}	0.552	1.225
Nb 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
N		384

Figure 5: Distribution of plots of less than 10 hectares in 1999



The thick red line materializes the 5 hectare threshold. Rainfed plots in the spring-summer cycle of less than 5 hectares benefited from the highest PROCAMPO per hectare payments following the 2003 and the 2009 reforms. * In 11 states, rainfed plots in the spring-summer cycle above 5 hectares and below a state specific threshold were also eligible to an improved per hectare payment from 2003 to 2009. This specific threshold (if below 10 hectares) is represented on the graph by a dashed line.

Figure 6: Rainfall during the rainy season - Z-score density by state (2000-2010)

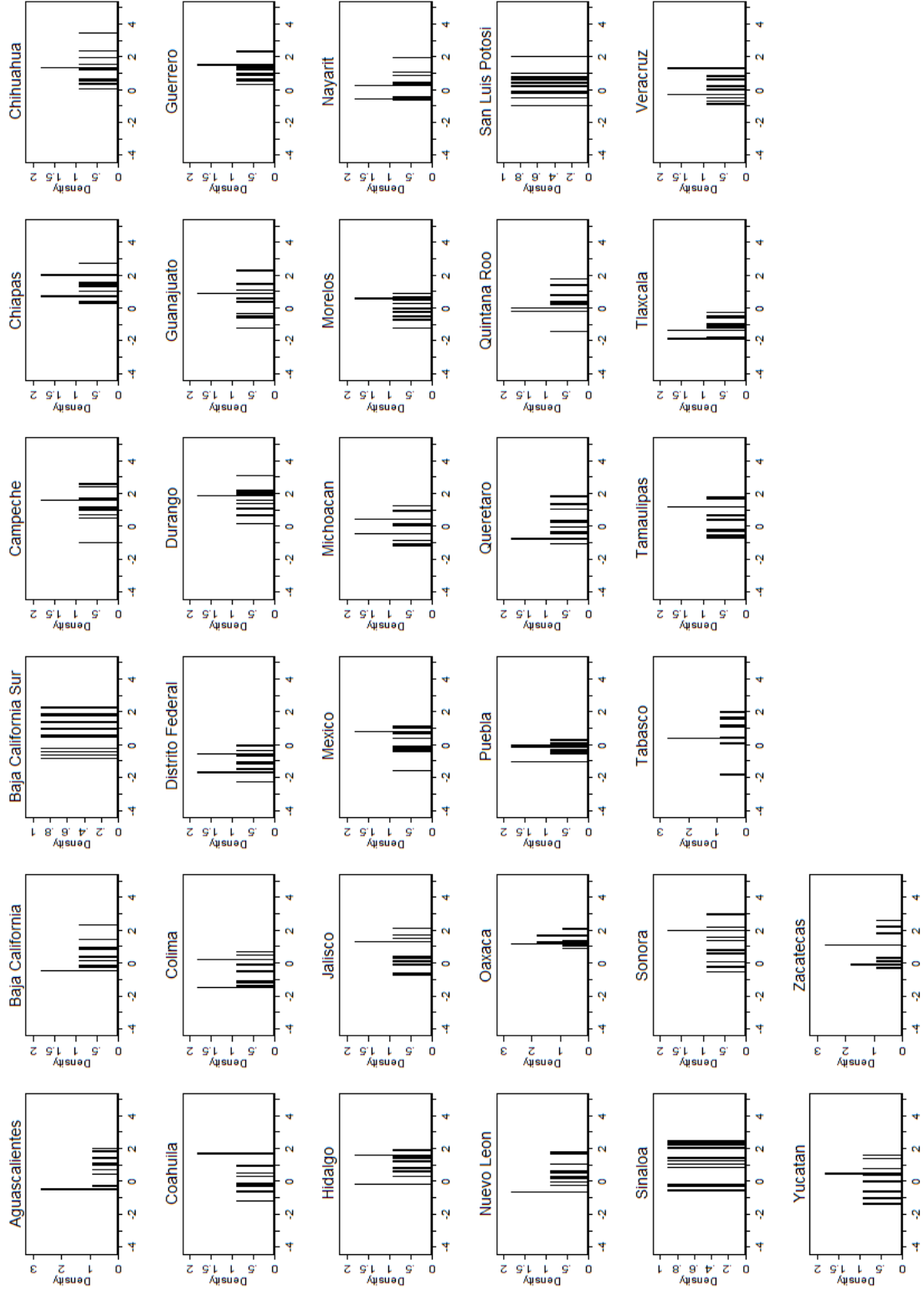


Figure 7: Rainfall during the dry season - Z-score density by state (2000-2010)

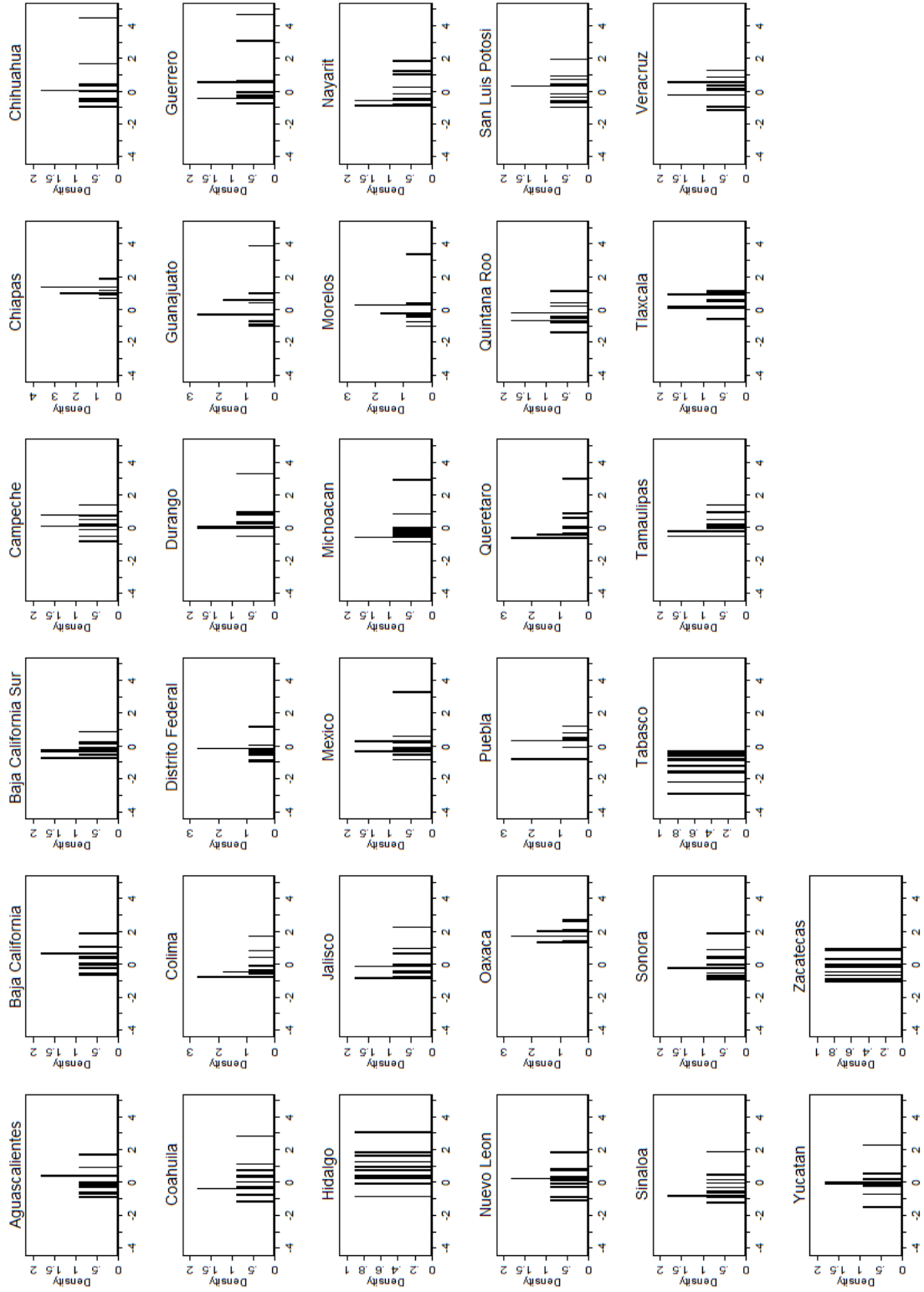


Figure 8: Temperature during the rainy season - Z-score density by state (2000-2010)

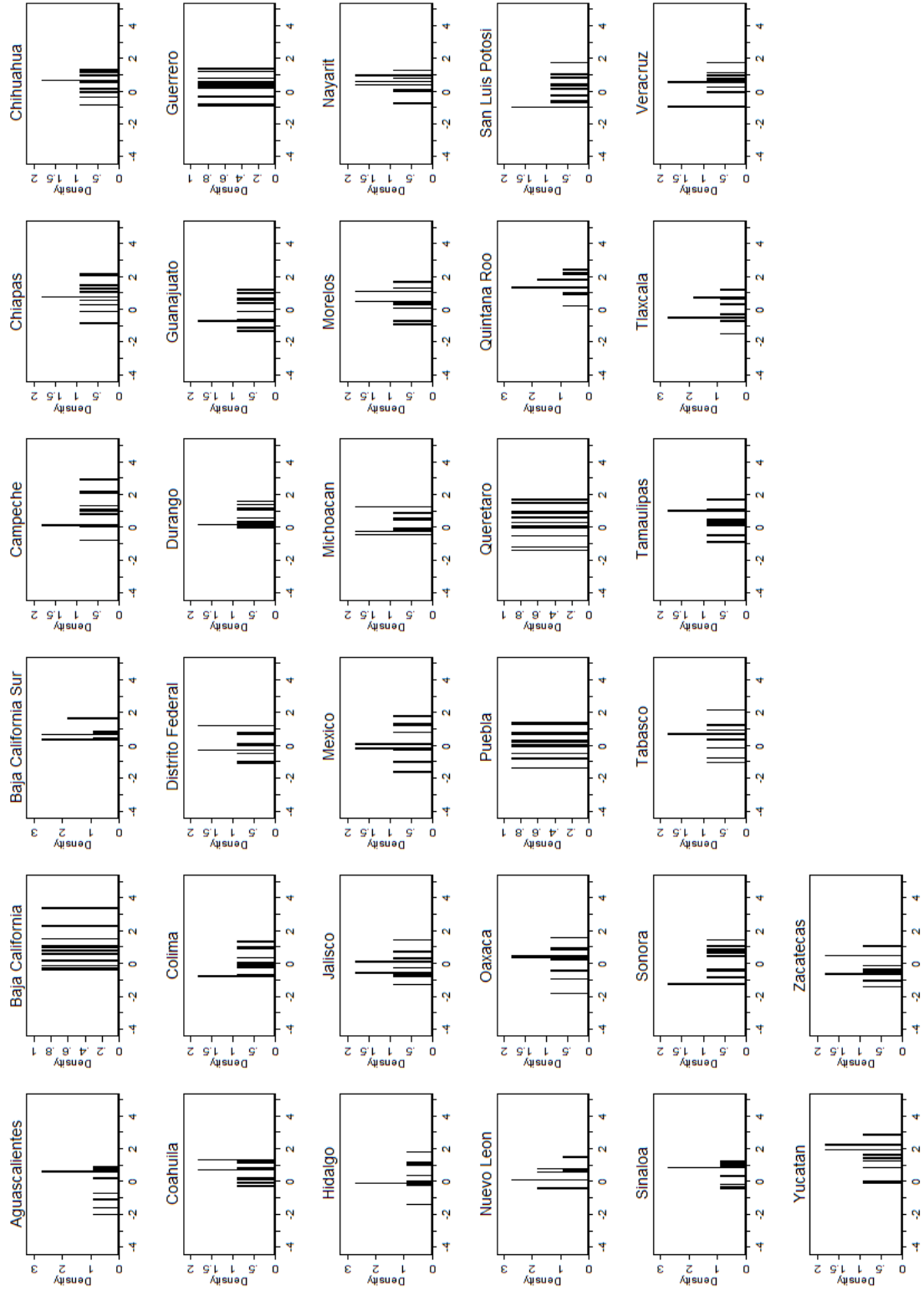


Figure 9: Temperature during the dry season - Z-score density by state (2000-2010)

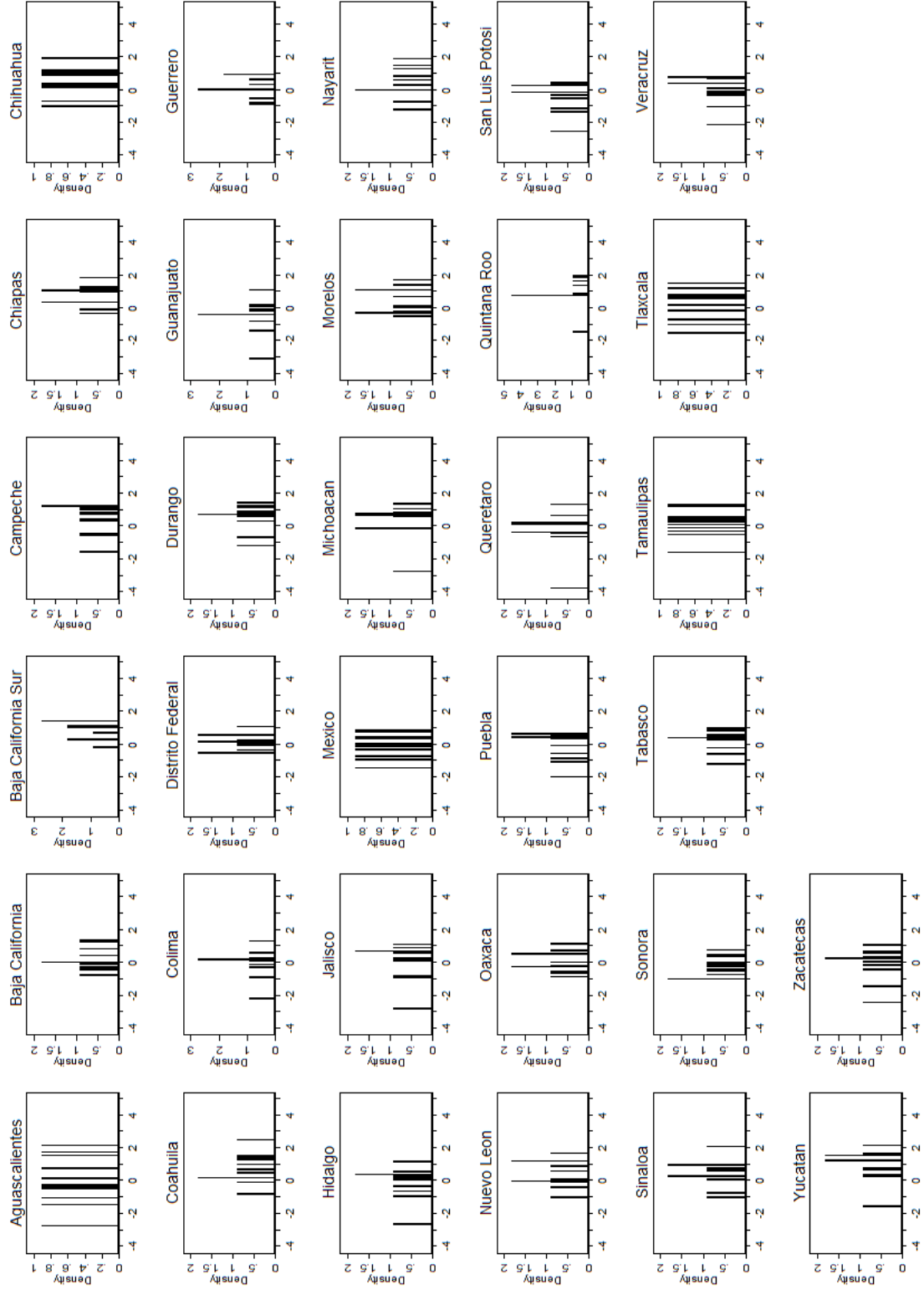


Table 6: Cross-correlation table

Variables	Rain deviation rainy s. $t-1$	Rain deviation dry s. $t-1$	Temp deviation rainy s. $t-1$	Temp deviation dry s. $t-1$	Hurricane in $t-1$	Hurricane max intensity $t-1$	Nb months rain > 90th pfile $t-1$
Rain deviation rainy s. $t-1$	1.00						
Rain deviation dry s. $t-1$	0.03	1.00					
Temp deviation rainy s. $t-1$	-0.18	-0.05	1.00				
Temp deviation dry s. $t-1$	-0.12	-0.25	0.36	1.00			
Hurricane in $t-1$	0.14	-0.04	0.06	0.05	1.00		
Hurricane max intensity $t-1$	0.18	-0.04	0.08	0.07	0.87	1.00	
Nb months rain > 90th pfile $t-1$	0.51	0.50	-0.11	-0.22	0.10	0.12	1.00

Appendix B: Impact of rainfall and temperatures

Table 7 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 7: Climatic factors and Mexico-US migration flows - 1995 and 1999-2012

Inv. hyperbol. sine dependent variable	Total male flows			Documented male flows			Undocumented male flows		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Hurricane in $t-1$	0.168 (0.19)	0.194 (0.19)	0.148 (0.20)	0.008 (0.17)	0.094 (0.16)	-0.004 (0.18)	0.041 (0.18)	0.039 (0.18)	0.029 (0.19)
Hurricane max intensity $t-1$	-0.026 (0.06)	-0.036 (0.06)	-0.025 (0.06)	0.009 (0.06)	-0.031 (0.06)	0.009 (0.07)	-0.010 (0.06)	-0.007 (0.06)	-0.008 (0.06)
Nb months rain >90th ptile $t-1$	-0.020 (0.04)	-0.057* (0.03)	-0.019 (0.04)	0.041 (0.05)	-0.016 (0.04)	0.049 (0.05)	-0.027 (0.03)	-0.040 (0.03)	-0.029 (0.03)
Rain deviation rainy s. $t-1$	-0.064 (0.05)			-0.173*** (0.06)			-0.004 (0.05)		
Rain deviation dry s. $t-1$	-0.063 (0.05)			0.004 (0.05)			-0.047 (0.05)		
Temp deviation rainy s. $t-1$	0.103 (0.07)	0.113* (0.06)		0.042 (0.08)	0.078 (0.08)		0.073 (0.06)	0.071 (0.05)	
Temp deviation dry s. $t-1$	-0.023 (0.05)	-0.016 (0.05)		-0.086 (0.06)	-0.099 (0.07)		0.039 (0.04)	0.047 (0.04)	
Positive rain deviations $t-1$ - rainy s.			-0.058 (0.06)			-0.155** (0.06)			-0.013 (0.06)
Negative rain deviations $t-1$ - rainy s.			-0.071 (0.08)			-0.205 (0.14)			0.017 (0.09)
Positive rain deviations $t-1$ - dry s.			0.018 (0.04)			0.038 (0.06)			0.028 (0.04)
Negative rain deviations $t-1$ - dry s.			-0.248** (0.11)			-0.056 (0.12)			-0.221** (0.10)
Positive temp deviations $t-1$ - rainy s.			0.065 (0.08)			0.001 (0.09)			0.077 (0.07)
Negative temp deviations $t-1$ - rainy s.			0.218** (0.10)			0.209 (0.14)			0.062 (0.09)
Positive temp deviations $t-1$ - dry s.			-0.020 (0.07)			-0.146 (0.09)			0.029 (0.06)
Negative temp deviations $t-1$ - dry s.			-0.041 (0.06)			-0.015 (0.10)			0.055 (0.05)
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 8: Climatic factors and Mexico-US migration flows, 2001-2012 - decomposition of shocks

Inv. hyperbol. sine dependent variable	Total male flows (1)	(2)	Documented male flows (3)	(4)	Undocumented male flows (5)	(6)
Hurricane in t_{-1}	0.135 (0.17)	0.273 (0.20)	0.030 (0.16)	0.170 (0.23)	-0.026 (0.14)	0.085 (0.18)
Hurricane max intensity t_{-1}	-0.022 (0.06)	-0.027 (0.06)	0.006 (0.06)	-0.092 (0.07)	0.011 (0.05)	0.028 (0.06)
Nb months rain >90th ptile t_{-1}	-0.030 (0.04)	0.020 (0.05)	0.027 (0.05)	0.125* (0.07)	-0.025 (0.04)	-0.003 (0.06)
Positive rain dev rainy s.	0.003 (0.07)	-0.021 (0.10)	-0.092 (0.07)	-0.121 (0.10)	-0.003 (0.07)	-0.012 (0.10)
Negative rain dev rainy s.	-0.097 (0.08)	-0.294*** (0.10)	-0.224* (0.13)	-0.513*** (0.17)	-0.020 (0.10)	-0.111 (0.12)
Positive rain dev dry s.	0.018 (0.04)	-0.013 (0.07)	0.029 (0.06)	0.082 (0.10)	0.022 (0.04)	-0.053 (0.08)
Negative rain dev dry s.	-0.042 (0.10)	-0.149 (0.10)	0.096 (0.12)	0.065 (0.14)	-0.075 (0.10)	-0.204 (0.14)
Positive temp dev s.	0.077 (0.07)	0.036 (0.08)	0.075 (0.09)	0.000 (0.09)	0.006 (0.07)	-0.021 (0.10)
Negative temp dev - rainy s.	0.204** (0.10)	0.183 (0.12)	0.159 (0.14)	0.159 (0.16)	0.083 (0.09)	0.053 (0.12)
Positive temp dev dry s.	-0.047 (0.08)	-0.197** (0.10)	-0.179* (0.11)	-0.321** (0.13)	-0.003 (0.07)	-0.084 (0.10)
Negative temp dev - dry s.	-0.027 (0.06)	0.075 (0.11)	-0.045 (0.10)	0.148 (0.16)	0.069 (0.05)	0.139 (0.09)
Log PROCAMPO around threshold +/- 1ha per capita t_{-1} - centered		0.822 (0.76)		1.183 (0.95)		0.033 (0.81)
Hurricane in t_{-1} XLog PROC. thresh.+/- 1ha pcap t_{-1}		-0.035 (0.12)		0.023 (0.16)		0.090 (0.11)
Nb months rain >90th ptile t_{-1} XLog PROC. thresh.+/- 1ha pcap t_{-1}		0.047 (0.03)		-0.011 (0.05)		0.041 (0.04)
Positive rain dev rainy s. XPROC. thresh +/- 1ha pcap t_{-1}		0.058 (0.05)		0.085 (0.07)		-0.062 (0.06)
Negative rain dev rainy s. XPROC. thresh +/- 1ha pcap t_{-1}		-0.008 (0.04)		-0.088* (0.05)		0.002 (0.05)
Positive rain dev dry s. XPROC. thresh +/- 1ha pcap t_{-1}		-0.015 (0.04)		0.085 (0.07)		-0.018 (0.05)
Negative rain dev dry s. XPROC. thresh +/- 1ha pcap t_{-1}		0.125* (0.08)		-0.039 (0.08)		0.105 (0.08)
Positive temp dev s. XPROC. thresh +/- 1ha pcap t_{-1}		0.027 (0.05)		0.000 (0.06)		-0.054 (0.06)
Negative temp dev - rainy s. XPROC. thresh +/- 1ha pcap t_{-1}		-0.015 (0.06)		-0.052 (0.07)		0.070 (0.07)
Positive temp dev dry s. XPROC. thresh +/- 1ha pcap t_{-1}		0.121* (0.06)		-0.063 (0.09)		0.112 (0.07)
Negative temp dev - dry s. XPROC. thresh +/- 1ha pcap t_{-1}		-0.091 (0.08)		-0.070 (0.09)		-0.048 (0.07)
Inverse hyperbolic sine Fonden per capita t_{-1}		0.050* (0.03)		0.100** (0.05)		-0.004 (0.03)
Hurricane in t_{-1} XInv. hyperb. sine Fonden pcap t_{-1}		-0.034 (0.03)		0.028 (0.04)		-0.055* (0.03)
Nb months rain >90th ptile t_{-1} XInv. hyperb. sine Fonden pcap t_{-1}		-0.021 (0.01)		-0.039* (0.02)		-0.008 (0.01)
Positive rain dev rainy s.X Fonden pcap t_{-1}		-0.002 (0.02)		-0.001 (0.02)		0.004 (0.02)
Negative rain dev rainy s.X Fonden pcap t_{-1}		0.090*** (0.03)		0.150** (0.06)		0.047 (0.03)
Positive rain dev dry s.X Fonden pcap t_{-1}		0.007 (0.02)		-0.037 (0.03)		0.026 (0.02)
Negative rain dev dry s. X Fonden pcap t_{-1}		0.044** (0.02)		0.026 (0.03)		0.044 (0.03)
Positive temp dev s.X Fonden pcap t_{-1}		0.021 (0.02)		0.047 (0.04)		0.011 (0.02)
Negative temp dev - rainy s.X Fonden pcap t_{-1}		0.009 (0.04)		-0.007 (0.04)		0.009 (0.03)
Positive temp dev dry s.X Fonden pcap t_{-1}		0.049 (0.03)		0.040 (0.04)		0.035 (0.03)
Negative temp dev - dry s.X Fonden pcap t_{-1}		-0.025 (0.03)		-0.046 (0.03)		-0.016 (0.02)
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 9: Climatic factors and Mexico-US migration flows : impact of Fonden, 1999-2012

Inv. hyp. sine dependent variable	Total male flows (1)	Documented male flows (2)	Undocumented male flows (3)
Hurricane in $t-1$	0.235 (0.22)	0.067 (0.22)	0.112 (0.21)
Hurricane max intensity $t-1$	-0.035 (0.07)	-0.076 (0.07)	0.025 (0.06)
Nb months rain >90th ptile $t-1$	0.043 (0.05)	0.123** (0.05)	0.008 (0.05)
Rain deviation rainy s. $t-1$	-0.146** (0.06)	-0.280*** (0.07)	-0.055 (0.07)
Rain deviation dry s. $t-1$	-0.203*** (0.06)	-0.025 (0.07)	-0.196*** (0.06)
Temp deviation rainy s. $t-1$	0.038 (0.06)	-0.030 (0.08)	0.042 (0.06)
Temp deviation dry s. $t-1$	-0.077 (0.06)	-0.107 (0.08)	0.011 (0.05)
Log PROCAMPO around threshold +/- 1ha per capita $t-1$ - centered	1.154* (0.63)	1.308† (0.80)	0.111 (0.66)
Hurricane in $t-1$ XLog PROC. thresh.+/- 1ha pcap $t-1$	-0.029 (0.10)	0.024 (0.13)	0.000 (0.13)
Nb months rain >90th ptile $t-1$ XLog PROC. thresh.+/- 1ha pcap $t-1$	0.042 (0.03)	0.021 (0.04)	0.004 (0.03)
Rain deviation rainy s. $t-1$ XLog PROC. thresh.+/- 1ha pcap $t-1$	0.022 (0.03)	0.013 (0.04)	0.008 (0.03)
Rain deviation dry s. $t-1$ XLog PROC. thresh.+/- 1ha pcap $t-1$	0.073** (0.03)	0.024 (0.04)	0.075* (0.04)
Temp deviation rainy s. $t-1$ XLog PROC. thresh.+/- 1ha pcap $t-1$	0.008 (0.02)	0.005 (0.03)	-0.007 (0.02)
Temp deviation dry s. $t-1$ XLog PROC. thresh.+/- 1ha pcap $t-1$	0.035 (0.04)	-0.054 (0.05)	0.047 (0.04)
Inverse hyperbolic sine Fonden per capita $t-1$	0.019 (0.02)	0.050 (0.03)	-0.009 (0.02)
Hurricane in $t-1$ XInv. hyperb. sine Fonden pcap $t-1$	-0.031 (0.04)	0.029 (0.04)	-0.062 (0.04)
Nb months rain >90th ptile $t-1$ XInv. hyperb. sine Fonden pcap $t-1$	-0.020* (0.01)	-0.034** (0.02)	-0.008 (0.01)
Rain deviation rainy s. $t-1$ XInv. hyperb. sine Fonden pcap $t-1$	0.030** (0.01)	0.047*** (0.02)	0.019 (0.01)
Rain deviation dry s. $t-1$ XInv. hyperb. sine Fonden pcap $t-1$	0.048*** (0.01)	0.008 (0.02)	0.051*** (0.01)
Temp deviation rainy s. $t-1$ XInv. hyperb. sine Fonden pcap $t-1$	0.031* (0.02)	0.045* (0.02)	0.010 (0.01)
Temp deviation dry s. $t-1$ XInv. hyperb. sine Fonden pcap $t-1$	0.021 (0.01)	0.002 (0.02)	0.016 (0.01)
N	448	448	448

Standard errors corrected for autocorrelation and spatial correlation in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 10: Public policies and past migration, 2000-2012

	Fonden Inv. hyp. sine amount per capita (1)	Log PROC around threshold per capita (2)	PROCAMPO Share non irrig. E_j (3)	1-Gini (4)
Male migration (inv. hyp. sine) in $t-1$	-0.085 (0.19)	0.008 (0.00)	0.000 (0.00)	-0.000 (0.00)
Hurricane in t	-1.521*** (0.56)	0.005 (0.01)	0.002 (0.00)	0.005 (0.00)
Hurricane max intensity t	0.923*** (0.15)	-0.001 (0.01)	-0.000 (0.00)	-0.002* (0.00)
Nb months rain >90th ptile t	0.064 (0.13)	0.001 (0.00)	-0.000 (0.00)	-0.001 (0.00)
Rain deviation rainy s. t	0.392** (0.17)	-0.004 (0.00)	-0.000 (0.00)	-0.001 (0.00)
Rain deviation dry s. t	0.052 (0.16)	-0.008* (0.00)	0.000 (0.00)	-0.000 (0.00)
Temp deviation rainy s. t	-0.005 (0.22)	0.005 (0.01)	-0.000 (0.00)	-0.000 (0.00)
Temp deviation dry s. t	0.406** (0.18)	-0.000 (0.01)	-0.000 (0.00)	0.000 (0.00)
Hurricane in $t-1$	-0.959 (0.67)	0.017 (0.01)	0.005* (0.00)	0.004 (0.00)
Nb months rain >90th ptile $t-1$	0.071 (0.13)	0.001 (0.00)	-0.000 (0.00)	-0.000 (0.00)
Hurricane max intensity $t-1$	0.779*** (0.19)	-0.008 (0.00)	-0.001* (0.00)	-0.002 (0.00)
Rain deviation rainy s. $t-1$	-0.184 (0.18)	0.002 (0.00)	0.000 (0.00)	-0.001* (0.00)
Rain deviation dry s. $t-1$	-0.294* (0.15)	-0.002 (0.00)	-0.000 (0.00)	-0.000 (0.00)
Temp deviation rainy s. $t-1$	0.155 (0.20)	0.011 (0.01)	-0.001 (0.00)	-0.003 (0.00)
Temp deviation dry s. $t-1$	-0.063 (0.21)	0.011* (0.01)	-0.001 (0.00)	0.001 (0.00)
N	416	416	416	416

Standard errors corrected for autocorrelation and spatial correlation in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 11: Climatic factors and Mexico-US migration flows : impact of public policies, 2001-2012 - Cube root dependent and Fonden variables

Cube root dependent variable	Total male flows (1)	Documented male flows (2)	Undocumented male flows (3)
Hurricane in t_{-1}	0.312* (0.18)	0.103 (0.20)	0.141 (0.14)
Hurricane max intensity t_{-1}	-0.080 (0.06)	-0.075 (0.06)	-0.020 (0.05)
Nb months rain >90th ptile t_{-1}	0.012 (0.04)	0.078* (0.04)	-0.005 (0.04)
Rain deviation rainy s. t_{-1}	-0.093 (0.06)	-0.150***	-0.054 (0.06)
Rain deviation dry s. t_{-1}	-0.137*** (0.04)	-0.018 (0.05)	-0.143*** (0.05)
Temp deviation rainy s. t_{-1}	0.092 (0.07)	0.062 (0.08)	0.020 (0.06)
Temp deviation dry s. t_{-1}	-0.123 (0.08)	-0.120 (0.09)	-0.032 (0.06)
Log PROCAMPO around threshold +/- 1ha per capita t_{-1} - centered	1.297** (0.63)	1.086 (0.72)	-0.040 (0.64)
Hurricane in t_{-1} XLog PROC. thresh.+/- 1ha pcap t_{-1}	0.021 (0.11)	0.050 (0.13)	0.060 (0.08)
Nb months rain >90th ptile t_{-1} XLog PROC. thresh.+/- 1ha pcap t_{-1}	0.027 (0.03)	0.031 (0.03)	-0.015 (0.03)
Rain deviation rainy s. t_{-1} XLog PROC. thresh.+/- 1ha pcap t_{-1}	0.039 (0.03)	-0.001 (0.03)	0.017 (0.03)
Rain deviation dry s. t_{-1} XLog PROC. thresh.+/- 1ha pcap t_{-1}	0.059* (0.03)	-0.005 (0.03)	0.084** (0.04)
Temp deviation rainy s. t_{-1} XLog PROC. thresh.+/- 1ha pcap t_{-1}	-0.001 (0.03)	-0.018 (0.03)	-0.021 (0.03)
Temp deviation dry s. t_{-1} XLog PROC. thresh.+/- 1ha pcap t_{-1}	0.057 (0.05)	-0.029 (0.04)	0.075* (0.04)
Cube root Fonden per capita t_{-1}	0.031 (0.02)	0.055* (0.03)	-0.004 (0.02)
Hurricane in t_{-1} XCube root Fonden t_{-1}	-0.025 (0.03)	0.025 (0.04)	-0.042* (0.02)
Nb months rain >90th ptile t_{-1} XCube root Fonden t_{-1}	-0.011 (0.01)	-0.027** (0.01)	-0.001 (0.01)
Rain deviation rainy s. t_{-1} XCube root Fonden t_{-1}	0.022* (0.01)	0.025** (0.01)	0.014 (0.01)
Rain deviation dry s. t_{-1} XCube root Fonden t_{-1}	0.029*** (0.01)	0.009 (0.01)	0.033*** (0.01)
Temp deviation rainy s. t_{-1} XCube root Fonden t_{-1}	0.015 (0.02)	0.024 (0.02)	0.007 (0.01)
Temp deviation dry s. t_{-1} XCube root Fonden t_{-1}	0.019 (0.01)	0.002 (0.01)	0.015 (0.01)
N	384	384	384

Standard errors corrected for autocorrelation and spatial correlation in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 12: Climatic factors and Mexico-US migration flows : impact of public policies, 2001-2012 - log dependent variables

Log dependent variable	Total male flows (1)	Documented male flows (2)	Undocumented male flows (3)
Hurricane in $t-1$	0.199 (0.27)	-0.021 (0.59)	0.044 (0.25)
Hurricane max intensity $t-1$	-0.013 (0.08)	-0.112 (0.17)	0.056 (0.09)
Nb months rain >90th ptile $t-1$	0.049 (0.05)	0.201* (0.11)	0.014 (0.06)
Rain deviation rainy s. $t-1$	-0.124* (0.07)	-0.376** (0.19)	-0.072 (0.10)
Rain deviation dry s. $t-1$	-0.110* (0.06)	0.000 (0.19)	-0.135* (0.08)
Temp deviation rainy s. $t-1$	0.034 (0.07)	0.114 (0.15)	0.027 (0.10)
Temp deviation dry s. $t-1$	-0.085 (0.08)	-0.273 (0.20)	0.007 (0.10)
Log PROCAMPO around threshold +/- 1ha per capita $t-1$ - centered	1.421* (0.76)	0.914 (1.86)	-1.307 (1.62)
Hurricane in $t-1$ XLog PROC. thresh.+/- 1ha pcap $t-1$	-0.050 (0.13)	0.235 (0.23)	0.071 (0.25)
Nb months rain >90th ptile $t-1$ XLog PROC. thresh.+/- 1ha pcap $t-1$	0.050 (0.04)	0.013 (0.07)	0.037 (0.06)
Rain deviation rainy s. $t-1$ XLog PROC. thresh.+/- 1ha pcap $t-1$	0.014 (0.03)	-0.042 (0.06)	-0.023 (0.07)
Rain deviation dry s. $t-1$ XLog PROC. thresh.+/- 1ha pcap $t-1$	0.036 (0.04)	0.054 (0.06)	0.064 (0.08)
Temp deviation rainy s. $t-1$ XLog PROC. thresh.+/- 1ha pcap $t-1$	0.032 (0.03)	-0.054 (0.05)	-0.017 (0.06)
Temp deviation dry s. $t-1$ XLog PROC. thresh.+/- 1ha pcap $t-1$	0.029 (0.05)	-0.041 (0.09)	0.097 (0.09)
Inverse hyperbolic sine Fonden per capita $t-1$	0.032 (0.02)	0.060 (0.06)	0.023 (0.05)
Hurricane in $t-1$ XInv. hyperb. sine Fonden pcap $t-1$	-0.039 (0.04)	0.031 (0.10)	-0.047 (0.05)
Nb months rain >90th ptile $t-1$ XInv. hyperb. sine Fonden pcap $t-1$	-0.020* (0.01)	-0.051 (0.03)	-0.021 (0.02)
Rain deviation rainy s. $t-1$ XInv. hyperb. sine Fonden pcap $t-1$	0.026* (0.01)	0.049 (0.04)	0.017 (0.03)
Rain deviation dry s. $t-1$ XInv. hyperb. sine Fonden pcap $t-1$	0.029** (0.01)	0.028 (0.05)	0.046*** (0.01)
Temp deviation rainy s. $t-1$ XInv. hyperb. sine Fonden pcap $t-1$	0.023 (0.02)	0.046 (0.06)	0.006 (0.02)
Temp deviation dry s. $t-1$ XInv. hyperb. sine Fonden pcap $t-1$	0.013 (0.02)	0.016 (0.04)	0.007 (0.02)
Dummy for zero male flows	-7.346*** (0.40)		
Dummy for zero documented flows		-3.144*** (0.31)	
Dummy for zero undocumented flows			-4.707*** (0.50)
N	384	384	384

Standard errors corrected for autocorrelation and spatial correlation in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 13: Impact of public policies 2001-2012 - Separate regression for Fonden and PRO-CAMPO

Inv. hyperbol. sine dependent variable	Total male flows (1)	(2)	Documented male flows (3)	(4)	Undocumented male flows (5)	(6)
Hurricane in $t-1$	0.121 (0.16)	0.261 (0.19)	-0.009 (0.19)	0.078 (0.23)	-0.025 (0.15)	0.094 (0.17)
Hurricane max intensity $t-1$	-0.005 (0.06)	-0.027 (0.06)	0.022 (0.07)	-0.061 (0.08)	0.003 (0.05)	0.044 (0.06)
Nb months rain >90th ptile $t-1$	-0.023 (0.03)	0.039 (0.04)	0.031 (0.05)	0.133** (0.06)	-0.019 (0.03)	-0.000 (0.04)
Rain deviation rainy s. $t-1$	-0.052 (0.05)	-0.101 [†] (0.06)	-0.149** (0.06)	-0.242*** (0.08)	-0.015 (0.05)	-0.056 (0.07)
Rain deviation dry s. $t-1$	-0.007 (0.04)	-0.123** (0.05)	0.032 (0.05)	-0.006 (0.07)	-0.011 (0.05)	-0.121** (0.06)
Temp deviation rainy s. $t-1$	0.091 (0.06)	0.062 (0.07)	0.070 (0.08)	0.043 (0.08)	0.022 (0.06)	-0.015 (0.07)
Temp deviation dry s. $t-1$	-0.046 (0.06)	-0.074 (0.06)	-0.107 (0.08)	-0.149* (0.09)	0.021 (0.05)	0.017 (0.06)
Log PROCAMPO around threshold +/- 1ha per capita $t-1$ - centered	1.109 (0.77)		1.028 (0.97)		0.223 (0.72)	
Hurricane in $t-1$ XLog PROC. thresh.+/- 1ha pcap $t-1$	-0.028 (0.12)		-0.004 (0.16)		0.094 (0.11)	
Nb months rain >90th ptile $t-1$ XLog PROC. thresh.+/- 1ha pcap $t-1$	0.052 [†] (0.03)		0.022 (0.04)		0.012 (0.03)	
Rain deviation rainy s. $t-1$ XLog PROC. thresh.+/- 1ha pcap $t-1$	0.031 (0.03)		0.006 (0.04)		-0.007 (0.03)	
Rain deviation dry s. $t-1$ XLog PROC. thresh.+/- 1ha pcap $t-1$	0.042 (0.04)		-0.000 (0.04)		0.058 (0.04)	
Temp deviation rainy s. $t-1$ XLog PROC. thresh.+/- 1ha pcap $t-1$	0.039 (0.03)		0.005 (0.04)		0.008 (0.03)	
Temp deviation dry s. $t-1$ XLog PROC. thresh.+/- 1ha pcap $t-1$	0.047 (0.05)		-0.056 (0.06)		0.059 (0.05)	
Inverse hyperbolic sine Fonden per capita $t-1$		0.041* (0.02)		0.072* (0.04)		-0.002 (0.03)
Hurricane in $t-1$ XInv. hyperb. sine Fonden pcap $t-1$		-0.043 (0.04)		0.019 (0.05)		-0.063* (0.03)
Nb months rain >90th ptile $t-1$ XInv. hyperb. sine Fonden pcap $t-1$		-0.025** (0.01)		-0.040** (0.02)		-0.008 (0.01)
Rain deviation rainy s. $t-1$ XInv. hyperb. sine Fonden pcap $t-1$		0.025* (0.01)		0.040* (0.02)		0.017 (0.01)
Rain deviation dry s. $t-1$ XInv. hyperb. sine Fonden pcap $t-1$		0.036*** (0.01)		0.009 (0.02)		0.037*** (0.01)
Temp deviation rainy s. $t-1$ XInv. hyperb. sine Fonden pcap $t-1$		0.025 [†] (0.02)		0.030 (0.03)		0.015 (0.01)
Temp deviation dry s. $t-1$ XInv. hyperb. sine Fonden pcap $t-1$		0.011 (0.01)		0.001 (0.02)		0.007 (0.01)
N	384	384	384	384	384	384

Standard errors corrected for autocorrelation and spatial correlation in parentheses

[†] $p < 0.13$, * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 14: Climatic factors and Mexico-US migration flows : impact of public policies, 2001-2012 - standard errors clustered at the state level

Inv hyper. sine dependent variable	Total male flows (1)	Documented male flows (2)	Undocumented male flows (3)
Hurricane in t_{-1}	0.232** (0.11)	0.047 (0.18)	0.077 (0.15)
Hurricane max intensity t_{-1}	-0.021 (0.05)	-0.060 (0.07)	0.032 (0.05)
Nb months rain >90th ptile t_{-1}	0.041 (0.04)	0.133** (0.06)	0.008 (0.05)
Rain deviation rainy s. t_{-1}	-0.120** (0.05)	-0.257*** (0.09)	-0.059 (0.04)
Rain deviation dry s. t_{-1}	-0.114** (0.05)	0.000 (0.06)	-0.129** (0.06)
Temp deviation rainy s. t_{-1}	0.048 (0.08)	0.011 (0.09)	-0.011 (0.08)
Temp deviation dry s. t_{-1}	-0.087 (0.06)	-0.131 (0.09)	0.004 (0.06)
Log PROCAMPO around threshold +/- 1ha per capita t_{-1} - centered	0.968 (0.95)	1.065 (1.13)	0.068 (1.24)
Hurricane in t_{-1} XLog PROC. thresh.+/- 1ha pcap t_{-1}	-0.022 (0.08)	0.028 (0.15)	0.087 (0.08)
Nb months rain >90th ptile t_{-1} XLog PROC. thresh.+/- 1ha pcap t_{-1}	0.053 (0.04)	0.028 (0.05)	0.009 (0.05)
Rain deviation rainy s. t_{-1} XLog PROC. thresh.+/- 1ha pcap t_{-1}	0.018 (0.02)	-0.010 (0.04)	-0.013 (0.03)
Rain deviation dry s. t_{-1} XLog PROC. thresh.+/- 1ha pcap t_{-1}	0.043 (0.04)	-0.010 (0.06)	0.063* (0.04)
Temp deviation rainy s. t_{-1} XLog PROC. thresh.+/- 1ha pcap t_{-1}	0.026 (0.02)	-0.002 (0.04)	-0.006 (0.03)
Temp deviation dry s. t_{-1} XLog PROC. thresh.+/- 1ha pcap t_{-1}	0.044 (0.04)	-0.068 (0.06)	0.061 (0.05)
Inverse hyperbolic sine Fonden per capita t_{-1}	0.035 (0.03)	0.064 (0.06)	-0.003 (0.03)
Hurricane in t_{-1} XInv. hyperb. sine Fonden pcap t_{-1}	-0.034 (0.04)	0.026 (0.06)	-0.056† (0.03)
Nb months rain >90th ptile t_{-1} XInv. hyperb. sine Fonden pcap t_{-1}	-0.023* (0.01)	-0.039 (0.03)	-0.008 (0.01)
Rain deviation rainy s. t_{-1} XInv. hyperb. sine Fonden pcap t_{-1}	0.025 (0.02)	0.043 (0.03)	0.015 (0.01)
Rain deviation dry s. t_{-1} XInv. hyperb. sine Fonden pcap t_{-1}	0.032** (0.01)	0.007 (0.01)	0.038** (0.02)
Temp deviation rainy s. t_{-1} XInv. hyperb. sine Fonden pcap t_{-1}	0.024 (0.02)	0.036 (0.03)	0.013 (0.01)
Temp deviation dry s. t_{-1} XInv. hyperb. sine Fonden pcap t_{-1}	0.013 (0.01)	-0.000 (0.02)	0.010 (0.01)
N	384	384	384

Standard errors clustered at the state level in parentheses
† $p < 0.12$, * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 15: Climatic factors and Mexico-US migration flows : impact of public policies, 2001-2012 - including additional controls

Inv. hyp. sine dependent variable	Total male flows (1)	Documented male flows (2)	Undocumented male flows (3)
Hurricane in $t-1$	0.270 (0.20)	0.021 (0.22)	0.135 (0.17)
Hurricane max intensity $t-1$	-0.026 (0.07)	-0.050 (0.07)	0.018 (0.06)
Nb months rain >90th ptile $t-1$	0.035 (0.04)	0.148*** (0.06)	-0.007 (0.05)
Ln GDP per capita $t-1$	0.703** (0.28)	0.601 (0.40)	0.258 (0.22)
Ln GDP per capita $t-1$ X post 2003	-0.211 (0.18)	-0.525*** (0.17)	0.138 (0.18)
Unemployment rate $t-1$	0.023 (0.04)	-0.052 (0.05)	0.069** (0.03)
Ln share of homicides $t-1$	-0.044 (0.08)	0.002 (0.12)	-0.123* (0.07)
Rain deviation rainy s. $t-1$	-0.105 [†] (0.06)	-0.250*** (0.08)	-0.049 (0.07)
Rain deviation dry s. $t-1$	-0.104** (0.05)	0.002 (0.07)	-0.119* (0.06)
Temp deviation rainy s. $t-1$	0.020 (0.06)	-0.009 (0.08)	-0.026 (0.07)
Temp deviation dry s. $t-1$	-0.061 (0.07)	-0.108 (0.10)	0.015 (0.07)
Log PROCAMPO around threshold +/- 1ha per capita $t-1$ - centered	0.452 (0.74)	0.277 (0.91)	0.015 (0.75)
Hurricane in $t-1$ XLog PROC. thresh./+/- 1ha pcap $t-1$	-0.002 (0.12)	0.052 (0.16)	0.091 (0.10)
Nb months rain >90th ptile $t-1$ XLog PROC. thresh./+/- 1ha pcap $t-1$	0.051 [†] (0.03)	0.028 (0.04)	0.007 (0.03)
Rain deviation rainy s. $t-1$ XLog PROC. thresh./+/- 1ha pcap $t-1$	-0.003 (0.03)	-0.039 (0.04)	-0.015 (0.03)
Rain deviation dry s. $t-1$ XLog PROC. thresh./+/- 1ha pcap $t-1$	0.025 (0.04)	-0.025 (0.04)	0.053 (0.05)
Temp deviation rainy s. $t-1$ XLog PROC. thresh./+/- 1ha pcap $t-1$	0.003 (0.03)	-0.033 (0.04)	-0.006 (0.03)
Temp deviation dry s. $t-1$ XLog PROC. thresh./+/- 1ha pcap $t-1$	0.034 (0.05)	-0.088 [†] (0.06)	0.064 (0.05)
Inverse hyperbolic sine Fonden per capita $t-1$	0.032 (0.02)	0.075** (0.04)	-0.011 (0.03)
Hurricane in $t-1$ XInv. hyperb. sine Fonden pcap $t-1$	-0.039 (0.03)	0.026 (0.04)	-0.059* (0.03)
Nb months rain >90th ptile $t-1$ XInv. hyperb. sine Fonden pcap $t-1$	-0.024** (0.01)	-0.042** (0.02)	-0.008 (0.01)
Rain deviation rainy s. $t-1$ XInv. hyperb. sine Fonden pcap $t-1$	0.026** (0.01)	0.038** (0.02)	0.019 (0.01)
Rain deviation dry s. $t-1$ XInv. hyperb. sine Fonden pcap $t-1$	0.036*** (0.01)	0.009 (0.02)	0.039*** (0.01)
Temp deviation rainy s. $t-1$ XInv. hyperb. sine Fonden pcap $t-1$	0.026 [†] (0.02)	0.031 (0.02)	0.020 (0.01)
Temp deviation dry s. $t-1$ XInv. hyperb. sine Fonden pcap $t-1$	0.013 (0.01)	-0.004 (0.02)	0.011 (0.01)
N	384	384	384

Standard errors corrected for autocorrelation and spatial correlation in parentheses

[†] $p < 0.12$, * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 16: Climatic factors and Mexico-US migration flows : impact of public policies, 2001-2012 - without 2010 (2009 being an exceptional drought)

Inv. hyp. sine dependent variable	Total male flows (1)	Documented male flows (2)	Undocumented male flows (3)
Hurricane in t_{-1}	0.268 (0.21)	0.077 (0.24)	0.118 (0.19)
Hurricane max intensity t_{-1}	-0.021 (0.07)	-0.063 (0.08)	0.025 (0.06)
Nb months rain >90th ptile t_{-1}	0.033 (0.05)	0.117** (0.06)	-0.000 (0.05)
Rain deviation rainy s. t_{-1}	-0.097 (0.07)	-0.225*** (0.08)	-0.036 (0.08)
Rain deviation dry s. t_{-1}	-0.122** (0.06)	-0.012 (0.07)	-0.139** (0.06)
Temp deviation rainy s. t_{-1}	0.037 (0.07)	0.005 (0.08)	-0.024 (0.07)
Temp deviation dry s. t_{-1}	-0.083 (0.07)	-0.121 (0.11)	0.015 (0.07)
Log PROCAMPO around threshold +/- 1ha per capita t_{-1} - centered	0.919 (0.81)	0.545 (0.95)	0.102 (0.85)
Hurricane in t_{-1} XLog PROC. thresh.+/- 1ha pcap t_{-1}	-0.010 (0.14)	0.025 (0.17)	0.114 (0.11)
Nb months rain >90th ptile t_{-1} XLog PROC. thresh.+/- 1ha pcap t_{-1}	0.059 (0.04)	0.018 (0.05)	0.007 (0.04)
Rain deviation rainy s. t_{-1} XLog PROC. thresh.+/- 1ha pcap t_{-1}	0.016 (0.03)	-0.015 (0.04)	-0.012 (0.03)
Rain deviation dry s. t_{-1} XLog PROC. thresh.+/- 1ha pcap t_{-1}	0.030 (0.04)	-0.022 (0.04)	0.064 (0.05)
Temp deviation rainy s. t_{-1} XLog PROC. thresh.+/- 1ha pcap t_{-1}	0.028 (0.03)	-0.008 (0.04)	-0.007 (0.04)
Temp deviation dry s. t_{-1} XLog PROC. thresh.+/- 1ha pcap t_{-1}	0.037 (0.05)	-0.084 (0.06)	0.060 (0.05)
Inverse hyperbolic sine Fonden per capita t_{-1}	0.041* (0.02)	0.062 (0.04)	0.000 (0.03)
Hurricane in t_{-1} XInv. hyperb. sine Fonden pcap t_{-1}	-0.046 (0.04)	0.014 (0.05)	-0.059* (0.03)
Nb months rain >90th ptile t_{-1} XInv. hyperb. sine Fonden pcap t_{-1}	-0.025* (0.01)	-0.039** (0.02)	-0.009 (0.01)
Rain deviation rainy s. t_{-1} XInv. hyperb. sine Fonden pcap t_{-1}	0.024* (0.01)	0.045** (0.02)	0.014 (0.02)
Rain deviation dry s. t_{-1} XInv. hyperb. sine Fonden pcap t_{-1}	0.035*** (0.01)	0.010 (0.02)	0.041*** (0.01)
Temp deviation rainy s. t_{-1} XInv. hyperb. sine Fonden pcap t_{-1}	0.034** (0.02)	0.049* (0.03)	0.018 (0.02)
Temp deviation dry s. t_{-1} XInv. hyperb. sine Fonden pcap t_{-1}	0.013 (0.02)	0.001 (0.02)	0.010 (0.01)
N	352	352	352

Standard errors corrected for autocorrelation and spatial correlation in parentheses

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

Table 17: Climatic factors and Mexico-US migration flows, 2001-2012 : impact of public policies - dropping bottom 5 percents

Inv. hyp. sine dependent variable	Total male flows (1)	Documented male flows (2)	Undocumented male flows (3)
Hurricane in t_{-1}	0.195 (0.17)	0.019 (0.23)	0.054 (0.16)
Hurricane max intensity t_{-1}	-0.030 (0.05)	-0.073 (0.07)	0.021 (0.05)
Nb months rain >90th ptile t_{-1}	0.034 (0.04)	0.109* (0.06)	0.011 (0.05)
Rain deviation rainy s. t_{-1}	-0.108** (0.05)	-0.265*** (0.07)	-0.040 (0.06)
Rain deviation dry s. t_{-1}	-0.152*** (0.05)	0.039 (0.08)	-0.156*** (0.05)
Temp deviation rainy s. t_{-1}	0.050 (0.06)	0.002 (0.08)	-0.007 (0.06)
Temp deviation dry s. t_{-1}	-0.128* (0.07)	-0.095 (0.11)	-0.040 (0.07)
Log PROCAMPO around threshold +/- 1ha per capita t_{-1} - centered	1.871*** (0.69)	0.861 (1.05)	1.527** (0.67)
Hurricane in t_{-1} XLog PROC. thresh.+/- 1ha pcap t_{-1}	-0.101 (0.10)	-0.011 (0.15)	-0.012 (0.10)
Nb months rain >90th ptile t_{-1} XLog PROC. thresh.+/- 1ha pcap t_{-1}	0.029 (0.03)	-0.009 (0.04)	0.010 (0.04)
Rain deviation rainy s. t_{-1} XLog PROC. thresh.+/- 1ha pcap t_{-1}	0.028 (0.03)	-0.010 (0.04)	-0.018 (0.03)
Rain deviation dry s. t_{-1} XLog PROC. thresh.+/- 1ha pcap t_{-1}	0.032 (0.04)	0.001 (0.04)	0.033 (0.04)
Temp deviation rainy s. t_{-1} XLog PROC. thresh.+/- 1ha pcap t_{-1}	0.023 (0.03)	-0.021 (0.03)	0.009 (0.03)
Temp deviation dry s. t_{-1} XLog PROC. thresh.+/- 1ha pcap t_{-1}	0.017 (0.05)	-0.094 (0.06)	0.035 (0.05)
Inverse hyperbolic sine Fonden per capita t_{-1}	0.012 (0.02)	0.033 (0.04)	-0.007 (0.03)
Hurricane in t_{-1} XInv. hyperb. sine Fonden pcap t_{-1}	-0.024 (0.03)	0.047 (0.05)	-0.043 (0.03)
Nb months rain >90th ptile t_{-1} XInv. hyperb. sine Fonden pcap t_{-1}	-0.011 (0.01)	-0.022 (0.02)	-0.007 (0.01)
Rain deviation rainy s. t_{-1} XInv. hyperb. sine Fonden pcap t_{-1}	0.023** (0.01)	0.044** (0.02)	0.016 (0.01)
Rain deviation dry s. t_{-1} XInv. hyperb. sine Fonden pcap t_{-1}	0.023** (0.01)	-0.007 (0.02)	0.029** (0.01)
Temp deviation rainy s. t_{-1} XInv. hyperb. sine Fonden pcap t_{-1}	0.024 (0.01)	0.048* (0.03)	0.016 (0.01)
Temp deviation dry s. t_{-1} XInv. hyperb. sine Fonden pcap t_{-1}	0.014 (0.02)	-0.007 (0.02)	0.005 (0.02)
N	364	364	364

Standard errors corrected for autocorrelation and spatial correlation in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Appendix D: Reforms of PROCAMPO

The first reform of PROCAMPO was the extension of the program to plots planted in any legal crop, as well as areas with livestock or under forestry exploitation (autumn-winter cycle 1995-96). Several pro-poor reforms were carried out, in 2001, 2002-2003 and 2009. Starting in 2001, rainfed plots smaller than one hectare cultivated in the Spring Summer cycle received a payment corresponding to one full hectare. The 2002-2003 reform increased in particular the amount per hectare received by small producers. In 2003, the rainfed plots cultivated in the Spring-Summer cycle were entitled to an increased amount, called *cuota preferente*, if their area was under 5 hectares. This increased amount was then reevaluated each year, in 2004 and 2005. In 11 states of the North ⁴¹, where land is dryer and rainfed plots are larger, the threshold was higher (from 6 hectares in Aguascalientes to 18 hectares in Baja California). The 2009 reform established a maximum amount of one hundred thousand pesos (approximately 7,000 US dollars) per beneficiary and agricultural cycle and increased the amount received by small non-irrigated plots in the spring cycle (Fox and Haight, 2010)⁴². The threshold for small plots was at the same time set to 5 hectares in all Mexican States.

⁴¹Aguascalientes, Baja California, Baja California Sur, Colima, Chihuahua, Durango, Jalisco, Sinaloa, Sonora, Tamaulipas and Zacatecas.

⁴²Rainfed plots of less than 5 hectares cultivated in the Spring Summer cycle benefited from an additional increase, the *cuota alianza*. The amount received jumped from MXN 1160 to MXN 1300 per hectare (approximately 100 US dollars).