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

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## Abstract

This paper uses state-level migration flow data between Mexico and the U.S. from 1999 to 2011 to investigate the migration response to climate shocks and the mitigating impact of an agricultural cash-transfer program (PROCAMPO) and a disaster fund (Fonden). Our results suggest that lower than average precipitations increase undocumented migration, especially from the most agricultural states. Fonden amounts are found to mitigate the effect of climate shocks on migration by lowering the undocumented migration response to precipitation anomalies. Similarly an increase in the state-level share of PROCAMPO funds to non-irrigated plots in the *ejido* sector decreases migration after a shock.

*Keywords* : International migration ; Climate change ; Public policies; Weather variability; Natural disasters ; Mexico-U.S. migration

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

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# 1 Introduction

Among the many consequences of climate change on economic activity, its impact on human mobility is a key issue. According to the UNHCR, individuals are today twice more likely to be forced to migrate due to environmental disasters than in 1970. The Internal Displacement Monitoring Centre estimates to 17.5 million the number of people displaced by weather-related disasters in 2014. However, these figures only capture the most visible part of climate-induced migration. 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). The impact of climate change on migration is found to be higher 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 cope with climatic shocks. However, in the rapidly growing body of literature concerned by the impact of climate change on migration, the mitigating role of public policies, though critical, has remained largely unexplored.

Taking advantage of a unique panel database on yearly Mexico-US migrant flows at the Mexican state level from 1999 to 2011, this paper investigates the impact of climatic factors on migration and the mitigating impact of two public programs, the cash-transfer agricultural program PROCAMPO, and the disaster fund Fonden. Following Chort and De La Rupelle (2016), the migration flow database is constructed based on individual data from the Survey of Migration at the Northern Border of Mexico (*Encuesta sobre Migración en la Frontera Norte de México* or EMIF Norte). Information on Mexican states of origin and survey weights are used to obtain yearly migration outflows from each Mexican state. In spite of the unusual design of the EMIF aimed at capturing transit migrants, the data collected, once aggregated, have been found to be fairly representative of Mexico-US migrant flows (Rendall et al., 2009)<sup>1</sup>. Three unique features and major

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<sup>1</sup>See also Chort and De La Rupelle (2016) for a detailed discussion of the advantages and drawbacks

advantages of the migration flow data constructed from the EMIF are the availability of a 13 year panel, the fine level of regional disaggregation, and the possibility to analyze documented and undocumented flows separately. The longitudinal dimension and infra-country level of disaggregation of our data allow us to control for all time-invariant specific characteristics of Mexican states of origin and year effects common to all Mexican states by using origin and year fixed-effects, and to deal with serial and spatial correlation issues following [Hsiang \(2010\)](#). The third characteristic of our data is that they provide us with rare information on illegal immigration flows to the US over a 15 year period, thus contributing to filling this gap in the migration literature ([Hanson, 2006](#)).

Migration flow data are merged to information on hurricanes coming from the US National Oceanic and Atmospheric Administration and satellite and land data on precipitations and temperatures. We take in particular advantage of the excellent satellite data provided by the Tropical Rainfall Measuring Mission, which was launched in 1997. This product, specifically designed to measure rainfalls in tropical contexts like the Mexican area, has two main features. First, it combines accurate satellite measures (it was the first to incorporate a precipitation radar and it relies on various state-of-the-art sensors), with local rain gauges. Second, it provides very fine grid data ( $0.25 \times 0.25$  degree) covering the whole territory<sup>2</sup>. This is an important feature given that our study is focused on infra-country phenomena, observed at the federated state level. The administrative borders of many federated states in Mexico are linked to the local topography and rugged terrain implies that precipitations can be very different across both sides of a border, justifying the use of high-definition data.

Finally, we combine migration and climate data with information on state-level payments of two governmental programs, the PROCAMPO program run by the Mexican Ministry of Agriculture (SAGARPA), and the disaster fund Fonden. The two programs, though of very different nature, are of particular relevance as PROCAMPO is the largest

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of using the EMIF data to construct migration flow aggregates.

<sup>2</sup>As a basis for comparison, the Standardized Precipitation-Evapotranspiration Index (SPEI) widely used in the literature ([Harari and La Ferrara, 2013](#)) is available at a  $0.5 \times 0.5$  degree definition which implies that each cell covers an area that is four times as large.

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. The specificities of each program imply that they may have a different mitigating impact. [Sadoulet et al. \(2001\)](#) find an income multiplier of 1.5-2.6 for the poorest category of PROCAMPO beneficiaries, which suggests 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. Beneficiaries of PROCAMPO are highly heterogenous, in particular due to the existence of the *ejido* sector which represents about half of the agricultural land, and around 60% of the agricultural population<sup>3</sup>. Households in the *ejido* sector are on average poorer and have significantly contributed to migration to the US ([Janvry et al., 1997](#)). Moreover, non-irrigated crops are expected to be more sensitive to climate anomalies. For those reasons, we choose to focus on the state-level share of transfers under PROCAMPO that are received by producers in the *ejido* sector for non-irrigated land.

The evaluation of the economic impact of the Fonden fund provided by [de Janvry et al. \(2016\)](#) shows a positive and sustained effect of the program on local economic activity and employment, suggesting that Fonden may affect migration responses to climatic shocks through different channels. The different mechanisms through which those two programs may impact migration after climate shocks are discussed in the following section.

We estimate OLS regressions using panel data over 1999-2011 on state-level Mexico-US migration flows with state and year fixed effects, standard errors being corrected for serial and spatial correlation. Among the main results of our empirical analysis, we provide evidence of a positive impact of lower than average rainfall during the dry season on migration flows from Mexico to the US, supporting the assumption of drought driven

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<sup>3</sup>The *ejido* sector characterizes communal land created by the land reform following the 1910 revolution. Members of agrarian communities were allocated land use rights, provided that they would not leave land uncultivated for more than two years.

migration and consistent with previous research on Mexico (Munshi, 2003; Pugatch and Yang, 2011; Chort, 2014; Chort and De La Rupelle, 2016). Being here able to separate documented and undocumented flow, we show that the latter finding is mostly driven by undocumented flows: drought at origin increases the flows of undocumented Mexicans immigrants to the United-States. Moreover, we find evidence of an heterogenous impact of climatic shocks on undocumented migrant flows: sizeable and significant effects are observed only for the most agricultural states which are ex-ante the most vulnerable, consistent with Beine and Parsons (2015) and Coniglio and Pesce (2015). Regarding the role of public policies, we find a mitigating impact of Fonden on the undocumented migration response to drought. Similarly, an increase in the share of PROCAMPO funds received by the *ejido* sector for non-irrigated land is found to decrease migration in response to abnormally low rainfall.

This article provides a bridge between the macroeconomic and microeconomic literature on the impact of climate on migration, as it focuses on a single country but explores the regional dynamics of climate-induced migrations by exploiting a panel of state level migration flows over a 13 year period. Our approach is fully in line with the macroeconomic literature on climate-induced migration initiated by Beine and Parsons (2015). We contribute to this strand of research by showing that climate shocks have heterogeneous impacts on migration not only depending on the season of the shock or the ex-ante vulnerability of locations of origin (Beine and Parsons, 2015; Coniglio and Pesce, 2015), but also on the type of migration, documented or undocumented.

In addition, our paper contributes to the literature investigating the impact of public policies on migration. In the Mexican context, most studies have focused on the large anti-poverty PROGRESA/*Oportunidades* program. Early evaluations of the PROGRESA anti-poverty program suggest that conditional cash-transfers reduce migration to the U.S. (Stecklov et al., 2005). By contrast, 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 heterogeneous impacts on different migrant flows. Consistent with this intuition, our results suggest that the two programs that we study have different impacts on documented and undocumented flows. We do not investigate here the potential mitigating impact of PROGRESA/*Oportunidades* because the program underwent substantial changes over the period of interest which are unlikely to be fully exogenous to ex-ante migration trends. We choose in this study to focus on the impact of two Mexican government programs explicitly related to climate (Fonden) and agriculture (PROCAMPO) which we believe to be arguably exogenous to migration.

## 2 Context and theoretical mechanisms

### 2.1 Climate and migration in Mexico

Studying the consequences of weather variability on migration in the Mexican context is particularly interesting for three reasons. First Mexico sits astride the Tropic of Cancer and has a large diversity of climatic characteristics, although almost all parts of the country are subject to hurricanes and tropical storms in summer and autumn<sup>4</sup>. Second, the economy of Mexican rural areas largely depends on agricultural activities<sup>5</sup>. 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](#)), while extreme phenomena such as hurricanes are expected to be more frequent and violent ([Emanuel, 2013](#); [Mendelsohn et al., 2012](#)). Although climate change is a long term phenomenon, focusing on the

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<sup>4</sup>The most recent 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.

<sup>5</sup>Although the share of agriculture in the Mexican GDP is low (3.5% in 2010-2014) agricultural employment represents 13 % of total employment and 21% of the population live in rural areas (World Development Indicators, The World Bank).

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.

In the context of Mexico, a number of previous papers have incidentally stressed the role of climatic events on migration (Munshi (2003), Pugatch and Yang (2011), Chort (2014), Chort and De La Rupelle (2016)). However, to date, few empirical studies have specifically focused on the impact of environmental factors on Mexican 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 census<sup>6</sup>. The contribution of our paper to this literature is twofold. First, we complement existing evidence on climate induced Mexico-US migration by exploiting longitudinal yearly data on a relatively long period and by analyzing separately documented and undocumented flows. Second and most importantly, while previous studies exclusively focused on the effect of climate shocks, we investigate and compare the potential mitigating impact of different public policies.

## 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,

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<sup>6</sup>All these issues are also conceptually discussed in Cohen et al. (2013) but without econometric validation, while Eakin (2005) uses ethnographic data to analyze the vulnerability of rural households to climatic hazards.



cotton, safflower and barley) in the three year period preceding the implementation of the program. The program went through several reforms, the first one being 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). Two pro-poor reforms were carried out, in 2002 and 2009, the 2002 reform increasing in particular the amount per hectare received by small producers, and the 2009 modification establishing a maximum amount of one hundred thousand pesos per beneficiary and agricultural cycle (Fox and Haight, 2010). Eligible producers receive cash transfers on a per-hectare basis twice a year, for each growing season. In an early evaluation of the program, Sadoulet et al. (2001) find a high multiplier for PROCAMPO transfers, consistent with the existence of liquidity constraints and suggesting that received amounts are massively invested by producers in agricultural inputs. While average payments in real terms tend to decline over the period, the different pro-poor reforms contributed to maintain the level of transfers to small producers (less than 5 ha) to around MXN 600 in constant 1994 prices<sup>7</sup>. Although PROCAMPO benefits are totally unrelated to climate events, this program is interesting as 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 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. (De Janvry et al., 2012; Valsecchi, 2014). Moreover, rainfed agriculture is expected to be more vulnerable to climate anomalies. We thus choose to focus on the state-level share of PROCAMPO funds received by producers in the *ejido* sector for non-irrigated

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<sup>7</sup>About USD 100 in 2010.

land, rather than on total amounts distributed.

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; de Janvry et al., 2016). Following an adverse shock, the procedure is launched with a declaration of a natural disaster and is subject to the decision of a damage assessment committee. The list of natural events qualifying for the program is not closed and includes in particular the following hydro-meteorological events: severe hail, hurricane, river flooding, rain flooding, severe rain, severe snow, severe drought, tropical storm, tornado. Since the start of the program, an average of 30 declarations of natural disasters has been registered each year. An evaluation of the impact of the program on economic recovery is provided by de Janvry et al. (2016) 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 contemporaneous climate shocks.

Importantly, 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. Indeed, entitlement to PROCAMPO is only based on agricultural land use and Fonden is explicitly targeted at natural disasters that are unpredictable and exogenous to migration decisions.

### **2.3 Theoretical mechanisms**

We discuss in this section the impact of two different types of public programs on climate-induced migration, an unconditional cash-transfer program, and a disaster fund, to mimic

the characteristics of the two programs, PROCAMPO and Fonden, presented above<sup>8</sup>. For simplicity, we choose to represent in the following discussion migration as an individual decision and to ignore remittances. While remittances are likely to contribute to explaining migration decision, especially after a shock, ignoring them is not expected to severely alter our predictions regarding the mitigating impact of public programs. Indeed, remittances received are likely to increase after a shock but they are unlikely to be correlated with public funds<sup>9</sup>. In spite of the 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.

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. Their utility depends additively on their wage, and on local amenities  $A_{H,1}$ . Utility of individual  $i$  in period 1 is given by:

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

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

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

where  $w_{F,i,2}$  is the foreign wage ( $w_{F,i,2} = \beta_{F,2}x_i$ ), depending on individual skills  $x_i$  and

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<sup>8</sup>Strictly speaking, the cash-transfers under PROCAMPO are not unconditional, but what matters in our study is that entitlement to the program is not affected by the migration of one household member provided that part of the household stays and maintains an agricultural activity.

<sup>9</sup>Remittances are not included either in the empirical analysis, for lack of state-level yearly data.

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, period 1 utility writes:

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

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

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

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

with  $\gamma_1 \leq \gamma_2 \leq 1$  and  $\delta_1 \leq \delta_2 \leq 1$ , as we assume both a persistence of the impact of shocks occurred in period 1 and an attenuation between period 1 and 2. Shocks are

assumed not to affect outcomes at destination.

Individual  $i$  decides to migrate if and only if:

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

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 climatic 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  $\gamma$  and  $\delta$  parameters at each period, and on the degree of persistence of the impact over the two periods.

However, more than the impact of a shock on migration, what is of interest for us is the potentially mitigating effect of public policies. We focus on two types of programs, an unconditional agricultural cash transfer program, and a disaster fund. The cash transfer program 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. Indeed, the operational rules and characteristics of PROCAMPO make it comparable to an unconditional cash-transfer program: provided that the migrant leaves at least one member of the household behind and that an agricultural activity is maintained, she retains her entitlement to the benefits of the program. 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.

The cash-transfer program thus affects individuals' maximization program in the following way. 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

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

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  $\alpha T$  ( $\gamma_2' > 0$ ), meaning that the recovery rate of agricultural productivity is increasing with the share of the first-period transfer that is invested in agriculture. As the transfer is assumed to be unconditional, the second-period transfer  $T$  appears on both sides of the inequality in [Equation 8](#). 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  $\alpha_i$  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 [de Janvry et al. \(2016\)](#), 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 writes:

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

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 climate shock is indeterminate, the disaster fund is found 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 climatic shock.

## 3 Data

### 3.1 Migration flows

Following [Chort and De La Rupelle \(2016\)](#), the migration flow data used in this paper are constructed from the EMIF surveys (Encuesta sobre Migración en la Frontera Norte

de México)<sup>10</sup>, 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 interviewed<sup>11</sup>. The representativeness of the EMIF data is assessed by [Rendall et al. \(2009\)](#) who conclude to the particularly good coverage of male flows and undocumented flows<sup>12</sup>. 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 13 waves of the EMIF survey that could be matched with climatic data covering the 1999-2011 period. As in [Chort and De La Rupelle \(2016\)](#), we choose to focus on male flows, since according to [Rendall et al. \(2009\)](#) the EMIF tends to under-represent migrant women. Using information collected in the survey, we are able to identify authorized and unauthorized migrants, and thus to separately analyze documented and undocumented migration flows<sup>13</sup>.

For a relatively small number of observations, we observe zero total and/or undocumented flows (5 state-year cells for total flows representing 1% of observations, and 12 state-year cells for undocumented flows representing 2.5% of the total 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. We explore two alternative ways of dealing with this issue. First, we set the value of the log migration rate to  $\ln(0.001)$  and

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<sup>10</sup><http://www.colef.net/emif/>

<sup>11</sup>The survey design is described in detail in each yearly report provided by the EMIF team, available at: <http://www.colef.mx/emif/publicacionesnte.php> and additional information on the survey design and the computation of the sampling weights are provided on the website of the EMIF (<http://www.colef.net/emif/diseniometodologico.php>).

<sup>12</sup>The advantages and drawbacks of using the EMIF data to analyze Mexico-US migration flows are also extensively discussed in [Chort and De La Rupelle \(2016\)](#)

<sup>13</sup>Undocumented migrants are defined as individuals who declare having no document to cross the border nor to work in the US.



control in all regressions for a dummy variable equal to one when the flow is zero. An arguably more adequate treatment of zero flows consists in taking the cube root function of the dependent variable rather than the log. The different methods provide very similar results. We choose to present in the main tables of the paper the results obtained with the cube root transformation of the migrant share, while regression results obtained with the alternative treatment of zero flows are shown in Appendix (Table 5)<sup>14</sup>.

Descriptive statistics are provided in Table 4. 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 1999-2011) are undocumented. From 2004 to 2011, 43.5% of documented migrants declare that they migrate for family reasons whereas 97% of undocumented migrants intend to migrate to the U.S. to work or in search of a job<sup>15</sup>. Note that the share of documented migrants migrating to join a family member has continuously increased over the period, reaching 60.2% in 2011, which reflects tightening migration restrictions in the U.S. These statistics confirm that documented and undocumented migrants flows have specific characteristics and must be studied separately.

### 3.2 Climatic shocks, economic variables, and public programs

We construct a state-level data set of hurricanes affecting Mexico between 1990 and 2012, from the Historical Hurricane Track tool developed by the U.S. National Oceanic and Atmospheric Administration (NOAA)<sup>16</sup>. We gather information on the number and intensity of hurricanes and storms affecting each Mexican State and create two yearly state-level variables for the number of hurricanes and storms, and the maximum storm intensity registered in the year.

In addition, we use satellite data from the “Tropical Rainfall Measuring Mission”

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<sup>14</sup>Alternative methods may seem more adequate to dealing with zero values of the dependent variable, such as the Poisson pseudo-maximum likelihood (PPML) estimator. However, the advantages of the PPML estimator, limited given the relatively small proportion of zeros, are outbalanced by the fact that it does not allow to correct for spatial and serial correlation or error terms, are outbalanced by the fact that it does not allow to correct for spatial and serial correlation or error terms.

<sup>15</sup>Detailed information on the main reason for migration is available since 2004 only.

<sup>16</sup><http://www.csc.noaa.gov/hurricanes/>

(TRMM)<sup>17</sup> 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 variables<sup>18</sup>. We construct rainfall and temperature state-level variables for the two main meteorological seasons in Mexico, the rainy season (spanning from May to October) and the dry season<sup>19</sup>. Following [Beine and Parsons \(2015\)](#), we create state-level normalized rainfall and air temperature variables (z-scores). However, we construct those measures of climate anomalies at the seasonal level, as seasonal variables have been found to be more relevant and precise than yearly indicators ([Hsiang, 2010](#); [Coniglio and Pesce, 2015](#))<sup>20</sup>.

Data on income, population, agriculture and crime come from the Mexican Instituto Nacional de Estadística y Geografía (INEGI)<sup>21</sup>. Since the definition of GDP aggregates

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<sup>17</sup>A survey published in 1998 in the *American Journal of Agricultural Economics* stresses the progress expected in improved climate measure and forecast from the TRMM mission.

<sup>18</sup>Alternative measures of climate shocks such as the Palmer Drought Severity Index (PDSI) or the Standardized Precipitation-Evapotranspiration Index (SPEI) are less suitable to our analysis as their resolution is lower (2.5 x 2.5 degree for the PDSI, 0.5 x 0.5 degree for the SPEI).

<sup>19</sup>We also investigate the impact of yearly shocks, but find no significant effect on migration (results available upon request).

<sup>20</sup>To construct seasonal z-scores, we first assign grid points to states based on latitude and longitude coordinates, then compute state-level total precipitations or average temperatures for each season, state-level long term seasonal averages and state-level seasonal standard deviations. Long term averages are obtained by combining the land and satellite data sources described above. The normalized variable is the state-level rainfall or temperature value minus the state-level long-run mean, divided by the state-level standard deviation over the observation period. For example, a positive value for the rainfall z-score for year  $t$  and season  $s$  in state  $i$  means that for year  $t$ , season  $s$  has been an especially rainy season in state  $i$ . Conversely, a negative value means that precipitations have been lower than (long-term) average in state  $i$  and season  $s$  of year  $t$ .

<sup>21</sup>Some of our variables taken from the census, and in particular Mexican population at the state level, are linearly extrapolated for the years in which they are not available.

by the INEGI has changed in 2003, we interact the lagged GDP variable with a dummy equal to one for years 2004 to 2009.

State level data on PROCAMPO payments were aggregated based on individual data provided by the Mexican ministry of agriculture (SAGARPA), which allows us to construct the share of total transfers at the state level received by individuals in the *ejido* sector. Aggregate data on total annual amounts distributed at the state level under the Fonden program come from the open data Mexican government’s website<sup>22</sup>.

## 4 Empirical model

We first estimate a regression of climate variables on migration, and then add interactions with variables for public policies. All regressions are panel regressions with origin and year fixed-effects, and are estimated with OLS. As common or idiosyncratic unobserved characteristics of states may induce serial and spatial correlation or error terms, we provide non-parametric estimates of the variance of the coefficients following [Conley and Ligon \(2002\)](#)<sup>23</sup>. Equations including public policies whose estimation results are shown in [Table 3](#) are of the following type:

$$\begin{aligned}
 MIGR_{i,t} = & \beta'_1 CLIM_{i,t-1,s} + \beta'_2 CLIM_{i,t-1,s} \times POL_{i,t-1} + \beta_3 POL_{i,t-1} \\
 & + \delta \ln GDP_{i,t-1} + \gamma' Z_{i,t-1} + D_i + D_t + \epsilon_{i,t}
 \end{aligned}$$

with  $MIGR_{i,t}$  the cube root of the migration rate from Mexican origin state  $i$  at time  $t$  (per 10,000 population),  $CLIM_{i,t-1,s}$  a set of climatic variables measured in origin state

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<sup>22</sup><https://datos.gob.mx/>

<sup>23</sup>The code for STATA developed by [Hsiang \(2010\)](#), based on [Conley \(1999\)](#) is available at <http://www.fight-entropy.com/2010/06/standard-error-adjustment-ols-for.html>. We modified it in order to account for fixed-effects and we corrected for the subsequent loss of degree of freedom. Parameters are estimated by OLS, and standard errors are corrected accounting for serial correlation over 1 period and for spatial correlation up to a distance cutoff set at 800km, representing the mean value of the distance between the capital cities of pairs of Mexican states. All results are robust to allowing for autocorrelation over 2 periods and to a 500km distance cutoff, representing the median value of the distance between the capital city of each state and Mexico city.

$i$  and season  $s$  of year  $t - 1$ , including rainfall and temperature anomalies and  $POL_{i,t-1}$  represents either the state-level amounts distributed under Fonden or the state-level share of PROCAMPO benefits distributed to farmers in the *ejido* sector.  $\ln GDP_{i,t-1}$  is the log of the real GDP per capita in state  $i$  at time  $t - 1$ , and  $Z_{i,t-1}$  a set of additional controls for Mexican states  $i$  at time  $t - 1$ , including the state-level unemployment rate and share of homicides at time  $t - 1$ .  $D_i$  and  $D_t$  are state and year fixed effects.

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. We expect a different impact of climatic shocks on migration depending on the type of economic activity in the Mexican states of origin. In particular, states in which agriculture is predominant are expected to be more vulnerable to adverse climatic shocks through direct channels such as crop destruction or lower yields, or to benefit more from positive shocks. We should thus observe larger effects of weather shocks on economic decisions in agricultural states. To explore potential non-linearities in the effect of climatic shocks on migration depending on state agricultural activity, we interact our climatic variables with dummies for the different quartiles of the share of agricultural land in total state area for 2002-2005.

In addition to climatic and agricultural variables and following [Beine and Parsons \(2015\)](#), we include in all specifications the state-level GDP per capita and unemployment rate measured in  $t - 1$ <sup>24</sup>. As in [Chort and De La Rupelle \(2016\)](#), we control for social factors likely to influence migration decisions by including the rate of homicides in the state of origin. The approach of [Cai et al. \(2016\)](#) and [Cattaneo and Peri \(2016\)](#) is different, as they choose to include only fixed effects as controls arguing that, by doing so, they are better able to measure the total effect of climate on migration. A similar argument is put forward by [Dallmann and Millock \(2016\)](#), who point out the fact that economic variables

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<sup>24</sup>As we do not observe internal migration flows in our data, we estimate alternative specifications, in which we further include in the set of regressors the log of the mean population weighted value of the GDP per capita in all other Mexican states, to partly capture the impact of a change in the attractiveness of other potential destinations which are not in our database, ie other Mexican states. Results are unchanged (available upon request).

are likely to be endogenous to contemporaneous climate shocks (Burke et al., 2015; Dell et al., 2009) and choose to exclude them from their analysis. However, parsimonious specifications imply the risk of omitting relevant factors explaining migration. As a way of avoiding these potential endogeneity concerns while accounting for the important role of non climate-related GDP growth on migration, we estimate an alternative specification in which our only economic and social control is the GDP per capita with a two-year lag, which is certainly exogenous enough to climate anomalies measured in  $t - 1$ . The results obtained are shown in Appendix (Table 6, Table 9) and are very similar to those of our main regressions.

## 5 Results

### 5.1 Impact of rainfall and temperatures

In order to first explore the impact of climate variables on migration, in Table 1, we present the estimation results of equation (1) without accounting for public policies, separately for total male flows (columns 1 and 2), documented male flows (columns 3 and 4) and undocumented male flows (columns 5 and 6). 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)<sup>25</sup>.

Consistent with Chort and De La Rupelle (2016), we find a significant and positive impact of GDP in Mexican states of origin, especially at the beginning of the period for documented flows, suggesting that growth at origin tends to increase migration<sup>26</sup>. The unemployment rate is found to significantly impact migration of the undocumented only, confirming that undocumented migration is a response to an increase in home

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<sup>25</sup>As already mentioned, results are robust to an alternative treatment of zero flows (see Table 5 in Appendix).

<sup>26</sup>As a change occurred in the computation of GDP in Mexico in 2003, the GDP variable is interacted with a dummy variable equal to one after 2003.

unemployment. Note already that the fact that documented migration is not significantly affected by unemployment is consistent with the greater diversity of migration motives among documented migrants, and contributes to explaining the different impact of the Fonden program on the two types of flows through the labor market channel. The sign of the coefficients on the homicide variable is negative (although not significant), consistent with [Chort and De La Rupelle \(2016\)](#)<sup>27</sup>.

Except for a weakly significant positive effect of the number of hurricanes on undocumented flows only (column 5) which is not robust across specifications, we find no significant impact of hurricanes on migration.

As for seasonal rainfall and temperature deviations, we find a negative and significant coefficient on the rainfall variable during the dry season and a positive and significant coefficient on the temperature variable during the rainy season. However, an analysis focused only on total flows obscures differences between documented and undocumented flows. In particular, the significant effect of rainfall deviations during the dry season is only found for undocumented flows, while the two significant coefficients for documented flows - on rainfall deviations during the rainy season and temperatures during the dry season- lose their significance when documented and undocumented flows are taken together.

Moreover, columns 2, 4 and 6 uncover heterogeneous effects depending on the agricultural activity in the state of origin. For undocumented flows, effects of rainfall anomalies during the dry season are driven by states in the highest two agricultural quartiles (column 6), consistent with the intuition that both undocumented flows and agricultural states are expected to be more sensitive to rainfall anomalies.

By contrast, the positive effect of anomalies in temperatures during the rainy season is found to be driven by states in the second quartile in terms of agricultural land share. This result is consistent with [Hsiang \(2010\)](#) who finds a larger negative impact of temperatures,

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<sup>27</sup>[Chort and De La Rupelle \(2016\)](#) show that the negative impact of violence is larger in the states where violence is directed at migrants (kidnapping and ransom demands), suggesting that an increase in violence is associated with higher migration costs.

especially during the hottest season, on productivity in non-agricultural sectors.

Table 1: Determinants of Mexico-US migration flows - Cube root dependent variables

	Total male flows (1)	Documented male flows (2)	Documented male flows (3)	Documented male flows (4)	Undocumented male flows (5)	Undocumented male flows (6)
Ln GDP per capita $t-1$	1.043*** (0.09)	0.999*** (0.08)	0.716*** (0.08)	0.725*** (0.07)	0.706*** (0.09)	0.669*** (0.08)
Ln GDP per capita $t-1$ X post 2003	-0.585*** (0.12)	-0.530*** (0.11)	-0.423*** (0.14)	-0.428*** (0.15)	-0.323** (0.13)	-0.293** (0.12)
Unemployment rate $t-1$	0.062* (0.04)	0.070* (0.04)	-0.017 (0.03)	-0.020 (0.04)	0.121*** (0.04)	0.138*** (0.03)
Ln share of homicides $t-1$	-0.112 (0.11)	-0.104 (0.11)	-0.027 (0.12)	-0.038 (0.11)	-0.039 (0.07)	-0.018 (0.08)
Nb hurricanes $t-1$	0.066 (0.07)	0.050 (0.08)	-0.055 (0.07)	-0.047 (0.08)	0.101* (0.06)	0.072 (0.06)
Hurricane max intensity $t-1$	-0.012 (0.03)	0.001 (0.04)	0.031 (0.04)	0.040 (0.05)	-0.040 (0.03)	-0.034 (0.03)
Rain deviations $t-1$ - rainy season	-0.056 (0.04)		-0.097** (0.04)		-0.009 (0.04)	
Rain deviations $t-1$ - dry season	-0.063* (0.04)		0.022 (0.04)		-0.056* (0.03)	
Temp deviations $t-1$ - rainy season	0.123*** (0.05)		0.088 (0.06)		0.062 (0.04)	
Temp deviations $t-1$ - dry season	-0.046 (0.04)		-0.100* (0.06)		0.032 (0.04)	
Rain $t-1$ X quartile 1 of agri share - rainy season		-0.186*** (0.07)		-0.209** (0.08)		-0.035 (0.07)
Rain $t-1$ X quartile 2 of agri share - rainy season		0.024 (0.07)		-0.112 (0.08)		-0.018 (0.08)
Rain $t-1$ X quartile 3 of agri share - rainy season		0.003 (0.06)		0.037 (0.04)		0.003 (0.06)
Rain $t-1$ X quartile 4 of agri share - rainy season		0.028 (0.06)		-0.026 (0.07)		0.050 (0.05)
Rain $t-1$ X quartile 1 of agri share - dry season		-0.069 (0.07)		0.021 (0.08)		-0.023 (0.06)
Rain $t-1$ X quartile 2 of agri share - dry season		0.008 (0.04)		0.060 (0.04)		-0.029 (0.04)
Rain $t-1$ X quartile 3 of agri share - dry season		-0.073 (0.05)		0.083 (0.08)		-0.113** (0.06)
Rain $t-1$ X quartile 4 of agri share - dry season		-0.127** (0.05)		-0.018 (0.06)		-0.107** (0.04)
Temp $t-1$ X quartile 1 of agri share - rainy season		0.074 (0.07)		0.165 (0.11)		-0.015 (0.06)
Temp $t-1$ X quartile 2 of agri share - rainy season		0.229*** (0.06)		0.087* (0.05)		0.154** (0.07)
Temp $t-1$ X quartile 3 of agri share - rainy season		0.211*** (0.06)		0.097 (0.06)		0.183*** (0.06)
Temp $t-1$ X quartile 4 of agri share - rainy season		0.096 (0.07)		0.050 (0.08)		0.028 (0.05)
Temp $t-1$ X quartile 1 of agri share - dry season		-0.121* (0.07)		-0.151 (0.10)		-0.046 (0.07)
Temp $t-1$ X quartile 2 of agri share - dry season		0.025 (0.06)		-0.106 (0.07)		0.106** (0.05)
Temp $t-1$ X quartile 3 of agri share - dry season		-0.037 (0.04)		0.017 (0.06)		-0.009 (0.04)
Temp $t-1$ X quartile 4 of agri share - dry season		-0.089 (0.05)		-0.139* (0.08)		0.033 (0.05)
N	416	416	416	416	416	416

Standard errors corrected for autocorrelation and spatial correlation in parentheses

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



Table 2: Determinants of Mexico-US migration flows : positive, negative and extreme climate shocks - Cube root dependent variables

	Total male flows (1)	(2)	Documented male flows (3)	(4)	Undocumented male flows (5)	(6)
Ln GDP per capita $t-1$	1.029*** (0.09)	1.033*** (0.08)	0.706*** (0.07)	0.689*** (0.08)	0.813*** (0.09)	0.837*** (0.09)
Ln GDP per capita $t-1$ X post 2003	-0.572*** (0.12)	-0.569*** (0.12)	-0.411*** (0.15)	-0.396*** (0.16)	-0.437*** (0.13)	-0.459*** (0.12)
Unemployment rate $t-1$	0.059 (0.04)	0.054 (0.04)	-0.020 (0.03)	-0.017 (0.04)	0.099*** (0.03)	0.100*** (0.03)
Ln share of homicides $t-1$	-0.103 (0.10)	-0.102 (0.10)	-0.024 (0.11)	-0.030 (0.11)	-0.041 (0.07)	-0.050 (0.07)
Nb hurricanes $t-1$	0.057 (0.07)	0.059 (0.07)	-0.061 (0.07)	-0.042 (0.06)	0.083 (0.07)	0.079 (0.07)
Hurricane max intensity $t-1$	-0.008 (0.03)	-0.011 (0.03)	0.034 (0.04)	0.026 (0.04)	-0.073*** (0.03)	-0.071** (0.03)
Positive rain deviations $t-1$ - rainy season	-0.052 (0.05)	-0.052 (0.05)	-0.053 (0.04)	-0.053 (0.04)	0.002 (0.05)	
Negative rain deviations $t-1$ - rainy season	-0.069 (0.09)	-0.069 (0.09)	-0.206** (0.10)	-0.069 (0.08)	0.053 (0.08)	
Positive rain deviations $t-1$ - dry season	-0.020 (0.04)	-0.020 (0.04)	0.041 (0.05)	0.041 (0.05)	-0.003 (0.04)	
Negative rain deviations $t-1$ - dry season	-0.161* (0.09)	-0.161* (0.09)	0.003 (0.09)	0.003 (0.09)	-0.171** (0.09)	
Positive temp deviations $t-1$ - rainy season	0.128** (0.06)	0.128** (0.06)	0.088 (0.08)	0.088 (0.08)	0.025 (0.04)	
Negative temp deviations $t-1$ - rainy season	0.142* (0.07)	0.142* (0.07)	0.136 (0.12)	0.136 (0.12)	0.059 (0.05)	
Positive temp deviations $t-1$ - dry season	-0.086* (0.05)	-0.086* (0.05)	-0.152** (0.07)	-0.152** (0.07)	0.001 (0.05)	
Negative temp deviations $t-1$ - dry season	0.007 (0.06)	0.007 (0.06)	-0.034 (0.09)	-0.034 (0.09)	0.069 (0.06)	
Rain deviations $t-1$ - rainy season		-0.058 (0.05)		-0.044 (0.05)		0.013 (0.06)
Rain deviations $t-1$ - dry season		-0.110* (0.06)		0.032 (0.06)		-0.073 (0.06)
Temp deviations $t-1$ - rainy season		0.169*** (0.06)		0.143** (0.06)		0.037 (0.05)
Temp deviations $t-1$ - dry season		-0.101* (0.06)		-0.073 (0.06)		-0.045 (0.05)
rain deviations $t-1$ - rainy season X zscore >1.5		0.023 (0.06)		-0.023 (0.06)		0.006 (0.06)
rain deviations $t-1$ - dry season X zscore >1.5		0.081 (0.08)		-0.012 (0.06)		0.048 (0.08)
temp deviations $t-1$ - rainy season X zscore >1.5		-0.056 (0.07)		-0.065 (0.09)		-0.024 (0.05)
temp deviations $t-1$ - dry season X zscore >1.5		0.073 (0.08)		-0.065 (0.08)		0.107 (0.07)
rain deviations $t-1$ - rainy season X zscore <-1		-0.072 (0.10)		-0.255** (0.12)		0.028 (0.10)
rain deviations $t-1$ - dry season X zscore <-1		0.070 (0.05)		0.010 (0.07)		0.028 (0.08)
temp deviations $t-1$ - rainy season X zscore <-1		-0.055 (0.06)		-0.124 (0.08)		0.074 (0.09)
temp deviations $t-1$ - dry season X zscore <-1		0.121* (0.06)		-0.001 (0.08)		0.142*** (0.04)

N

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Standard errors corrected for autocorrelation and spatial correlation in parentheses

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

Table 2 allows 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. First, the coefficient on hurricane intensity is now significant for undocumented flows suggesting that a greater shock lowers the probability of migrating. This result is in line with Halliday (2006) who finds that an increase in the damages caused by the 2001 earthquake in El Salvador reduced migration to the U.S., consistent with the need for labor at home.

Regarding documented flows, results shown in column 3 suggest that the negative coefficient on rainfall deviations during the rainy season observed in Table 1 (columns 3 and 4) is driven by negative rainfall deviations. Since by construction all negative deviations variables take negative or zero values, the negative and significant coefficient on the negative rain deviations variable (rainy season) in Table 2, column 3, indicates that lower than average precipitations at origin during the rainy season increase documented migration. The impact of temperature anomalies during the dry season goes through positive shocks: an increase in temperatures decreases documented migration.

For undocumented flows, when introducing separately the different types of shocks, we find a negative coefficient on the negative rainfall variable during the dry season (column 7). Lower than average rainfall during the dry season increase undocumented migration suggestive of drought-driven migration. This finding is 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).

Columns 2, 4 and 6 explore the effect of large shocks by interacting rainfall and temperature variables with dummies for large positive shocks (z-score, i.e. normalized deviations from the long-term average over 1.5) and negative shocks (z-score below -1). The asymmetry in the chosen thresholds for positive and negative shocks derives from the shape of their distribution<sup>28</sup>. Results shown in column 4 suggest that the negative

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<sup>28</sup>Given the distributions of rainfall and temperature shocks which are skewed to the right (except for temperature shocks during the dry season), and as a result of climate change, positive shocks outnumber negative shocks: deviations below -1.5 are fewer (around 2%) than above 1.5 (around 10%). This feature justifies the use of asymmetric thresholds.

coefficient on rainfall shocks during the rainy season observed for documented migrant flows is driven by large negative shocks (with a z-score lower than -1). For undocumented flows, as indicated by the negative coefficient on extreme negative temperature deviations during the dry season, abnormally low negative temperatures during the dry season are found to increase migration.

Consistent with these findings, our main results are robust to the exclusion of year 2010 which follows the exceptional drought episode of 2009<sup>29</sup>. Results are shown in [Table 7](#) in Appendix, replicating [Table 1](#).

## 5.2 Role of public policies

In [Table 3](#), we explore the effect of the two public programs presented in Section 2, PROCAMPO and Fonden, on climate-driven migration. 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. We choose to adopt the same methodology as for the dependent variables to deal with this issue and consider the cube root of the yearly per capita amounts received, rather than the log<sup>30</sup>. Regarding PROCAMPO, our variable of interest is the state-level share of total transfers received by farmers in the *ejido* sector.

As the first payments under the Fonden program were effective in 2000, the sample is restricted to the 2000-2011 period. Columns 1, 4, and 7 replicate specifications 1, 3, and 5 of [Table 1](#) on the reduced sample, adding the two policy variables. The comparison of the two tables shows that the effect of climatic variables on migration is robust on the 2000-2011 sub-period.

First, we find no robust evidence of an impact of the two policy variables when they are not interacted with climatic shocks. The coefficient on Fonden amounts is positive for

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<sup>29</sup>Climate variables enter our main specifications with one lag.

<sup>30</sup>Note that results are qualitatively unchanged when taking the log of Fonden amounts (per capita) to which we add 0.01 (which is lower than the lowest observed value for the variable in the sample), see [Table 8](#) in Appendix.

total and documented male flows, yet it is not significant when interaction terms between Fonden amounts and climatic variables are included. The coefficient on the share of PROCAMPO funds received by households in the *ejido* sector for non-irrigated land is never significant.

When interacting the amounts distributed under PROCAMPO or Fonden and rainfall and temperature variables we find contrasted results<sup>31</sup>. The interaction term between rainfall deviations in the dry season and the per capita amounts distributed under Fonden is positive and significant for undocumented flows. As noted above, negative deviations in rainfall during the dry season increase migration. The interaction with Fonden suggests a mitigating effect of the Fonden program: a concurrent increase in the Fonden variable limits or even outbalances the effect of a drought. Note that the impact of Fonden is driven by undocumented flows (column 9).

The effect of PROCAMPO is broader, affecting both documented and undocumented flows in response to temperature and rainfall anomalies. An increase in the share of PROCAMPO received by producers in the non-irrigated *ejido* sector is associated with a lower total migration response to rainfall deviations, for both documented and undocumented flows, suggesting that PROCAMPO also contributes to mitigating the migration response to climate anomalies. By contrast, the effect of the interaction term between PROCAMPO and temperature anomalies during the dry season is driven by undocumented flows. As shown in [Table 2](#), the effect of temperature anomalies during the dry season on undocumented migration is driven by large negative shocks. In the light of these results, more redistributive PROCAMPO transfers seem to limit the increase in undocumented migration due to lower than average temperatures.

Most results are robust to restricting the set of economic and social controls to the GDP with a two-year lag (see [Table 9](#) in Appendix) or to taking both the dependent and Fonden variables in log rather than use a cube root transformation ([Table 8](#)).

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<sup>31</sup>In alternative specifications we add interaction terms between PROCAMPO and Fonden payments and hurricane variables. The coefficients on the interaction terms for hurricane variables are never significant (results available upon request).

Differences in the impact of Fonden on documented and undocumented flows may be explained in part by the different motivations behind the two types of migrations. Results presented in [Table 3](#), column 7, show that unlike documented flows, undocumented flows are highly sensitive to variations in unemployment. This finding is consistent with descriptive evidence on the different motives for migrating in the two groups. Indeed, while the overwhelming majority of undocumented migrants (over 97%) migrate for labor related reasons, documented migration motives are more diverse with family reunification playing an important role. The coefficient on the unemployment variable is slightly lower when including interaction terms between Fonden amounts and climatic variables, suggesting that part of the unemployment effect may be captured by the Fonden interactions. This result is consistent with the labor market impact of Fonden evidenced by [de Janvry et al. \(2016\)](#) and highlighted in the theoretical discussion presented above. Indeed, one of the impacts of Fonden is to increase local labor demand, and since undocumented migration is more sensitive to employment than documented migration, we expect Fonden to have a greater mitigating impact on undocumented than on documented migration.

The absence of mitigating impact of Fonden on documented flows may also stem from the fact that documented migrants are more likely than undocumented migrants to have relatives in the US and thus to receive remittances if they are hit by a negative shock. For households connected to a migrant in the US, remittances may substitute efficiently to public funding to help them to recover after a shock, which could contribute to explaining why an increase in Fonden amounts has no impact on documented migration. One limitation of our data is that we have no measure of remittances received at the infra-state level.

Another explanation for the differences between documented and undocumented flows could be linked to the specific time schedules of the two types of migration. Indeed, in order to migrate to the US with official documents, candidates need to await visas for several months. We may thus observe a delayed impact of shocks and public policies, current documented migration being affected by climate shocks and transfers that oc-

curred two years earlier rather than the previous year. We investigate this assumption by exploring the impact of climate shocks and public programs with two lags. We do not find any impact of climate shocks two years earlier on current documented and undocumented migration, which rules out such an interpretation based on different times constraints (results available upon request).

Regarding PROCAMPO, in line with the theoretical discussion, the mitigating impact of the share of PROCAMPO received by producers in the non-irrigated *ejido* sector suggests that PROCAMPO funds are invested in the agricultural sector rather than used to fund migration after a negative rainfall shock. This finding is also consistent with the survey data used in [Sadoulet et al. \(2001\)](#), according to which 70% of farmers in *ejidos* use PROCAMPO funds to buy agricultural inputs.

The coefficients obtained imply substantial effects, both for climate shocks and public policies <sup>32</sup>. A negative rainfall anomaly of one standard deviation below the average leads to an increase of 2.4 points<sup>33</sup> of the total migration rate. Considering the average value of 37 migrants per 10,000 inhabitants, an increase of 2.4 is sizeable and is comparable to the effect of an increase of 1 percentage point in the unemployment rate, which is found to increase the total migration rate by 2.1 points per 10,000 and the undocumented migration rate by 2.5 points per 10,000.

Both public policies reduce substantially the impact of climate anomalies on migration. Such mitigating impact is particularly observed for undocumented migration in response to rainfall anomalies. On average, 70% of PROCAMPO amounts are paid for non-irrigated land in the *ejido* sector. The share of PROCAMPO funds distributed to the most vulnerable farmers would need to increase by 18 percentage points to offset the effect of a negative rainfall shock of one standard deviation. As for Fonden, our results suggest that an increase by 6 pesos per inhabitant would be sufficient to counter the impact of a negative rainfall anomaly of one standard deviation.

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<sup>32</sup>The effects are computed considering the mean values of the variables, as displayed in [Table 4](#). Since the dependent variable is the cube root of the migration rate, the derivative of the migration rate with respect to any independent variable depends on the value of the dependent variable.

<sup>33</sup>Per 10,000 inhabitants.

Table 3: Determinants of Mexico-US migration flows - Impact of public policies, 2001-2011 - Cube root dependent variables

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Total male flows			Documented male flows			Undocumented male flows		
Ln GDP per capita $t-1$	0.894*** (0.15)	0.909*** (0.15)	0.871*** (0.14)	0.526*** (0.14)	0.529*** (0.14)	0.514*** (0.15)	0.640*** (0.15)	0.662*** (0.16)	0.613*** (0.15)
Ln GDP per capita $t-1$ X post 2003	-0.450*** (0.14)	-0.419*** (0.15)	-0.369** (0.14)	-0.344** (0.17)	-0.330** (0.17)	-0.320* (0.17)	-0.175 (0.17)	-0.178 (0.17)	-0.086 (0.17)
Unemployment rate $t-1$	0.046 (0.04)	0.043 (0.04)	0.033 (0.04)	-0.030 (0.04)	-0.028 (0.04)	-0.031 (0.04)	0.100*** (0.03)	0.100*** (0.03)	0.086*** (0.03)
Ln share of homicides $t-1$	0.020 (0.11)	-0.011 (0.11)	0.023 (0.10)	0.045 (0.14)	0.029 (0.15)	0.045 (0.14)	0.005 (0.08)	-0.031 (0.08)	0.011 (0.07)
Nb hurricanes $t-1$	0.100 (0.08)	0.114 (0.08)	0.125 (0.08)	-0.014 (0.08)	0.001 (0.08)	-0.005 (0.09)	0.112* (0.07)	0.120* (0.07)	0.132** (0.07)
Hurricane max intensity $t-1$	-0.046 (0.04)	-0.056 (0.04)	-0.061 (0.04)	-0.003 (0.06)	-0.016 (0.05)	-0.010 (0.06)	-0.047 (0.03)	-0.060* (0.03)	-0.062** (0.03)
Share PROCAMPO to <i>Ejidotes</i> (non-irrig.) $t-1$	0.488 (0.52)	0.386 (0.56)	0.363 (0.49)	0.904 (0.78)	0.874 (0.82)	0.874 (0.76)	0.887 (0.36)	0.890 (0.39)	-0.037 (0.35)
Cube root amount Fonden $t-1$	0.035* (0.02)	0.032 (0.02)	0.011 (0.02)	0.042* (0.02)	0.040* (0.02)	0.033 (0.02)	0.011 (0.02)	0.010 (0.02)	-0.020 (0.02)
Rain deviations $t-1$ - rainy season	-0.062 (0.05)	-0.075 (0.12)	-0.075 (0.05)	-0.110** (0.05)	-0.061 (0.11)	-0.105* (0.06)	-0.022 (0.05)	0.083 (0.09)	-0.060 (0.06)
Rain deviations $t-1$ - dry season	-0.044 (0.03)	-0.374*** (0.09)	-0.147*** (0.05)	0.024 (0.04)	-0.237** (0.11)	0.011 (0.07)	-0.043 (0.03)	-0.215** (0.11)	-0.146*** (0.05)
Temp deviations $t-1$ - rainy season	0.143** (0.06)	0.089 (0.11)	0.136*** (0.05)	0.137** (0.07)	0.070 (0.14)	0.130** (0.06)	0.034 (0.04)	0.082 (0.10)	0.016 (0.05)
Temp deviations $t-1$ - dry season	-0.081 (0.05)	-0.346*** (0.12)	-0.125** (0.06)	-0.152** (0.08)	-0.295* (0.16)	-0.177* (0.09)	0.016 (0.05)	-0.163 (0.13)	-0.004 (0.06)
Rain deviations $t-1$ - rainy season X share PROCAMPO to <i>Ejidotes</i> (non-irrig.) $t-1$		0.011 (0.15)			-0.079 (0.15)			-0.164 (0.12)	
Rain deviations $t-1$ - dry season X share PROCAMPO to <i>Ejidotes</i> (non-irrig.) $t-1$		0.420*** (0.09)			0.333*** (0.12)			0.215* (0.12)	
Temp deviations $t-1$ - rainy season X share PROCAMPO to <i>Ejidotes</i> (non-irrig.) $t-1$		0.056 (0.14)			0.076 (0.19)			-0.097 (0.12)	
Temp deviations $t-1$ - dry season X share PROCAMPO to <i>Ejidotes</i> (non-irrig.) $t-1$		0.343** (0.15)			0.186 (0.19)			0.259* (0.16)	
Rain deviations $t-1$ - rainy season X Cube root amt Fonden $t-1$			0.005 (0.01)						0.015 (0.01)
Rain deviations $t-1$ - dry season X Cube root amt Fonden $t-1$			0.040*** (0.01)						0.041*** (0.01)
Temp deviations $t-1$ - rainy season X Cube root amt Fonden $t-1$			0.009 (0.02)						0.013 (0.01)
Temp deviations $t-1$ - dry season X Cube root amt Fonden $t-1$			0.023** (0.01)						0.013 (0.01)
N	352	352	352	352	352	352	352	352	352

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

## 6 Conclusion

Using unique panel data documenting migration flows from Mexican states to the US over the 1995-2009 period, we explore the impact of hurricanes, rainfall and temperature shocks on migration rates to the US and the mitigating role of two public programs of different types, the PROCAMPO agricultural cash-transfer program and the Fonden disaster fund. 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 the micro-based state-level data that we use allow us to separately analyse documented and undocumented flows. We find that seasonal weather variability has a strong impact on outmigration rates from Mexican states, though affecting differently documented and undocumented flows. In particular, lower than average precipitations and temperatures during the dry season significantly increase undocumented migration, consistent with [Munshi \(2003\)](#) or [Nawrotzki et al. \(2013\)](#), especially from the most agricultural states. Note that climate shocks are expected to affect both internal and international migration. As we focus on international migration, our results provide a lower bound of the impact of climatic factors on human mobility. Regarding the role played by public policies, we find evidence of a mitigating impact of the disaster fund Fonden and the agricultural cash-transfers PROCAMPO, especially on undocumented flows. An increase in amounts transferred under Fonden or in the share of PROCAMPO received by farmers in the *ejido* sector for non-irrigated land reduces the undocumented migration response to rainfall anomalies. PROCAMPO also limits documented migration after a negative climate event, while Fonden is found to have no impact on documented migration. As weather variability is believed to increase as a consequence of climate change, recurring droughts episodes are expected to contribute to increase migration flows from Mexican states. We find that a more redistributive agricultural cash-transfer program, although disconnected from weather-related shocks, tends to limit climate-induced migration. In addition, consistent with [de Janvry et al. \(2016\)](#), this paper highlights the impact on climate-induced migra-



tion of well targeted public policies such as disaster funds, which may be explained by a faster economic recovery.

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# Appendix

Table 4: Summary statistics

Variable	Mean	Std. Dev.	N
Cube root male migration rate	3.343	1.142	416
Cube root male documented migration rate	2.111	1.132	416
Cube root male undocumented migration rate	2.812	1.111	416
Ln male migration rate	3.371	1.479	416
Ln male documented migration rate	1.411	2.939	416
Ln undocumented male migration rate	2.728	1.904	416
Ln GDP per capita $t_{-1}$	4.811	0.584	416
Ln GDP per capita $t_{-1}$ X post 2003	2.827	2.281	416
Unemployment rate $t_{-1}$	3.118	1.392	416
Ln share of homicides $t_{-1}$ per $10^5$ pop	2.186	0.716	416
Nb hurricanes $t_{-1}$	0.293	0.637	416
Hurricane max intensity $t_{-1}$	0.519	1.182	416
Rain deviations $t_{-1}$ - rainy season	0.525	1.038	416
Rain deviations $t_{-1}$ - dry season	0.128	1.01	416
Temp deviations $t_{-1}$ - rainy season	0.534	0.994	416
Temp deviations $t_{-1}$ - dry season	0.263	0.939	416
Rain $t_{-1}$ X quartile 1 of agri share - rainy season	0.168	0.581	416
Rain $t_{-1}$ X quartile 2 of agri share - rainy season	0.221	0.594	416
Rain $t_{-1}$ X quartile 3 of agri share - rainy season	0.057	0.494	416
Rain $t_{-1}$ X quartile 4 of agri share - rainy season	0.079	0.578	416
Rain $t_{-1}$ X quartile 1 of agri share - dry season	0.021	0.449	416
Rain $t_{-1}$ X quartile 2 of agri share - dry season	0.09	0.616	416
Rain $t_{-1}$ X quartile 3 of agri share - dry season	-0.014	0.425	416
Rain $t_{-1}$ X quartile 4 of agri share - dry season	0.031	0.517	416
Temp $t_{-1}$ X quartile 1 of agri share - rainy season	0.223	0.595	416
Temp $t_{-1}$ X quartile 2 of agri share - rainy season	0.122	0.463	416
Temp $t_{-1}$ X quartile 3 of agri share - rainy season	0.088	0.542	416
Temp $t_{-1}$ X quartile 4 of agri share - rainy season	0.101	0.575	416
Temp $t_{-1}$ X quartile 1 of agri share - dry season	0.138	0.486	416
Temp $t_{-1}$ X quartile 2 of agri share - dry season	0.075	0.417	416
Temp $t_{-1}$ X quartile 3 of agri share - dry season	0.029	0.497	416
Temp $t_{-1}$ X quartile 4 of agri share - dry season	0.021	0.517	416
Rain deviations $t_{-1}$ - rainy season X zscore > 1.5	0.373	0.804	416
Rain deviations $t_{-1}$ - dry season X zscore > 1.5	0.21	0.724	416
Temp deviations $t_{-1}$ - rainy season X zscore > 1.5	0.302	0.796	416
Temp deviations $t_{-1}$ - dry season X zscore > 1.5	0.128	0.472	416
Rain deviations $t_{-1}$ - rainy season X zscore < -1	-0.105	0.373	416
Rain deviations $t_{-1}$ - dry season X zscore < -1	-0.091	0.349	416
Ln amount Procampo $t_{-1}$ thousands pesos per $10^4$ pop (2001-2011)	4.581	1.25	352
Share PROCAMPO to <i>Ejidors</i> (non-irrig.) $t_{-1}$ (2001-2011)	0.73	0.282	352
Cube root amount Fonden $t_{-1}$ pesos per capita (2001-2011)	1.936	2.408	352

Table 5: Determinants of Mexico-US migration flows - Log dependent variables

	Total male flows (1)	Documented male flows (3)	Documented male flows (4)	Undocumented male flows (5)	Undocumented male flows (6)
Ln GDP per capita $t-1$	1.016*** (0.11)	0.967*** (0.11)	0.841*** (0.21)	0.483*** (0.11)	0.443*** (0.11)
Ln GDP per capita $t-1$ X post 2003	-0.471*** (0.15)	-0.400*** (0.16)	-0.746* (0.45)	-0.789* (0.47)	0.037 (0.16)
Unemployment rate $t-1$	0.053 (0.04)	0.058 (0.04)	0.035 (0.08)	0.033 (0.08)	0.164*** (0.06)
Ln share of homicides $t-1$	-0.134 (0.14)	-0.126 (0.14)	-0.017 (0.28)	-0.022 (0.26)	0.013 (0.13)
Nb hurricanes $t-1$	0.020 (0.13)	0.016 (0.13)	-0.231 (0.24)	0.116 (0.15)	0.098 (0.15)
Hurricane max intensity $t-1$	0.010 (0.07)	0.012 (0.07)	0.052 (0.11)	-0.004 (0.07)	-0.001 (0.07)
Rain deviations $t-1$ - rainy season	-0.078 (0.05)	-0.078 (0.05)	-0.249** (0.13)	-0.055 (0.06)	
Rain deviations $t-1$ - dry season	-0.044 (0.05)	-0.044 (0.05)	0.107 (0.13)	-0.047 (0.06)	
Temp deviations $t-1$ - rainy season	0.097* (0.06)	0.097* (0.06)	0.136 (0.13)	0.125 (0.08)	
Temp deviations $t-1$ - dry season	-0.038 (0.04)	-0.038 (0.04)	-0.230* (0.13)	0.038 (0.07)	
zeroNSUR_men	-6.860*** (0.49)	-6.796*** (0.48)			
Rain $t-1$ X quartile 1 of agri share - rainy season		-0.210** (0.10)	-0.429 (0.32)		-0.098 (0.16)
Rain $t-1$ X quartile 2 of agri share - rainy season		-0.021 (0.07)	-0.437** (0.19)		-0.084 (0.10)
Rain $t-1$ X quartile 3 of agri share - rainy season		-0.005 (0.06)	0.050 (0.07)		0.003 (0.07)
Rain $t-1$ X quartile 4 of agri share - rainy season		-0.016 (0.06)	-0.100 (0.16)		-0.008 (0.06)
Rain $t-1$ X quartile 1 of agri share - dry season		-0.027 (0.12)	0.106 (0.29)		0.062 (0.13)
Rain $t-1$ X quartile 2 of agri share - dry season		0.001 (0.05)	0.140 (0.12)		-0.066 (0.06)
Rain $t-1$ X quartile 3 of agri share - dry season		-0.073 (0.05)	0.218 (0.19)		-0.117 (0.08)
Rain $t-1$ X quartile 4 of agri share - dry season		-0.105** (0.06)	0.070 (0.14)		-0.112** (0.05)
Temp $t-1$ X quartile 1 of agri share - rainy season		-0.023 (0.10)	0.253 (0.30)		0.044 (0.13)
Temp $t-1$ X quartile 2 of agri share - rainy season		0.229*** (0.08)	0.081 (0.15)		0.243** (0.10)
Temp $t-1$ X quartile 3 of agri share - rainy season		0.212*** (0.08)	0.206 (0.206)		0.261** (0.10)
Temp $t-1$ X quartile 4 of agri share - rainy season		0.087 (0.08)	0.037 (0.15)		0.085 (0.08)
Temp $t-1$ X quartile 1 of agri share - dry season		-0.003 (0.13)	-0.299 (0.44)		-0.005 (0.16)
Temp $t-1$ X quartile 2 of agri share - dry season		-0.014 (0.06)	-0.272 (0.17)		0.077 (0.08)
Temp $t-1$ X quartile 3 of agri share - dry season		-0.057 (0.04)	-0.032 (0.12)		0.005 (0.06)
Temp $t-1$ X quartile 4 of agri share - dry season		-0.090 (0.06)	-0.236 (0.15)		0.048 (0.06)
zeroNSUR_mendoc			-3.221*** (0.32)		
zeroNSUR_men_undoccrosswork				-4.571*** (0.40)	-4.559*** (0.40)
N	416	416	416	416	416

Standard errors corrected for autocorrelation and spatial correlation in parentheses

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

Table 6: Determinants of Mexico-US migration flows (GDP with two lags, without unemployment and homicides) - Cube root dependent variables

	Total male flows (1)	(2)	Documented male flows (3)	(4)	Undocumented male flows (5)	(6)
Ln GDP per capita $t-2$	0.967*** (0.06)	0.949*** (0.06)	0.592*** (0.07)	0.596*** (0.07)	0.756*** (0.06)	0.764*** (0.05)
Ln GDP per capita X post 2003 $t-2$	-0.556*** (0.12)	-0.524*** (0.10)	-0.297*** (0.13)	-0.302*** (0.14)	-0.363*** (0.12)	-0.372*** (0.10)
Nb hurricanes $t-1$	0.062 (0.08)	0.047 (0.09)	-0.056 (0.07)	-0.048 (0.09)	0.092 (0.07)	0.076 (0.07)
Hurricane max intensity $t-1$	-0.013 (0.04)	0.000 (0.04)	0.030 (0.04)	0.039 (0.05)	-0.039 (0.03)	-0.035 (0.03)
Rain deviations $t-1$ - rainy season	-0.068* (0.04)	-0.068* (0.04)	-0.106*** (0.04)	-0.106*** (0.04)	-0.013 (0.04)	-0.013 (0.04)
Rain deviations $t-1$ - dry season	-0.066* (0.04)	-0.066* (0.04)	0.017 (0.04)	0.017 (0.04)	-0.054 (0.04)	-0.054 (0.04)
Temp deviations $t-1$ - rainy season	0.142*** (0.05)	0.142*** (0.05)	0.100* (0.06)	0.100* (0.06)	0.076*** (0.04)	0.076*** (0.04)
Temp deviations $t-1$ - dry season	-0.058 (0.04)	-0.058 (0.04)	-0.103* (0.06)	-0.103* (0.06)	0.024 (0.04)	0.024 (0.04)
Rain $t-1$ X quartile 1 of agri share - rainy season	-0.202*** (0.07)	-0.202*** (0.07)	-0.221*** (0.08)	-0.221*** (0.08)	-0.047 (0.08)	-0.047 (0.08)
Rain $t-1$ X quartile 2 of agri share - rainy season	-0.009 (0.08)	-0.009 (0.08)	-0.155** (0.08)	-0.155** (0.08)	-0.035 (0.08)	-0.035 (0.08)
Rain $t-1$ X quartile 3 of agri share - rainy season	-0.029 (0.06)	-0.029 (0.06)	0.027 (0.05)	0.027 (0.05)	-0.044 (0.07)	-0.044 (0.07)
Rain $t-1$ X quartile 4 of agri share - rainy season	0.031 (0.04)	0.031 (0.04)	-0.042 (0.05)	-0.042 (0.05)	0.074* (0.04)	0.074* (0.04)
Rain $t-1$ X quartile 1 of agri share - dry season	-0.075 (0.07)	-0.075 (0.07)	0.016 (0.08)	0.016 (0.08)	-0.029 (0.07)	-0.029 (0.07)
Rain $t-1$ X quartile 2 of agri share - dry season	0.008 (0.04)	0.008 (0.04)	0.046 (0.05)	0.046 (0.05)	-0.007 (0.04)	-0.007 (0.04)
Rain $t-1$ X quartile 3 of agri share - dry season	-0.122*** (0.04)	-0.122*** (0.04)	0.022 (0.07)	0.022 (0.07)	-0.136*** (0.05)	-0.136*** (0.05)
Rain $t-1$ X quartile 4 of agri share - dry season	-0.098* (0.06)	-0.098* (0.06)	0.020 (0.07)	0.020 (0.07)	-0.103** (0.04)	-0.103** (0.04)
Temp $t-1$ X quartile 1 of agri share - rainy season	0.090 (0.07)	0.090 (0.07)	0.174* (0.10)	0.174* (0.10)	-0.000 (0.07)	-0.000 (0.07)
Temp $t-1$ X quartile 2 of agri share - rainy season	0.218*** (0.06)	0.218*** (0.06)	0.089* (0.05)	0.089* (0.05)	0.101* (0.06)	0.101* (0.06)
Temp $t-1$ X quartile 3 of agri share - rainy season	0.225*** (0.07)	0.225*** (0.07)	0.112* (0.06)	0.112* (0.06)	0.181*** (0.05)	0.181*** (0.05)
Temp $t-1$ X quartile 4 of agri share - rainy season	0.121 (0.08)	0.121 (0.08)	0.052 (0.09)	0.052 (0.09)	0.057 (0.05)	0.057 (0.05)
Temp $t-1$ X quartile 1 of agri share - dry season	-0.117* (0.07)	-0.117* (0.07)	-0.155 (0.10)	-0.155 (0.10)	-0.017 (0.07)	-0.017 (0.07)
Temp $t-1$ X quartile 2 of agri share - dry season	0.023 (0.06)	0.023 (0.06)	-0.137* (0.08)	-0.137* (0.08)	0.106* (0.05)	0.106* (0.05)
Temp $t-1$ X quartile 3 of agri share - dry season	-0.083* (0.05)	-0.083* (0.05)	-0.028 (0.06)	-0.028 (0.06)	-0.020 (0.04)	-0.020 (0.04)
Temp $t-1$ X quartile 4 of agri share - dry season	-0.075 (0.06)	-0.075 (0.06)	-0.087 (0.09)	-0.087 (0.09)	0.013 (0.05)	0.013 (0.05)
N	416	416	416	416	416	416

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



Table 7: Determinants of Mexico-US migration flows - 1999-2011, without 2010 (2009 being an exceptional drought) - Cube root dependent variables

	Total male flows (1)	(2)	Documented male flows (3)	(4)	Undocumented male flows (5)	(6)
Ln GDP per capita $t-1$	1.039*** (0.09)	1.002*** (0.08)	0.699*** (0.08)	0.717*** (0.07)	0.707*** (0.09)	0.689*** (0.08)
Ln GDP per capita $t-1$ X post 2003	-0.605*** (0.12)	-0.546*** (0.11)	-0.441*** (0.14)	-0.447*** (0.15)	-0.351*** (0.14)	-0.338*** (0.12)
Unemployment rate $t-1$	0.066 (0.04)	0.069 (0.05)	-0.010 (0.04)	-0.017 (0.04)	0.126*** (0.04)	0.143*** (0.05)
Ln share of homicides $t-1$	-0.114 (0.12)	-0.111 (0.13)	-0.014 (0.13)	-0.034 (0.12)	-0.024 (0.08)	-0.012 (0.08)
Nb hurricanes $t-1$	0.066 (0.07)	0.051 (0.08)	-0.059 (0.07)	-0.054 (0.08)	0.116* (0.06)	0.091 (0.06)
Hurricane max intensity $t-1$	-0.009 (0.04)	-0.002 (0.04)	0.034 (0.04)	0.039 (0.05)	-0.041 (0.03)	-0.041 (0.03)
Rain deviations $t-1$ - rainy season	-0.048 (0.04)		-0.080** (0.04)		-0.005 (0.04)	
Rain deviations $t-1$ - dry season	-0.067* (0.04)		0.015 (0.04)		-0.060* (0.03)	
Temp deviations $t-1$ - rainy season	0.127** (0.05)		0.094 (0.06)		0.064 (0.04)	
Temp deviations $t-1$ - dry season	-0.046 (0.04)		-0.097* (0.06)		0.032 (0.04)	
Rain $t-1$ X quartile 1 of agri share - rainy season		-0.159** (0.08)		-0.157* (0.09)		-0.005 (0.07)
Rain $t-1$ X quartile 2 of agri share - rainy season		0.002 (0.09)		-0.154 (0.10)		-0.046 (0.09)
Rain $t-1$ X quartile 3 of agri share - rainy season		-0.023 (0.06)		0.034 (0.04)		-0.053 (0.07)
Rain $t-1$ X quartile 4 of agri share - rainy season		0.033 (0.05)		-0.034 (0.05)		0.070 (0.05)
Rain $t-1$ X quartile 1 of agri share - dry season		-0.080 (0.08)		0.001 (0.08)		-0.031 (0.06)
Rain $t-1$ X quartile 2 of agri share - dry season		0.027 (0.04)		0.063 (0.05)		-0.011 (0.04)
Rain $t-1$ X quartile 3 of agri share - dry season		-0.113*** (0.04)		0.024 (0.07)		-0.131*** (0.05)
Rain $t-1$ X quartile 4 of agri share - dry season		-0.109* (0.06)		0.026 (0.07)		-0.125*** (0.05)
Temp $t-1$ X quartile 1 of agri share - rainy season		0.076 (0.07)		0.177* (0.11)		-0.031 (0.07)
Temp $t-1$ X quartile 2 of agri share - rainy season		0.218*** (0.06)		0.060 (0.04)		0.132** (0.06)
Temp $t-1$ X quartile 3 of agri share - rainy season		0.220*** (0.07)		0.098 (0.06)		0.201*** (0.05)
Temp $t-1$ X quartile 4 of agri share - rainy season		0.104 (0.07)		0.034 (0.09)		0.052 (0.05)
Temp $t-1$ X quartile 1 of agri share - dry season		-0.115 (0.08)		-0.132 (0.10)		-0.043 (0.07)
Temp $t-1$ X quartile 2 of agri share - dry season		0.037 (0.06)		-0.135* (0.08)		0.123** (0.05)
Temp $t-1$ X quartile 3 of agri share - dry season		-0.066 (0.05)		-0.021 (0.06)		-0.010 (0.05)
Temp $t-1$ X quartile 4 of agri share - dry season		-0.078 (0.07)		-0.078 (0.09)		0.011 (0.05)
N	416	416	416	416	416	416

Standard errors corrected for autocorrelation and spatial correlation in parentheses

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

Table 8: Determinants of Mexico-US migration flows - Impact of public policies (Fonden in log), 2001-2011 - Cube root dependent variables

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Total male flows			Documented male flows			Undocumented male flows		
Ln GDP per capita $t-1$	0.918*** (0.15)	0.932*** (0.15)	0.859*** (0.14)	0.553*** (0.13)	0.557*** (0.13)	0.514*** (0.16)	0.650*** (0.15)	0.672*** (0.16)	0.603*** (0.14)
Ln GDP per capita $t-1$ X post 2003	-0.467*** (0.15)	-0.437*** (0.15)	-0.359** (0.14)	-0.365** (0.17)	-0.351** (0.17)	-0.308* (0.18)	-0.183 (0.17)	-0.185 (0.17)	-0.089 (0.16)
Unemployment rate $t-1$	0.049 (0.04)	0.047 (0.04)	0.038 (0.04)	-0.026 (0.04)	-0.024 (0.04)	-0.026 (0.04)	0.102*** (0.03)	0.102*** (0.03)	0.088** (0.03)
Ln share of homicides $t-1$	0.029 (0.11)	-0.005 (0.11)	0.047 (0.10)	0.056 (0.14)	0.037 (0.15)	0.059 (0.14)	0.007 (0.08)	-0.031 (0.08)	0.027 (0.07)
Nb hurricanes $t-1$	0.091 (0.08)	0.105 (0.08)	0.110 (0.08)	-0.023 (0.08)	-0.009 (0.08)	-0.018 (0.08)	0.109 (0.07)	0.117* (0.07)	0.125* (0.07)
Hurricane max intensity $t-1$	-0.035 (0.04)	-0.045 (0.03)	-0.050 (0.04)	0.009 (0.05)	-0.003 (0.05)	-0.001 (0.05)	-0.042 (0.03)	-0.055* (0.03)	-0.053* (0.03)
Share PROCAMPO to Ejidos (non-irrig.) $t-1$	0.453 (0.53)	0.349 (0.56)	0.318 (0.48)	0.865 (0.78)	0.832 (0.82)	0.837 (0.74)	0.072 (0.36)	0.071 (0.39)	-0.058 (0.34)
Ln amount Fonden $t-1$	0.019* (0.01)	0.015 (0.01)	-0.001 (0.01)	0.023* (0.01)	0.021* (0.01)	0.012 (0.01)	0.003 (0.01)	0.003 (0.01)	-0.013 (0.01)
Rain deviations $t-1$ - rainy season	-0.057 (0.05)	-0.071 (0.12)	-0.067 (0.05)	-0.105** (0.05)	-0.055 (0.11)	-0.110** (0.05)	-0.018 (0.05)	0.085 (0.09)	-0.030 (0.05)
Rain deviations $t-1$ - dry season	-0.044 (0.03)	-0.369*** (0.09)	-0.089** (0.03)	0.024 (0.135**)	-0.231** (0.11)	0.015 (0.05)	-0.042 (0.11)	-0.215** (0.11)	-0.087** (0.03)
Temp deviations $t-1$ - rainy season	0.141** (0.06)	0.092 (0.11)	0.156*** (0.06)	0.092 (0.06)	0.075 (0.13)	0.147*** (0.07)	0.034 (0.04)	0.081 (0.10)	0.041 (0.04)
Temp deviations $t-1$ - dry season	-0.078 (0.05)	-0.351*** (0.12)	-0.089* (0.05)	-0.149** (0.07)	-0.300* (0.16)	-0.157** (0.08)	0.018 (0.05)	-0.167 (0.13)	0.014 (0.05)
Rain deviations $t-1$ - rainy season X share PROCAMPO to Ejidos (non-irrig.) $t-1$		0.012 (0.15)			-0.080 (0.15)			-0.162 (0.12)	
Rain deviations $t-1$ - dry season X share PROCAMPO to Ejidos (non-irrig.) $t-1$		0.414*** (0.09)			0.325*** (0.12)			0.215* (0.12)	
Temp deviations $t-1$ - rainy season X share PROCAMPO to Ejidos (non-irrig.) $t-1$		0.049 (0.14)			0.065 (0.19)			-0.096 (0.12)	
Temp deviations $t-1$ - dry season X share PROCAMPO to Ejidos (non-irrig.) $t-1$		0.356** (0.15)			0.200 (0.19)			0.267* (0.16)	
Rain deviations $t-1$ - rainy season X Ln amt Fonden $t-1$			0.008 (0.01)			0.009 (0.01)			0.006 (0.01)
Rain deviations $t-1$ - dry season X Ln amt Fonden $t-1$			0.028*** (0.01)			0.005 (0.01)			0.029*** (0.01)
Temp deviations $t-1$ - rainy season X Ln amt Fonden $t-1$			0.010 (0.01)			0.005 (0.02)			0.010 (0.01)
Temp deviations $t-1$ - dry season X Ln amt Fonden $t-1$			0.018** (0.01)			0.011 (0.01)			0.010 (0.01)
N	352	352	352	352	352	352	352	352	352

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

Table 9: Determinants of Mexico-US migration flows - Impact of public policies (GDP with two lags, without unemployment and homicides), 2001-2011 - Cube root dependent variables

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Total male flows			Documented male flows			Undocumented male flows		
Ln GDP per capita $t-2$	0.879*** (0.11)	0.880*** (0.11)	0.878*** (0.10)	0.436*** (0.12)	0.425*** (0.12)	0.428*** (0.13)	0.690*** (0.12)	0.694*** (0.13)	0.689*** (0.12)
Ln GDP per capita X post 2003 $t-2$	-0.448*** (0.13)	-0.441*** (0.13)	-0.393*** (0.12)	-0.197 (0.15)	-0.166 (0.15)	-0.176 (0.14)	-0.258* (0.15)	-0.256* (0.15)	-0.201 (0.15)
Nb hurricanes $t-1$	0.092 (0.09)	0.104 (0.09)	0.114 (0.09)	-0.015 (0.09)	-0.002 (0.08)	-0.006 (0.09)	0.101 (0.08)	0.110 (0.08)	0.117 (0.08)
Hurricane max intensity $t-1$	-0.045 (0.04)	-0.054 (0.04)	-0.058 (0.04)	-0.004 (0.06)	-0.016 (0.06)	-0.012 (0.06)	-0.046 (0.04)	-0.059 (0.04)	-0.057* (0.03)
Share PROCAMPO to <i>Ejidotes</i> (non-irrig.) $t-1$	0.518 (0.52)	0.391 (0.55)	0.355 (0.49)	0.674 (0.72)	0.635 (0.76)	0.661 (0.71)	0.400 (0.45)	0.384 (0.46)	0.234 (0.43)
Cube root amount Fonden $t-1$	0.039** (0.02)	0.035* (0.02)	0.014 (0.03)	0.042* (0.02)	0.040* (0.02)	0.030 (0.02)	0.016 (0.02)	0.015 (0.02)	-0.014 (0.02)
Rain deviations $t-1$ - rainy season	-0.074 (0.05)	-0.096 (0.11)	-0.086* (0.05)	-0.112** (0.05)	-0.070 (0.11)	-0.113* (0.06)	-0.032 (0.05)	0.063 (0.09)	-0.065 (0.06)
Rain deviations $t-1$ - dry season	-0.046 (0.04)	-0.366*** (0.09)	-0.153*** (0.05)	0.022 (0.04)	-0.238** (0.11)	0.006 (0.06)	-0.045 (0.04)	-0.213* (0.11)	-0.151*** (0.05)
Temp deviations $t-1$ - rainy season	0.153** (0.06)	0.096 (0.11)	0.148*** (0.06)	0.148** (0.07)	0.062 (0.14)	0.139** (0.06)	0.043 (0.04)	0.102 (0.10)	0.029 (0.05)
Temp deviations $t-1$ - dry season	-0.084* (0.05)	-0.358*** (0.12)	-0.131** (0.06)	-0.152** (0.08)	-0.310* (0.16)	-0.180* (0.09)	0.012 (0.05)	-0.177 (0.12)	-0.010 (0.05)
Rain deviations $t-1$ - rainy season X share PROCAMPO to <i>Ejidotes</i> (non-irrig.) $t-1$		0.028 (0.15)			-0.067 (0.15)			-0.148 (0.12)	
Rain deviations $t-1$ - dry season X share PROCAMPO to <i>Ejidotes</i> (non-irrig.) $t-1$		0.407*** (0.10)			0.331*** (0.11)			0.210 (0.13)	
Temp deviations $t-1$ - rainy season X share PROCAMPO to <i>Ejidotes</i> (non-irrig.) $t-1$		0.071 (0.13)			0.112 (0.17)			-0.106 (0.12)	
Temp deviations $t-1$ - dry season X share PROCAMPO to <i>Ejidotes</i> (non-irrig.) $t-1$		0.349** (0.15)			0.201 (0.19)			0.267* (0.15)	
Rain deviations $t-1$ - rainy season X Cube root amt Fonden $t-1$			0.006 (0.01)			0.000 (0.01)			0.014 (0.01)
Rain deviations $t-1$ - dry season X Cube root amt Fonden $t-1$			0.042*** (0.01)			0.005 (0.01)			0.043*** (0.01)
Temp deviations $t-1$ - rainy season X Cube root amt Fonden $t-1$			0.007 (0.02)			0.011 (0.03)			0.008 (0.01)
Temp deviations $t-1$ - dry season X Cube root amt Fonden $t-1$			0.024** (0.01)			0.013 (0.01)			0.013 (0.01)
N	352	352	352	352	352	352	352	352	352

Standard errors corrected for autocorrelation and spatial correlation in parentheses

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