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

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# ABSTRACT

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

This paper uses state-level data on migration flows 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). While lower than average precipitations increase undocumented migration, especially from the most agricultural states, Fonden amounts decrease the undocumented migration response to abnormally low precipitations during the dry season. Changes equalizing the distribution of PROCAMPO and favoring vulnerable producers in the non irrigated ejido sector mitigate the impact of droughts on migration, especially for a high initial level of inequality.

**JEL Classification:** F22, Q54, Q18 , 015, J61

**Keywords:** international migration, climate, public policies, weather variability, natural disasters, Mexico-U.S. migration, inequality

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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. 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 climate 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 cope with climatic 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 change. 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 change on migration.

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. Migration flow data are constructed based on individual data from the Survey of Migration at the Northern Border of Mexico (*Encuesta sobre Migración en la Frontera Norte de México* or EMIF Norte). 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)[1]. Three unique features and major advantages of the migration flow data constructed from the EMIF are the availability of a 13 year panel, the fine level of regional disaggregation,

[1]See also Chort and De La Rupelle (2016) for a detailed discussion of the advantages and drawbacks of using the EMIF data to construct migration flow aggregates.

and the possibility to analyze documented and undocumented flows separately[2]. 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 undocumented 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 satellite and land data on precipitations and temperatures. We take in particular advantage of the very precise satellite data provided by the Tropical Rainfall Measuring Mission. 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 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 PROCAMPO beneficiaries in the *ejido* sector[3], 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 in our period of interest about half of the agricultural land, and

[2]Undocumented migrants are defined as individuals who declare having no document to cross the border nor to work in the US (see also the data section).

[3]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.

around 60% of the agricultural population. Households in the *ejido* sector are on average poorer and have significantly contributed to migration to the US (de Janvry et al., 1997). Two waves of reforms of PROCAMPO in the 2000s have increased the amounts per hectare received by producers cultivating small plots (less than 5 hectares), and by producers cultivating non-irrigated crops in the spring cycle.

Overall, although Martínez González et al. (2017) find that PROCAMPO subsidies have increased the income of tenant farmers, they suggest that PROCAMPO has contributed to increase income inequalities in Mexico. For those reasons, we investigate not only the effect of total amounts of PROCAMPO, but also distributional issues with several measures of inequality in the allocation of transfers. 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.

Identification relies on the assumption that changes in amounts - or inequality - of transfers received under the two programs are not caused by changes in migration patterns. Note that any time-invariant difference in state-level access to such programs is captured by state fixed-effects. We believe Fonden to be arguably exogenous enough to migration trends. Indeed, the disbursement of Fonden funds requires a declaration by the municipality which has experienced a natural disaster, as defined by Fonden operating rules, and the visit of a federal damage assessment committee.

PROCAMPO amounts are defined at the federal level and the set of eligible plots has been set in the 1990s. Following the two waves of reforms in the 2000s, strategic manipulation of plot size declared by producers and corruption arrangements may raise endogeneity concerns. To address this issue, we consider the set of all plots eligible in 1999[4] and their characteristics, before any reform took place, and apply to them the national variations in PROCAMPO paiements which followed in the subsequent years[5].

[4]Using the universe of PROCAMPO claims in 1999 for each state

[5]To retrieve information on national variations in PROCAMPO payments, we use the median return to plot characteristics in each year using information on 36.9 millions PROCAMPO claims between 1999 and 2011 and cross check the obtained figures with administrative sources.

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. We test the robustness of our results using the grouped fixed effect estimator developed by Bonhomme and Manresa (2015) which allows to control for time-varying unobserved heterogeneity patterns shared by groups of observations.

We find that undocumented Mexico-U.S. migration is highly sensitive to droughts in Mexico, consistent with previous studies in the same or comparable contexts (Munshi, 2003; Pugatch and Yang, 2011; Chort, 2014; Chort and De La Rupelle, 2016; Baez et al., 2017b,a). However, we provide evidence of the mitigating impact of the disaster fund Fonden. Similarly, a more equal distribution of PROCAMPO transfers is found to limit climate-induced migration.

This study is related 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 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 different migrant flows. Consistent with this intuition, our results show that the two programs that we study have different impacts on documented and undocumented flows.

Note that climatic shocks are expected to affect not only international migration but also internal relocation flows (see Marchiori et al. (2012), Gröger and Zylberberg (2016), Baez et al. (2017b) and, in the Mexican context Ruiz (2017)). Since we focus on international migration, our results provide a lower bound for the impact of climatic factors on human mobility.

# 2 Context and policies

## 2.1 Climate and migration in Mexico

Studying the consequences of weather variability on migration in the Mexican context is particularly interesting for three reasons. First Mexico sits astride the Tropic of Cancer and has a large diversity of climatic characteristics, although almost all parts of the country are subject to hurricanes and tropical storms in summer and autumn[6]. Second, the economy of Mexican rural areas largely depends on agricultural activities[7]. 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 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

[6]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.

[7]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).

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[8]. 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, 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 2002-2003 and 2009. The 2002-2003 reform increased in particular the amount per hectare received by small producers : plots smaller than 5 hectares would receive higher PROCAMPO benefits, while for plots smaller than one hectare, the payment was rounded to a full hectare. The 2009 modification established a maximum amount of one hundred thousand pesos per beneficiary and agricultural cycle and increased the

[8] 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.

amount received by non-irrigated plots in the spring 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[9]. Although PROCAMPO benefits are totally unrelated to climate events, this program is interesting because it is directed at agriculture, which is expected to be particularly affected by climate shocks. The coverage of the program is high, as the number of beneficiaries of PROCAMPO was 2,471,802 in 2010, representing 63% of agricultural production units. However the population of beneficiaries of PROCAMPO is highly heterogeneous, ranging from large producers cultivating irrigated land in the Northern part of the country to small farmers cultivating rainfed crops on a few hectares, mostly found in the *ejido* sector which represents 56% of Mexican agricultural land. The *ejido* sector has been associated with economic under-development ; besides limited property rights, it has also been plagued with the historical legacy of the 16th century demographic population collapse, including coercive institutions and rampant corruption (Sellars and Alix-Garcia, 2018). The *ejido* sector has undergone several changes in the 1990s leading to more individual control over *ejido* land, including a titling program initiated in 1993. Such reforms have been found to contribute to increasing migration flows to the U.S. (de Janvry et al., 2015; Valsecchi, 2014).

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

[9] About USD 100 in 2010.

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. Fonden is explicitly targeted at natural disasters that are unpredictable and exogenous to migration decisions. Eligibility to PROCAMPO 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 as regards 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). 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 use data on the universe of PROCAMPO claims (36.9 million individual claims between 1999 and 2011) to compute an exogenous measure of PROCAMPO transfers for each year and for each state. We retrieve the national variations in PROCAMPO amount per hectare by considering the median return to eligible hectares for the different irrigation status, producer categories and growing seasons. We double check using administrative sources that the obtained figures are correct. Then, we construct for each state and year a predicted measure of PROCAMPO transfers by combining the 1999 distribution of plot characteristics with the median yearly return to those characteristics. This predicted measure of PROCAMPO transfers thus depends only on nationwide changes in return to plot characteristics. In particular, state-level variations of total amounts, or changes in inequality measures of the distribution of PROCAMPO amounts, are driven by the state distribution of plots around the 5-hectare threshold in 1999, not by any strategic manipulation which could have followed the different reforms. Last, once the impact of state invariant characteristics has been accounted for with state fixed-effects, this predicted PROCAMPO measure is arguably exogenous to migration.

## 2.3 Expected effects and potential channels

We discuss in this section the impact of two different types of public programs on climate-induced migration : an unconditional cash-transfer program and a disaster fund that mimic the characteristics of the two programs PROCAMPO and Fonden. We have in mind a standard theoretical framework in which migration decision is taken based on a comparison of expected utilities and subject to liquidity or credit constraints. The latter assumption implies the existence of a pool of individuals willing to migrate but who are forced to stay for lack of sufficiently high income. Individual utility at home and abroad is expected to depend on local wage and amenities. We depart from Cattaneo and Peri (2016) and assume that climate shocks can affect both amenities, through the destruction of infrastructures for example, and wage at origin, by lowering productivity. Agricultural productivity is expected to be directly impacted by climate shocks, but productivity in non-agricultural sectors may also be negatively affected by adverse shocks (Hsiang, 2010). According to these two channels, a negative climate shock is expected to increase migration. A third effect goes in the opposite direction: through its impact on local wages, a negative climatic shock will reduce individual ability to fund migration costs and will tend to lower migration in case of credit or liquidity constraints. The resulting total impact of a negative climate shock on migration is indeterminate.

We now focus on the potentially mitigating effect of public policies by considering the impact of an unconditional agricultural cash transfer program[10], and a disaster fund, on the migration decision after a shock.

If the amounts received under the cash-transfer program are mostly invested in agricultural production, 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. 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. However, the transfer could also be used to fund migration. Provided that individual migration was initially subject to liquidity constraints, then the program would increase migration, consistent with the assumptions made by Angelucci (2015) for *Oportunidades*. 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. Through Fonden, funds are transferred to localities that suffered from a negative climate shock. Empirical evidence provided by de Janvry et al. (2016) suggest that the transfers received by localities contribute to the reconstruction infrastructures and generate a boom in the non-agricultural sector, due to the demand for labor created by reconstruction needs. 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

[10]Note that 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. However, as notes above, to avoid endogeneity issues we use predicted rather than actual amounts for PROCAMPO in our empirical analysis.

migration.

### Undocumented *versus* documented migrants

Documented migrants are likely to differ from undocumented ones along many dimensions, and in particular as regards their networks: documented migrants are likely to rely on stronger networks at destination than undocumented ones. Migration cost is expected to depend negatively on the size and strength of networks at destination. This suggests that migration costs could be cheaper for candidates to emigration being able to migrate with legal documents. All else equal, an increase in PROCAMPO transfers after a negative shock would thus increase undocumented migration more than documented migration as undocumented migrants have a tighter budget constraint.

On the other hand, thanks to their stronger networks, potential documented migrants may receive greater amounts of remittances that would play an insurance role against negative shocks, including climate shocks. As a consequence, an increase in PROCAMPO transfers would result into a greater post-shock income for potential documented migrants. The mitigating effect of PROCAMPO should thus be larger for documented migration than undocumented one. Considering both propositions together, the difference in the response of documented and undocumented migration to an increase in PROCAMPO transfers after a shock is unclear.

As for Fonden, the main effect of the disaster fund is to increase the value of the home option. Given that candidates to undocumented migration are expected to be provided less insurance by their networks, they are also expected to be more sensitive to an increase in Fonden than documented migrants.

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, especially for undocumented migrants. 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, especially undocumented flows, in response to an adverse climatic shock.

# 3 Data

## 3.1 Migration flows

Migration flow data are constructed from the EMIF surveys (Encuesta sobre Migración en la Frontera Norte de México)[11], 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[12]. 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[13]. To evaluate further the geographic representativeness of the EMIF, we compare the weighted state-level migration data from the EMIF to migration data from the ENADID (*Encuesta Nacional de la Dinámica Demográfica*) (Instituto Nacional de Estadística and Geografía (Mexico) and Consejo Nacional de Población (Mexico), 2011). 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

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

[12] 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`).

[13] 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)

received by Chiapas with regard to its number of international migrants (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).

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. We 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 documented and undocumented migrants, and thus to separately analyze 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.

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. To deal with this issue, we use a cube root transformation of the dependent variable. However, our results are robust to using the log migration rate, set the value of the log migration rate to $ln(0.001)$ for zero flows, and control in all regressions for a dummy variable equal to one when the flow is zero (results shown in Table 9). Both transformations of the dependent variable allow us to estimate our model with OLS. [14].

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

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 1999-2011) are undocumented.

### 3.2 Climate 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 variables[15]. 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[16]. 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) [17].

[15] 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).

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

[17] 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

A description of the state-level variability of the constructed measures of climate anomalies is provided in figures 8 to 11 in Appendix. These graphs show that, within each state, we observe substantial variation in the different z-scores.

In addition, 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)[18]. 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. These two variables are included in the set of controls in all regressions.

Data on income, population, agriculture and crime come from the Mexican Instituto Nacional de Estadística y Geografía (INEGI)[19]. Since the definition of GDP aggregates 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). Aggregate data on total annual amounts distributed at the state level under the Fonden program come from the open data Mexican government's website[20].

# 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

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 $t$.

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

[19] 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.

[20] `https://datos.gob.mx/`

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)[21]. Equations including public policies whose estimation results are shown in Table 2 and Table 3 are of the following type:

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

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 $i$ and season $s$ of year $t-1$, and $POL_{i,t-1}$ represents either the state-level amounts distributed under Fonden or different measures of PROCAMPO amounts and their distribution. $lnGDP_{i,t-1}$ 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.

[21]The code for STATA developed by Hsiang (2010), based on Conley (1999) is available at `http://www.fight-entropy.com/2010/06/standard-error-adjustment-ols-for.html`. We modified it in order to account for fixed-effects and we corrected for the subsequent loss of degree of freedom. Parameters are estimated by OLS, and standard errors are corrected accounting for serial correlation over 1 period and for spatial correlation up to a distance cutoff set at 500 km. The cutoff has been chosen after examining the Moran's I index (for male migration rate) using different distance thresholds. Moran's I is significant up to a cutoff of 1600km, and decreases from 0.4 to 0.01 as the distance cutoff increases from 200 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.

We control in our main specifications for the number of hurricanes and their maximum intensity, as well as the state-level GDP per capita, the unemployment rate and the rate of homicides in the Mexican state of origin, measured in $t-1$[22]. All our main results are however robust to controlling only for GDP per capita with a two-year lag, which is certainly exogenous enough to climate anomalies measured in $t-1$ (see Table 10) [23].

As 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 growing season, irrigation status, total area cultivated by the producer. We then retrieve the evolution of per-hectare payment by computing the median return for each year for all different types of plots[24]. We cross check the obtained figures with administrative sources. 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 "predicted" PROCAMPO variables.[25]

[22]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).

[23]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 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, our focus is on the impact of policies. Parsimonious specifications would imply the risk of omitting relevant factors correlated with both policies and migration variations.

[24]We know that a few states have departed from the national rule. So for a given year, we first compute the median for each state, and then consider the median of these medians.

[25]Note that results are robust to using the (potentially endogenous) raw value of PROCAMPO amounts - tables are available upon request.

# 5 Results

## 5.1 Impact of rainfall and temperatures

In order to investigate the mitigating effect of public policies, which is the primary objective of this paper, we first need to assess the impact of climate on migration. Results are shown in Table 1 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)[26]. All regressions include controls for the logarithm of the GDP per capita at origin, the unemployment rate, the logarithm of the homicide rate, the number and the intensity of hurricanes - all variables with a lag of one year. However, our results are unchanged when controlling only for the logarithm of the GDP per capita in $t-2$, which is unlikely to be correlated with climate shocks in $t-1$ (see Table 10).

We find a negative and significant effect of precipitations during the dry season and a positive and significant coefficient of temperature during the rainy season. Being able to distinguish documented and undocumented flows, we find that the impact of precipitations during the dry season is significant only for undocumented flows (col. 7). By contrast, documented migration is found to be affected by rainfall deviations during the rainy season and by temperatures during the dry season.

Columns 2, 5 and 8 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 top two agricultural quartiles (column 8), consistent with the intuition that agricultural states might be more sensitive to rainfall anomalies. By contrast, the positive effect of anomalies in temperatures during the rainy season is

[26] As already mentioned, results are robust to an alternative treatment of zero flows (results available upon request).

found to be driven by states in the second and third quartiles in terms of agricultural land share. This result is consistent with Hsiang (2010) who finds a larger negative impact of temperatures, especially during the hottest season, on productivity in non-agricultural sectors.

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[27].

Documented migration increases following negative rainfall shocks during the rainy season[28]. Undocumented migration increases following negative rain shocks during the dry season. As for temperatures, documented migration is sensitive to positive temperature shocks during the dry season, while undocumented migration rather responds (weakly) to negative temperature shocks during the dry season. 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)[29].

The magnitude of the effect is sizeable. On average, in our sample, the number of male migrants is equal to 49 per 10000 inhabitants, with a median of 37 and a standard deviation of 46. A change from 0 to -1 for the rainfall z-score during the dry season contributes to increasing the migration rate by 2.3 per 10 000 inhabitants. Our specification being non-linear, the effect of a change in the rainfall z-score depends on the initial value of the variable [30]. Our results indicate that the impact of a negative rain shock is slightly higher when the initial value of the z-score is negative[31].

[27] For each type of climate anomaly, the specifications disentangle positive and negative z-scores.

[28] Since by construction all negative deviations variables take negative or zero values, the negative and significant coefficient on the negative rain deviations variable in the column 6 of Table 1 indicates that negative rainfall shocks increase documented migration.

[29] Results are robust to the exclusion of year 2010 which follows the exceptional drought episode of 2009. Results are available upon request.

[30] The computation of marginal effects is detailed in the Appendix.

[31] If in year $t-1$ one state has experienced below than average precipitations, a more severe drought in year $t$ will have a stronger impact on migration - the difference is however very small

## Table 1: Climatic factors and Mexico-US migration flows

| Cube root dependent variable | Total male flows | | | Documented male flows | | | Undocumented male flows | | |
|---|---|---|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) |
| Rain deviations $_{t-1}$ - rainy season | -0.058 | | | -0.100*** | | | -0.013 | | |
| | (0.04) | | | (0.04) | | | (0.04) | | |
| Rain deviations $_{t-1}$ - dry season | -0.068** | | | 0.016 | | | -0.066** | | |
| | (0.03) | | | (0.04) | | | (0.03) | | |
| Temp deviations $_{t-1}$ - rainy season | 0.125* | | | 0.091 | | | 0.067 | | |
| | (0.07) | | | (0.07) | | | (0.05) | | |
| Temp deviations $_{t-1}$ - dry season | -0.049 | | | -0.104* | | | 0.026 | | |
| | (0.05) | | | (0.06) | | | (0.04) | | |
| Rain $_{t-1}$ X quartile 1 of agri share - rainy season | | -0.191** | | | -0.215*** | | | -0.044 | |
| | | (0.07) | | | (0.08) | | | (0.08) | |
| Rain $_{t-1}$ X quartile 2 of agri share - rainy season | | 0.021 | | | -0.115 | | | -0.023 | |
| | | (0.07) | | | (0.08) | | | (0.07) | |
| Rain $_{t-1}$ X quartile 3 of agri share - rainy season | | 0.003 | | | 0.037 | | | 0.003 | |
| | | (0.06) | | | (0.05) | | | (0.06) | |
| Rain $_{t-1}$ X quartile 4 of agri share - rainy season | | 0.025 | | | -0.029 | | | 0.046 | |
| | | (0.06) | | | (0.07) | | | (0.06) | |
| Rain $_{t-1}$ X quartile 1 of agri share - dry season | | -0.079 | | | 0.009 | | | -0.040 | |
| | | (0.08) | | | (0.08) | | | (0.07) | |
| Rain $_{t-1}$ X quartile 2 of agri share - dry season | | 0.004 | | | 0.055 | | | -0.036 | |
| | | (0.04) | | | (0.04) | | | (0.04) | |
| Rain $_{t-1}$ X quartile 3 of agri share - dry season | | -0.081* | | | 0.074 | | | -0.125*** | |
| | | (0.05) | | | (0.08) | | | (0.05) | |
| Rain $_{t-1}$ X quartile 4 of agri share - dry season | | -0.129** | | | -0.021 | | | -0.110*** | |
| | | (0.05) | | | (0.06) | | | (0.04) | |
| Temp $_{t-1}$ X quartile 1 of agri share - rainy season | | 0.076 | | | 0.167 | | | -0.013 | |
| | | (0.09) | | | (0.12) | | | (0.07) | |
| Temp $_{t-1}$ X quartile 2 of agri share - rainy season | | 0.238*** | | | 0.097 | | | 0.168** | |
| | | (0.08) | | | (0.07) | | | (0.07) | |
| Temp $_{t-1}$ X quartile 3 of agri share - rainy season | | 0.212*** | | | 0.099 | | | 0.185*** | |
| | | (0.08) | | | (0.08) | | | (0.06) | |
| Temp $_{t-1}$ X quartile 4 of agri share - rainy season | | 0.097 | | | 0.052 | | | 0.030 | |
| | | (0.08) | | | (0.09) | | | (0.05) | |
| Temp $_{t-1}$ X quartile 1 of agri share - dry season | | -0.126 | | | -0.157 | | | -0.053 | |
| | | (0.10) | | | (0.12) | | | (0.07) | |
| Temp $_{t-1}$ X quartile 2 of agri share - dry season | | 0.017 | | | -0.116* | | | 0.092 | |
| | | (0.06) | | | (0.07) | | | (0.07) | |
| Temp $_{t-1}$ X quartile 3 of agri share - dry season | | -0.040 | | | 0.014 | | | -0.014 | |
| | | (0.05) | | | (0.06) | | | (0.04) | |
| Temp $_{t-1}$ X quartile 4 of agri share - dry season | | -0.090 | | | -0.141* | | | 0.030 | |
| | | (0.06) | | | (0.08) | | | (0.06) | |
| Positive rain deviations $_{t-1}$ - rainy season | | | -0.056 | | | -0.057 | | | -0.035 |
| | | | (0.06) | | | (0.05) | | | (0.05) |
| Negative rain deviations $_{t-1}$ - rainy season | | | -0.067 | | | -0.204* | | | 0.031 |
| | | | (0.09) | | | (0.11) | | | (0.08) |
| Positive rain deviations $_{t-1}$ - dry season | | | -0.024 | | | 0.036 | | | -0.024 |
| | | | (0.04) | | | (0.05) | | | (0.04) |
| Negative rain deviations $_{t-1}$ - dry season | | | -0.169** | | | -0.006 | | | -0.173** |
| | | | (0.08) | | | (0.09) | | | (0.07) |
| Positive temp deviations $_{t-1}$ - rainy season | | | 0.130* | | | 0.091 | | | 0.088 |
| | | | (0.08) | | | (0.09) | | | (0.06) |
| Negative temp deviations $_{t-1}$ - rainy season | | | 0.148 | | | 0.143 | | | 0.038 |
| | | | (0.09) | | | (0.12) | | | (0.07) |
| Positive temp deviations $_{t-1}$ - dry season | | | -0.094 | | | -0.161** | | | -0.023 |
| | | | (0.06) | | | (0.08) | | | (0.06) |
| Negative temp deviations $_{t-1}$ - dry season | | | 0.010 | | | -0.031 | | | 0.096 † |
| | | | (0.08) | | | (0.09) | | | (0.06) |
| N | 416 | 416 | 416 | 416 | 416 | 416 | 416 | 416 | 416 |

Standard errors corrected for autocorrelation and spatial correlation in parentheses
† $p < 0.11$, * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$
Controls not shown: log GDP per capita in $t-1$, unemployment rate in $t-1$, log share of homicides in $t-1$, number of hurricanes in $t-1$, and hurricane intensity in $t-1$.

## 5.2 Mitigating impact of public policies

In Table 2, we explore the effects 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 consider the cube root of the yearly per capita amounts received, but our results are robust to alternative choices[32]. Regarding PROCAMPO, our variable of interest is the log predicted per capita amount received at the state level.

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, 4, and 7 of Table 1 on this shorter period, adding to the set of independent variables 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.

[32] Our 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). Results are shown in Table 8.

## Table 2: Climatic factors and Mexico-US migration flows : impact of public policies, 2001-2011

| Cube root dependent variable | | male flows | | | Documented male flows | | | Undocumented male flows | |
|---|---|---|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) |
| Log pred. PROCAMPO per cap $_{t-1}$ | 0.459 | 0.413 | 0.588 | 0.599 | 0.290 | 0.758 | -0.378 | -0.266 | -0.283 |
| | (0.75) | (0.76) | (0.74) | (0.76) | (0.81) | (0.77) | (0.68) | (0.68) | (0.70) |
| Cube root amount Fonden $_{t-1}$ | 0.037** | 0.037** | 0.011 | 0.043** | 0.043** | 0.032 | 0.013 | 0.012 | -0.016 |
| | (0.02) | (0.02) | (0.02) | (0.02) | (0.02) | (0.02) | (0.02) | (0.02) | (0.02) |
| Rain deviations $_{t-1}$ - rainy season | -0.068 | -0.371 | -0.083 | -0.113** | -0.202 | -0.112* | -0.027 | 0.003 | -0.062 |
| | (0.05) | (0.34) | (0.05) | (0.05) | (0.42) | (0.06) | (0.05) | (0.28) | (0.06) |
| Rain deviations $_{t-1}$ - dry season | -0.049 | -0.112 | -0.150*** | 0.022 | 0.407 | 0.010 | -0.056* | -0.319 | -0.153*** |
| | (0.03) | (0.37) | (0.04) | (0.04) | (0.43) | (0.06) | (0.03) | (0.41) | (0.04) |
| Temp deviations $_{t-1}$ - rainy season | 0.141* | 0.124 | 0.130* | 0.131 | 0.441 | 0.119 | 0.049 | -0.020 | 0.031 |
| | (0.08) | (0.35) | (0.07) | (0.08) | (0.32) | (0.08) | (0.05) | (0.30) | (0.06) |
| Temp deviations $_{t-1}$ - dry season | -0.086 | -0.035 | -0.129* | -0.156* | 0.833* | -0.181** | 0.003 | -0.432 | -0.014 |
| | (0.06) | (0.45) | (0.07) | (0.08) | (0.50) | (0.09) | (0.05) | (0.38) | (0.05) |
| Rain deviations $_{t-1}$ - rainy season X Log pred. PROCAMPO per cap $_{t-1}$ | | 0.026 | | | 0.008 | | | -0.003 | |
| | | (0.03) | | | (0.03) | | | (0.02) | |
| Rain deviations $_{t-1}$ - dry season X Log pred. PROCAMPO per cap $_{t-1}$ | | 0.005 | | | -0.034 | | | 0.023 | |
| | | (0.03) | | | (0.04) | | | (0.04) | |
| Temp deviations $_{t-1}$ - rainy season X Log pred. PROCAMPO per cap $_{t-1}$ | | 0.002 | | | -0.028 | | | 0.006 | |
| | | (0.03) | | | (0.03) | | | (0.03) | |
| Temp deviations $_{t-1}$ - dry season X Log pred. PROCAMPO per cap $_{t-1}$ | | -0.005 | | | -0.085** | | | 0.038 | |
| | | (0.04) | | | (0.04) | | | (0.03) | |
| Rain deviations $_{t-1}$ - rainy season X Cube root amount Fonden $_{t-1}$ | | | 0.006 | | | -0.001 | | | 0.014 |
| | | | (0.01) | | | (0.01) | | | (0.01) |
| Rain deviations $_{t-1}$ - dry season X Cube root amount Fonden $_{t-1}$ | | | 0.039*** | | | 0.004 | | | 0.039*** |
| | | | (0.01) | | | (0.01) | | | (0.01) |
| Temp deviations $_{t-1}$ - rainy season X Cube root amount Fonden $_{t-1}$ | | | 0.010 | | | 0.012 | | | 0.010 |
| | | | (0.01) | | | (0.03) | | | (0.01) |
| Temp deviations $_{t-1}$ - dry season X Cube root amount Fonden $_{t-1}$ | | | 0.024 | | | 0.013 | | | 0.012 |
| | | | (0.01) | | | (0.01) | | | (0.01) |
| N | 352 | 352 | 352 | 352 | 352 | 352 | 352 | 352 | 352 |

Standard errors corrected for autocorrelation and spatial correlation in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$
Controls not shown: log GDP per capita in $t-1$, unemployment rate in $t-1$, log share of homicides in $t-1$, number of hurricanes in $t-1$, and hurricane intensity in $t-1$.

First, the coefficient on Fonden amounts is positive for total and documented male flows, yet it is not significant when interaction terms between Fonden amounts and climatic variables are included. By contrast, the coefficient on PROCAMPO transfers is never significant.

When interacting the amounts distributed under PROCAMPO or Fonden and rainfall and temperature variables we find contrasted results. The interaction with Fonden suggests a mitigating effect of the Fonden program for undocumented flows: a concurrent increase in the Fonden variable limits or even outbalances the effect of a drought[33]. Such result might seem puzzling at first, since the program is primarily intended at the reconstruction of damaged low-income housing and infrastructures (de Janvry et al., 2016) and droughts are not expected to have such a damaging impact on infrastructures. However 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. Indeed, 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)[34]. As a consequence, normal rainfall may result in runoff and flooding with potential devastating consequences if they occur after a period of drought. Such mechanism may thus explain why we find a mitigating impact of Fonden during drier than average periods. Note that drought induced Hortonian runoff accelerate soil degradation, which in turn decreases the water holding capacity of soils.

We find no evidence of any mitigating effect of PROCAMPO amounts on total and undocumented flows after a rainfall shock, yet an increase in PROCAMPO amounts reduces the impact of temperature deviations on documented flows. Positive temperature deviations during the dry season have in average a negative impact on documented

[33] As noted above, negative deviations in rainfall during the dry season increase migration. 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.

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

flows. However, once an interaction term between temperature deviations during the dry season and the log of predicted PROCAMPO amount is introduced, the main effect of temperature deviations becomes positive while the coefficient on the interaction between temperature deviations during the dry season and PROCAMPO amounts is negative and significant. Temperature deviations have a smaller impact on migration when PROCAMPO amounts per capita increase.

**Documented *vs.* undocumented**

The absence of mitigating impact of Fonden on documented flows may stem from the fact that documented migrants are more likely than undocumented ones 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 state level to test this interpretation.

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 occurred 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).

### Distributional effects

The interpretation of our results with respect to PROCAMPO deserves further exploration. Pro-poor reforms of PROCAMPO have increased the amounts received by the smallest producers and have contributed to reduce inequalities. Table 3 presents the estimation results of models including two different measures of inequality in the distribution of PROCAMPO. 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. Both measures are based on predicted PROCAMPO amounts : they combine the distribution of plots per producers in 1999 with the yearly evolution of the PROCAMPO benefits they were theoretically entitled to in the subsequent years (see the discussion above). To facilitate the reading of the table, both measures are constructed such that an increase in the variable represents a more redistributive program. We control in all specifications for the log of predicted PROCAMPO amounts.

A change in the redistributive attributes of PROCAMPO is found to affect both documented and undocumented flows in response to temperature and rainfall anomalies. A decrease in the Gini for PROCAMPO amounts or 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. Results in columns 3 to 6 highlight differences between documented and undocumented migration. More redistributive reforms mitigate the impact of rainfall shocks for documented migration. For undocumented flows, this mitigating impact is observed only for the share of PROCAMPO to non irrigated *ejido* plots. As for temperatures, more redistributive PROCAMPO transfers have a mitigating impact in that they limit the increase in undocumented migration due to lower than average temperatures[35].

[35] As shown in Table 1, undocumented migration responds to negative temperature deviations.

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.

## Table 3: Impact of public policies : inequality measures of PROCAMPO

| Cube root dependent variable | Total male flows | | Documented male flows | | Undocumented male flows | |
|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) |
| 1 - Gini pred. PROCAMPO amount $_{t-1}$ | -1.470 | | -6.088 | | -3.230 | |
| | (5.26) | | (6.93) | | (5.04) | |
| Pred. sh. PROCAMPO non irrig. *ejidos* $_{t-1}$ | | -13.031** | | -14.661** | | -11.230** |
| | | (5.34) | | (7.19) | | (5.42) |
| Rain deviations $_{t-1}$ - rainy season | -0.025 | -0.084 | -0.216 | -0.044 | 0.234 | 0.041 |
| | (0.25) | (0.10) | (0.29) | (0.11) | (0.22) | (0.09) |
| Rain deviations $_{t-1}$ - dry season | -0.427** | -0.416*** | -0.358* | -0.231** | -0.241 | -0.294*** |
| | (0.20) | (0.10) | (0.21) | (0.11) | (0.20) | (0.11) |
| Temp deviations $_{t-1}$ - rainy season | 0.250 | 0.107 | 0.445 | 0.103 | -0.054 | 0.079 |
| | (0.37) | (0.14) | (0.42) | (0.16) | (0.28) | (0.10) |
| Temp deviations $_{t-1}$ - dry season | -0.732* | -0.401** | -0.686* | -0.317 | -0.498* | -0.237* |
| | (0.39) | (0.17) | (0.39) | (0.20) | (0.29) | (0.12) |
| Rain deviations $_{t-1}$ - rainy season X 1 - Gini pred. PROCAMPO amount $_{t-1}$ | -0.112 | | 0.178 | | -0.529 | |
| | (0.48) | | (0.57) | | (0.43) | |
| Rain deviations $_{t-1}$ - dry season X 1 - Gini pred. PROCAMPO amount $_{t-1}$ | 0.686* | | 0.710* | | 0.318 | |
| | (0.37) | | (0.41) | | (0.39) | |
| Temp deviations $_{t-1}$ - rainy season X 1 - Gini pred. PROCAMPO amount $_{t-1}$ | -0.246 | | -0.647 | | 0.183 | |
| | (0.67) | | (0.78) | | (0.55) | |
| Temp deviations $_{t-1}$ - dry season X 1 - Gini pred. PROCAMPO amount $_{t-1}$ | 1.199* | | 0.967 | | 0.919* | |
| | (0.73) | | (0.72) | | (0.55) | |
| Rain deviations $_{t-1}$ - rainy season X Pred. sh. PROCAMPO non irrig. *ejidos* $_{t-1}$ | | 0.028 | | -0.094 | | -0.101 |
| | | (0.13) | | (0.14) | | (0.11) |
| Rain deviations $_{t-1}$ - dry season X Pred. sh. PROCAMPO non irrig. *ejidos* $_{t-1}$ | | 0.483*** | | 0.342** | | 0.314** |
| | | (0.12) | | (0.14) | | (0.14) |
| Temp deviations $_{t-1}$ - rainy season X Pred. sh. PROCAMPO non irrig. *ejidos* $_{t-1}$ | | 0.025 | | 0.011 | | -0.076 |
| | | (0.17) | | (0.20) | | (0.13) |
| Temp deviations $_{t-1}$ - dry season X Pred. sh. PROCAMPO non irrig. *ejidos* $_{t-1}$ | | 0.384* | | 0.193 | | 0.313** |
| | | (0.20) | | (0.23) | | (0.15) |
| N | 352 | 352 | 352 | 352 | 352 | 352 |

Standard errors corrected for autocorrelation and spatial correlation in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$
Controls not shown: log GDP per capita in $t-1$, unemployment rate in $t-1$, log share of homicides in $t-1$,
number of hurricanes in $t-1$, hurricane intensity in $t-1$, cube root amount Fonden in $t-1$, and log predicted amount of PROCAMPO per capita in $t-1$.

**Magnitude of the effects**

The coefficients shown in Table 2 and Table 3 suggest that both public policies reduce substantially the impact of climate anomalies on migration. As a result of our specification choices, the marginal effects of the interaction between climate shocks and policy variables depend on the initial values of the variables. We thus choose to present them in graphic form (Figures 1b, 2b and 3b), with a focus on rainfall shocks during the dry season[36]. We also report graphically confidence intervals for an initial value of the rainfall z-score equal to zero (Figures 1a, 2a and 3a).

Fonden has a clear mitigating effect: when the rainfall z-score decreases from 0 to -1, an increase in Fonden amounts from 74 pesos per capita to 314 pesos per capita[37] implies a decrease in the migration response to the negative rainfall shock by 2.6 points (per 10 000 inhabitants). Given that the sample mean is 49 migrants per 10 000 inhabitants, and that Fonden funds are often disbursed in localized areas, the mitigating impact of Fonden appears non negligible.

Regarding PROCAMPO, a more equitable allocation of distributed amounts is found to limit the impact of climate shocks on migration. If the share of PROCAMPO allocated to non-irrigated *ejido* plots increases from 44% to 73%[38], the impact of a negative rainfall shock of 1 s.d. below the mean on migration is reduced by about 5 (per 10,000), corresponding to a 10 percent decrease. Note that the larger the initial level of ineqality in the distribution of PROCAMPO, the stronger the mitigating effect of a more equal distribution. In addition, a more equitable allocation is found to have the larger mitigating impact when drought conditions are worsening, i.e. for a negative value of the initial level of the rainfall z-score.

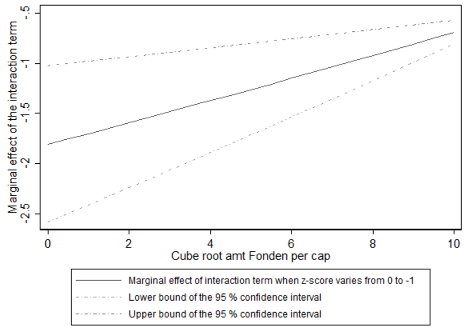
[36]See Appendix B for details on the calculation of the marginal effect.

[37]74 pesos per capita is the sample mean of Fonden amount per capita. An increase of the cube root amount by 2.6 translates into an increase from 74 to 314 pesos per capita in the raw amount.

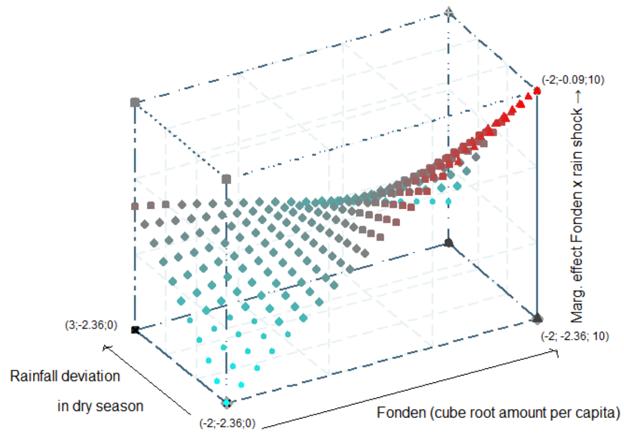
[38]73% is the sample mean ; 44% is one standard deviation below the sample mean.

Figure 1: Marginal effect of the interaction between Fonden (cube root amount per capita) and a negative variation in the z-score of dry season rainfall on the migration rate (per 10000 population).

(a) when the initial value of the rainfall z-score is zero.



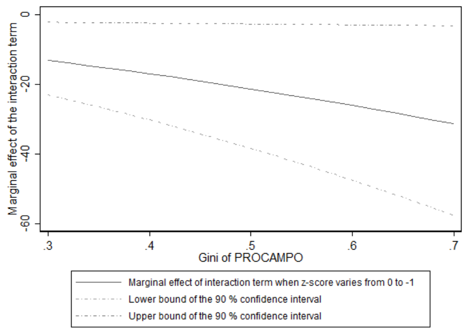

(b) For different initial values of the rainfall z-score.



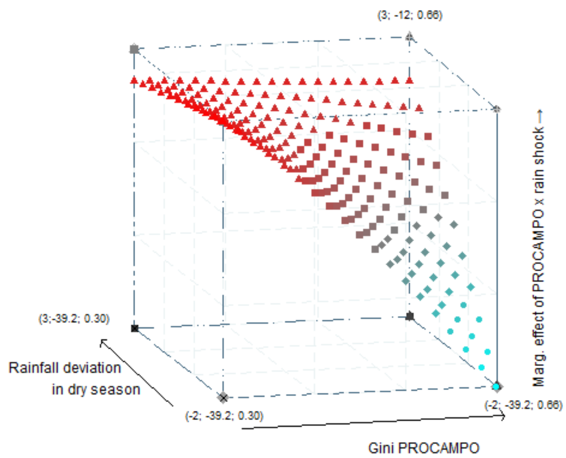

Coordinates in parentheses :(z-score; marginal effect of the interaction z-score X Fonden amount on the migration rate; Fonden cube root amount per capita).

Figure 2: Marginal effect of the interaction between PROCAMPO Gini and a negative variation in the z-score of dry season rainfall on the migration rate (per 10000 population).

(a) when the initial value of the rainfall z-score is zero.



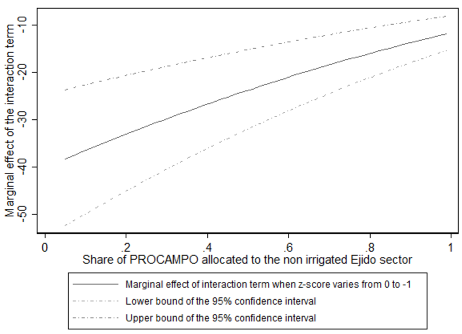

(b) For different initial values of the rainfall z-score.



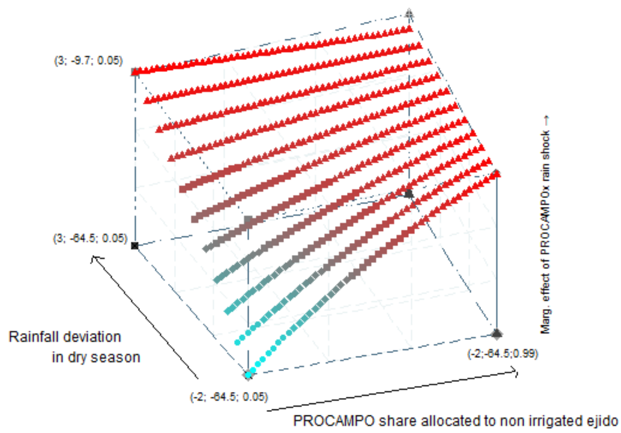

Coordinates in parentheses : (z-score; marginal effect of the interaction z-score X PROCAMPO gini on the migration rate; PROCAMPO gini).

Figure 3: Marginal effect of the interaction between the PROCAMPO share allocated to the non irrigated *ejido* sector and a negative variation in the z-score of dry season rainfall on the migration rate (per 10000 population).

(a) when the initial value of the rainfall z-score is zero.




(b) For different initial values of the rainfall z-score.




Coordinates in parentheses : (z-score; marginal effect of the interaction z-score X PROCAMPO share going to non irrigated *ejidos*; PROCAMPO share going to non irrigated *ejidos*).

### 5.3 Group fixed-effects estimations and additional robustness checks

We apply to the analysis of migration flows the estimator developed by Bonhomme and Manresa (2015) which allows to control for time-varying unobserved heterogeneity patterns shared by groups of observations. 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 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 2 and Table 3 with the number of groups varying from 2 to 7. Results with 4 groups are shown in Appendix (Table 11) and are very similar to those presented in the main tables.

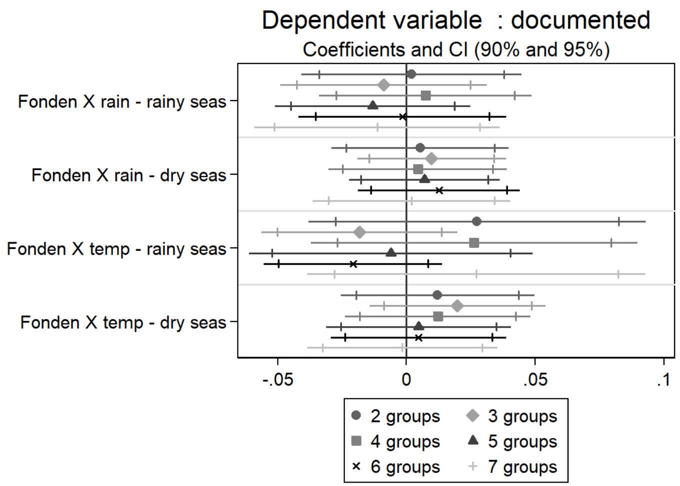



Figure 4: GFE coefficients for Fonden, documented flows

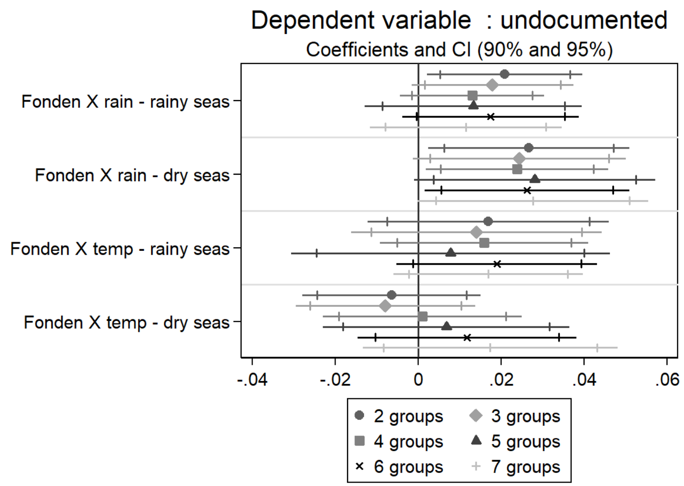



Figure 5: GFE coefficients for Fonden, undocumented flows

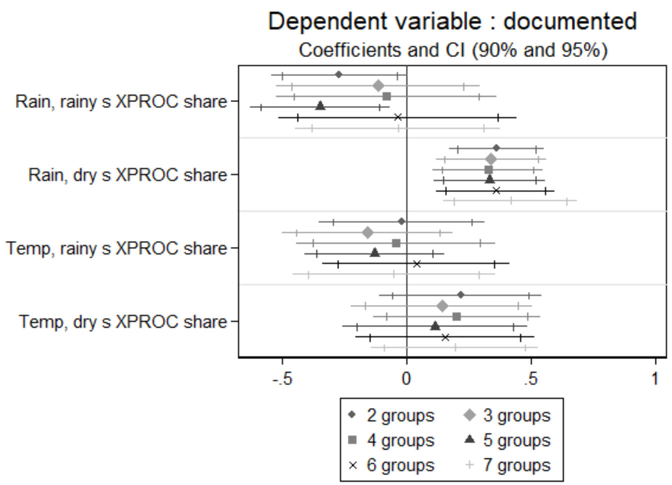



Figure 6: GFE coefficients for PROCAMPO (predicted share of PROCAMPO amounts to non-irrigated *ejido* land), documented flows

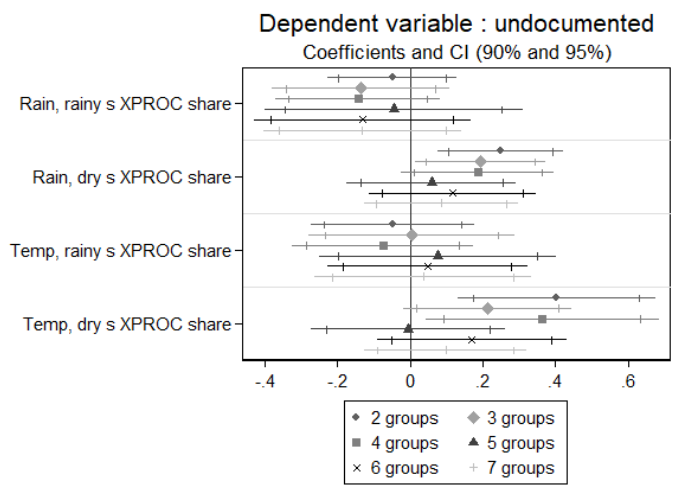



Figure 7: GFE coefficients for PROCAMPO (predicted share of PROCAMPO amounts to non-irrigated *ejido* land), undocumented flows

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.

Figures 4 to 7 display the coefficients obtained with the GFE estimator for the variables of interest, namely the interactions between Fonden or PROCAMPO (share of PROCAMPO funds to non-irrigated *ejido* land), and climate variables, depending on the number of groups. Standard errors are obtained after a blockbootstrap of 1000 replications. Results for the Gini of the PROCAMPO distribution are presented in Figures 12 and 13 in the appendix. The graphs all show that both the order of magnitude and significance of the coefficients are consistent with the results previously obtained.

The main difference concerns the interaction between PROCAMPO and temperature deviations, which is not significant anymore. Moreover, the effects of the interaction between PROCAMPO and rain deviations are significant for undocumented flows only for a small number of groups (2 to 4).

The impact of Fonden is consistent with the hypothesis made in the theoretical framework. The results obtained suggest that PROCAMPO has a strong impact through agricultural investment, and that documented migrants enjoy a greater return to their investments. This interpretation is consistent with the results obtained by Sadoulet et al. (2001) who find higher income multiplier effects of PROCAMPO on medium and large *ejido* farms. Indeed we expect the probability of migrating without document to be negatively correlated with land size.

**Robustness**

Our definition of the dry season is such that it aggregates the first and the last quarters of a given civil year in a single period. However, our results are robust to the disaggregation of seasons by quarters. We find that most of the observed effect is driven by shocks occurring during the last quarter[39].

In addition, our results are robust to restricting the set of economic and social controls to the GDP with a two-year lag (see Table 10 in Appendix) or to taking the dependent or Fonden variables in log rather than using a cube root transformation (Table 8 and

[39] Table available upon request.

Table 9). The only difference is that the coefficients on the interaction between the Gini measure of PROCAMPO and climate shocks are not significant anymore.

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 12 and are very close to those presented in our main tables.

# 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 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 mitigate the impact of climate shocks on migration. We find that seasonal weather variability has a strong impact on outmigration rates from Mexican states, especially when considering undocumented migration. Yet our results highlight the importance of a disaster fund, Fonden, as well as of reforms reducing inequalities in the agricultural sector, in lowering the migration response to climate shocks. An increase in amounts transferred under Fonden limits the undocumented migration response to abnormally low rainfall during the dry season. In addition, an increase in the redistributive attributes of PROCAMPO - in particular, a larger share received by farmers in the *ejido* sector for non-irrigated land - reduces both documented and undocumented migration after a drought.

In addition, our results stress the strong impact that lower than average precipitations and temperatures during the dry season have on undocumented migration, consistent with Munshi (2003) or Nawrotzki et al. (2013), especially from the most agricultural states.

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. Consistent with de Janvry et al. (2016), 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. Although disconnected from weather-related shocks, redistributive PROCAMPO reforms appear to have reduced the impact of droughts on migration.

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# Appendix A: Additional tables and figures

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. | 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 |
| Log predicted PROCAMPO per $10^4$ inhab. (2001-2011) $_{t-1}$ | 11.473 | 1.226 | 352 |
| (1 - Gini of predicted PROCAMPO transfers) $_{t-1}$ | 0.48 | 0.084 | 352 |
| Predicted share of PROCAMPO for non irrigated ejido $_{t-1}$ | 0.734 | 0.291 | 352 |
| Cube root amount Fonden $_{t-1}$ pesos per capita (2001-2011) | 1.936 | 2.408 | 352 |

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

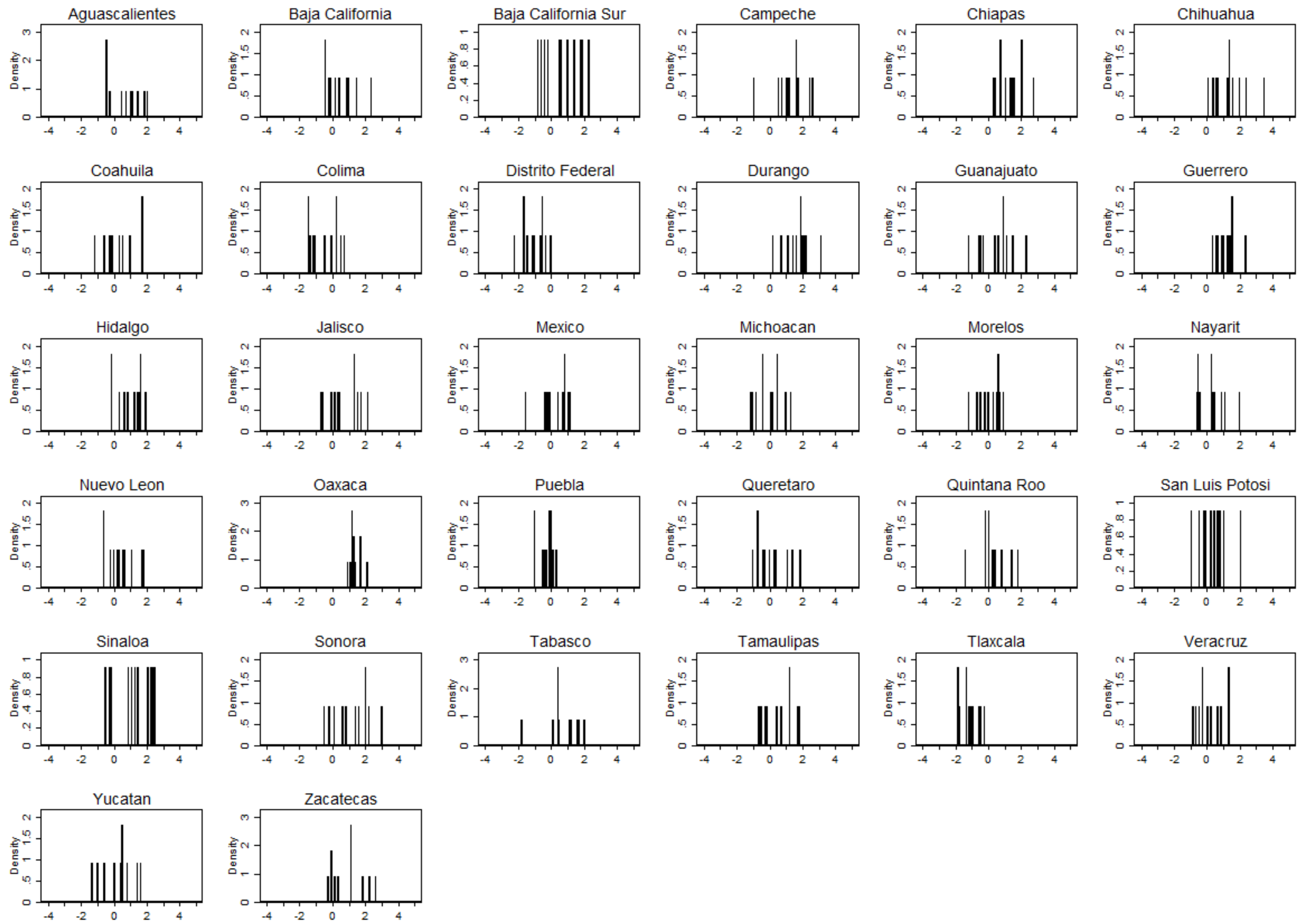

Figure 9: Rainfall during the dry season - Z-score density by state (2000-2010)

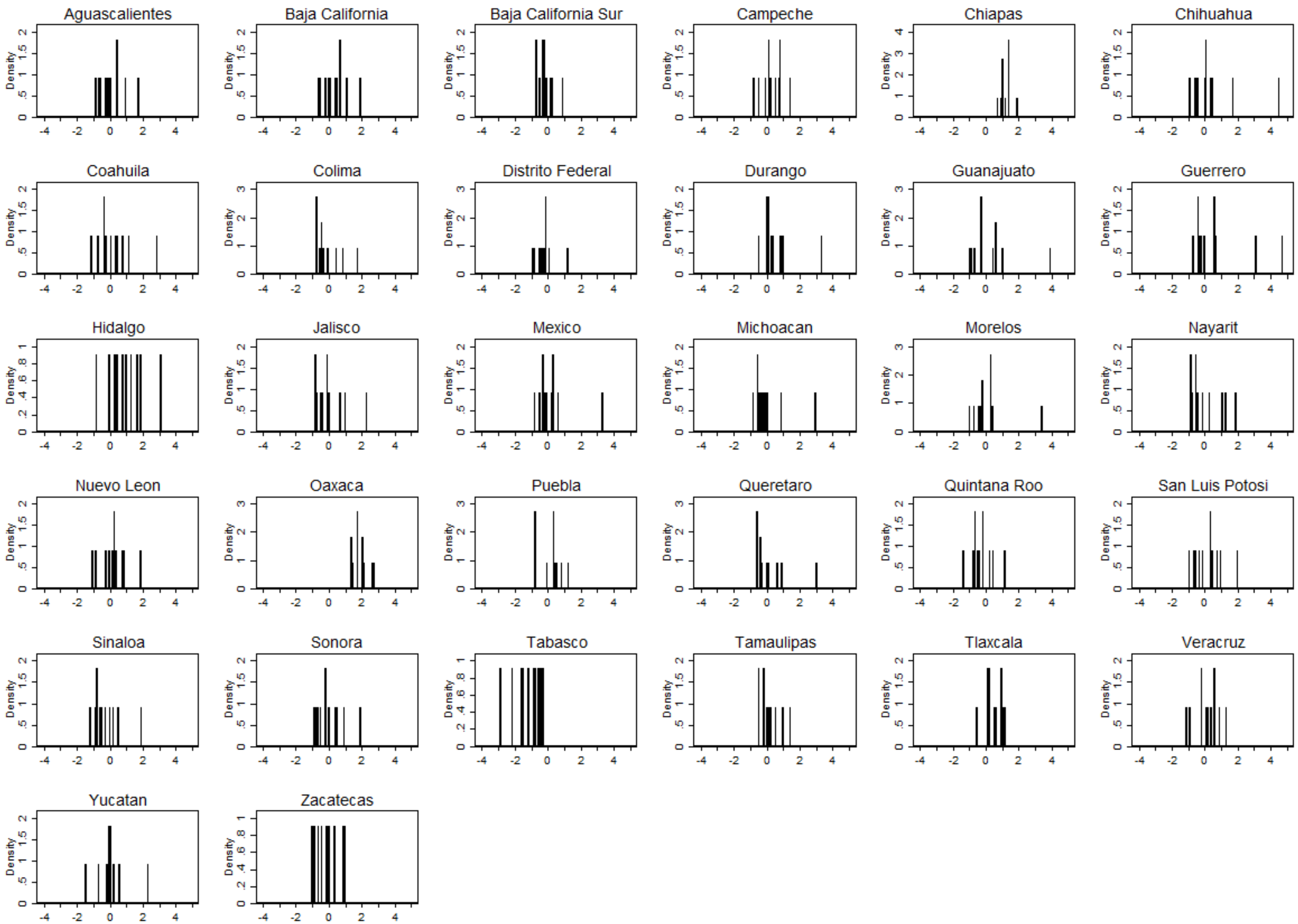

Figure 10: Temperature during the rainy season - Z-score density by state (2000-2010)

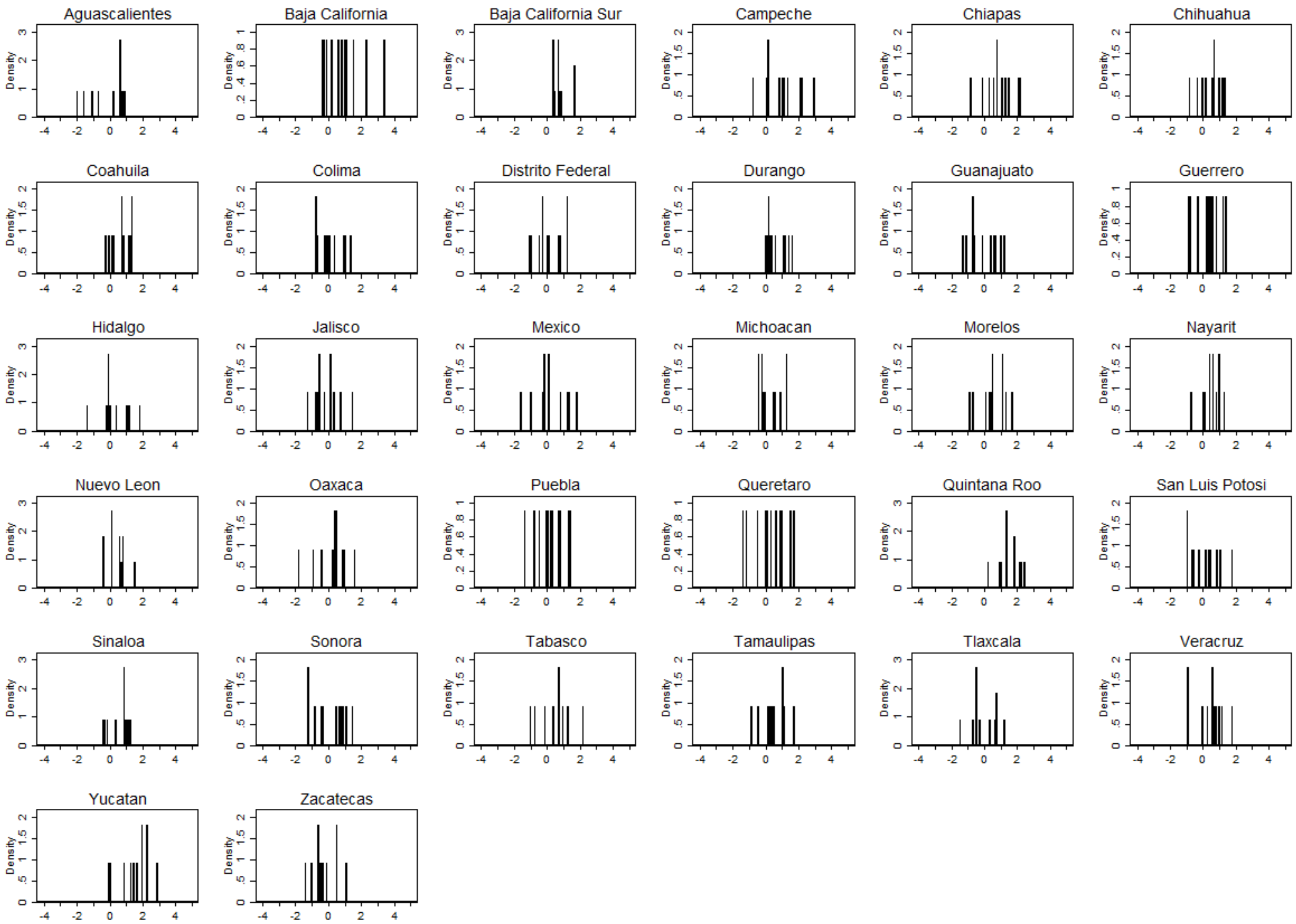

Figure 11: Temperature during the dry season - Z-score density by state (2000-2010)

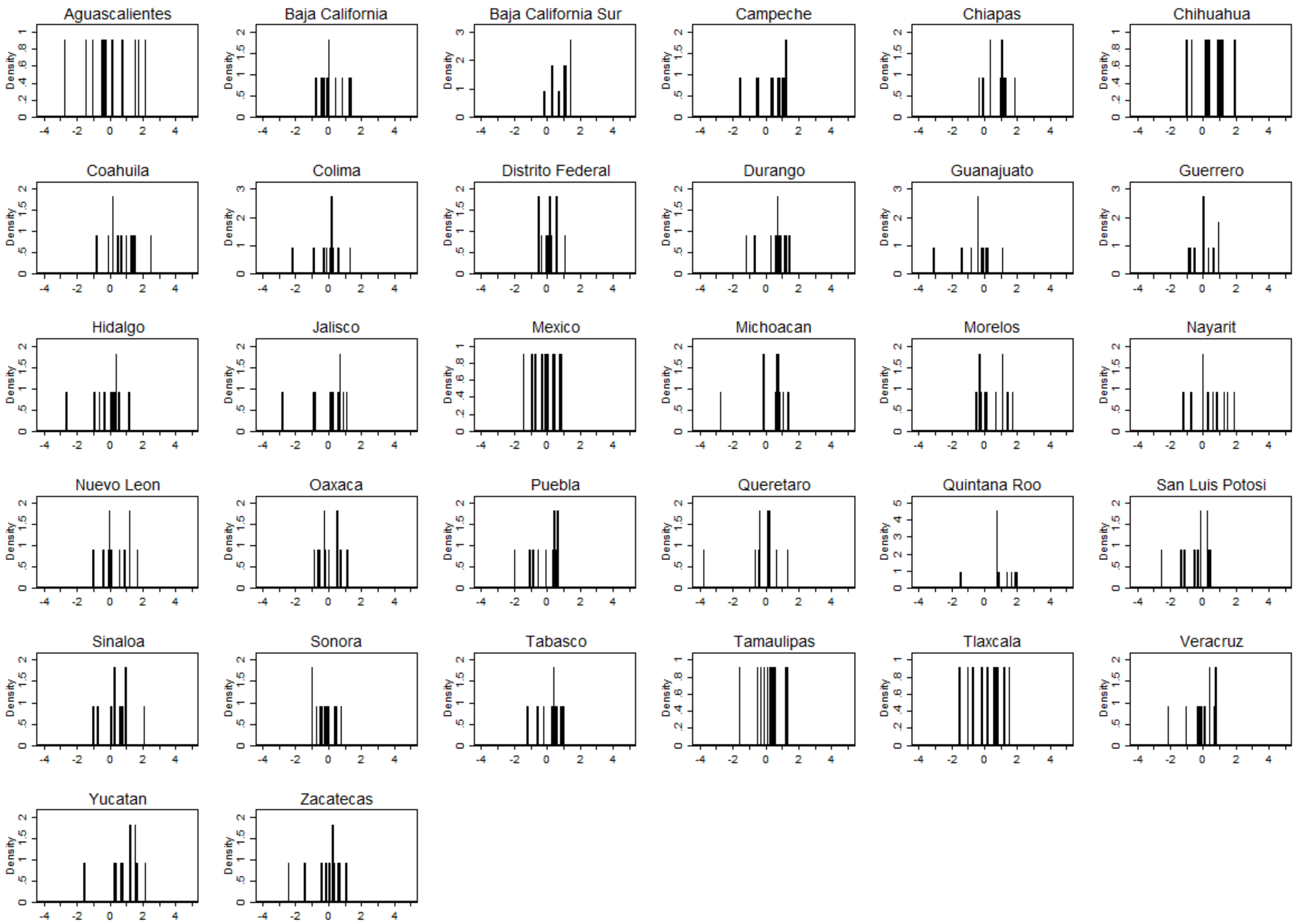

Table 6: Climatic factors and Mexico-US migration flows (GDP with two lags, without unemployment and homicides)

| Cube root dependent variable | Total male flows | | | Documented male flows | | | Undocumented male flows | | |
|---|---|---|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) |
| Rain deviations $_{t-1}$ - rainy season | -0.048 | | | -0.076** | | | -0.009 | | |
| | (0.04) | | | (0.04) | | | (0.04) | | |
| Rain deviations $_{t-1}$ - dry season | -0.067* | | | 0.005 | | | -0.059* | | |
| | (0.04) | | | (0.04) | | | (0.03) | | |
| Temp deviations $_{t-1}$ - rainy season | 0.096 | | | 0.057 | | | 0.055 | | |
| | (0.07) | | | (0.07) | | | (0.05) | | |
| Temp deviations $_{t-1}$ - dry season | -0.019 | | | -0.062 | | | 0.037 | | |
| | (0.05) | | | (0.06) | | | (0.04) | | |
| Rain $_{t-1}$ X quartile 1 of agri share - rainy season | | -0.158** | | | -0.124 | | | -0.058 | |
| | | (0.08) | | | (0.08) | | | (0.08) | |
| Rain $_{t-1}$ X quartile 2 of agri share - rainy season | | -0.026 | | | -0.133* | | | -0.046 | |
| | | (0.07) | | | (0.08) | | | (0.07) | |
| Rain $_{t-1}$ X quartile 3 of agri share - rainy season | | 0.029 | | | 0.035 | | | 0.029 | |
| | | (0.06) | | | (0.05) | | | (0.06) | |
| Rain $_{t-1}$ X quartile 4 of agri share - rainy season | | 0.016 | | | -0.043 | | | 0.049 | |
| | | (0.06) | | | (0.06) | | | (0.05) | |
| Rain $_{t-1}$ X quartile 1 of agri share - dry season | | -0.101 | | | 0.003 | | | -0.078 | |
| | | (0.08) | | | (0.08) | | | (0.07) | |
| Rain $_{t-1}$ X quartile 2 of agri share - dry season | | 0.014 | | | 0.047 | | | 0.001 | |
| | | (0.04) | | | (0.04) | | | (0.04) | |
| Rain $_{t-1}$ X quartile 3 of agri share - dry season | | -0.070 | | | 0.046 | | | -0.089* | |
| | | (0.05) | | | (0.07) | | | (0.05) | |
| Rain $_{t-1}$ X quartile 4 of agri share - dry season | | -0.123** | | | -0.031 | | | -0.095** | |
| | | (0.05) | | | (0.06) | | | (0.04) | |
| Temp $_{t-1}$ X quartile 1 of agri share - rainy season | | 0.010 | | | 0.082 | | | -0.031 | |
| | | (0.10) | | | (0.12) | | | (0.07) | |
| Temp $_{t-1}$ X quartile 2 of agri share - rainy season | | 0.170* | | | 0.067 | | | 0.099 | |
| | | (0.09) | | | (0.06) | | | (0.08) | |
| Temp $_{t-1}$ X quartile 3 of agri share - rainy season | | 0.198** | | | 0.090 | | | 0.177*** | |
| | | (0.08) | | | (0.08) | | | (0.06) | |
| Temp $_{t-1}$ X quartile 4 of agri share - rainy season | | 0.088 | | | 0.022 | | | 0.039 | |
| | | (0.09) | | | (0.09) | | | (0.06) | |
| Temp $_{t-1}$ X quartile 1 of agri share - dry season | | -0.077 | | | -0.073 | | | -0.052 | |
| | | (0.10) | | | (0.13) | | | (0.08) | |
| Temp $_{t-1}$ X quartile 2 of agri share - dry season | | 0.080 | | | -0.049 | | | 0.127* | |
| | | (0.07) | | | (0.07) | | | (0.07) | |
| Temp $_{t-1}$ X quartile 3 of agri share - dry season | | -0.028 | | | 0.017 | | | 0.006 | |
| | | (0.05) | | | (0.06) | | | (0.04) | |
| Temp $_{t-1}$ X quartile 4 of agri share - dry season | | -0.068 | | | -0.104 | | | 0.031 | |
| | | (0.06) | | | (0.08) | | | (0.05) | |
| Positive rain deviations $_{t-1}$ - rainy season | | | -0.062 | | | -0.053 | | | -0.042 |
| | | | (0.05) | | | (0.05) | | | (0.05) |
| Negative rain deviations $_{t-1}$ - rainy season | | | 0.010 | | | -0.118 | | | 0.086 |
| | | | (0.08) | | | (0.11) | | | (0.08) |
| Positive rain deviations $_{t-1}$ - dry season | | | -0.020 | | | 0.026 | | | -0.023 |
| | | | (0.04) | | | (0.05) | | | (0.04) |
| Negative rain deviations $_{t-1}$ - dry season | | | -0.192** | | | -0.026 | | | -0.157** |
| | | | (0.09) | | | (0.09) | | | (0.07) |
| Positive temp deviations $_{t-1}$ - rainy season | | | 0.066 | | | 0.029 | | | 0.052 |
| | | | (0.07) | | | (0.08) | | | (0.06) |
| Negative temp deviations $_{t-1}$ - rainy season | | | 0.190** | | | 0.176 | | | 0.072 |
| | | | (0.09) | | | (0.13) | | | (0.07) |
| Positive temp deviations $_{t-1}$ - dry season | | | -0.032 | | | -0.099 | | | 0.010 |
| | | | (0.07) | | | (0.08) | | | (0.06) |
| Negative temp deviations $_{t-1}$ - dry season | | | -0.007 | | | -0.024 | | | 0.080† |
| | | | (0.08) | | | (0.09) | | | (0.05) |
| N | 352 | 352 | 352 | 352 | 352 | 352 | 352 | 352 | 352 |

Standard errors corrected for autocorrelation and spatial correlation in parentheses
† $p < 0.11$, * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$
Controls not shown: log GDP per capita in $t-1$, unemployment rate in $t-1$, log share of homicides in $t-1$, number of hurricanes in $t-1$, and hurricane intensity in $t-1$.

Table 7: Climatic factors and Mexico-US migration flows - 1999-2011, without 2010 (2009 being an exceptional drought)

| Cube root dependent variable | Total male flows | | | Documented male flows | | | Undocumented male flows | | |
|---|---|---|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) |
| Rain deviations $_{t-1}$ - rainy season | -0.049 | | | -0.082** | | | -0.009 | | |
| | (0.05) | | | (0.04) | | | (0.05) | | |
| Rain deviations $_{t-1}$ - dry season | -0.071** | | | 0.008 | | | -0.070** | | |
| | (0.04) | | | (0.04) | | | (0.03) | | |
| Temp deviations $_{t-1}$ - rainy season | 0.129* | | | 0.098 | | | 0.068 | | |
| | (0.07) | | | (0.07) | | | (0.05) | | |
| Temp deviations $_{t-1}$ - dry season | -0.049 | | | -0.101 | | | 0.027 | | |
| | (0.05) | | | (0.06) | | | (0.04) | | |
| Rain $_{t-1}$ X quartile 1 of agri share - rainy season | | -0.163* | | | -0.162* | | | -0.012 | |
| | | (0.08) | | | (0.09) | | | (0.08) | |
| Rain $_{t-1}$ X quartile 2 of agri share - rainy season | | 0.006 | | | -0.125 | | | -0.043 | |
| | | (0.08) | | | (0.09) | | | (0.08) | |
| Rain $_{t-1}$ X quartile 3 of agri share - rainy season | | 0.009 | | | 0.037 | | | -0.002 | |
| | | (0.06) | | | (0.06) | | | (0.07) | |
| Rain $_{t-1}$ X quartile 4 of agri share - rainy season | | 0.022 | | | -0.022 | | | 0.036 | |
| | | (0.07) | | | (0.07) | | | (0.06) | |
| Rain $_{t-1}$ X quartile 1 of agri share - dry season | | -0.086 | | | -0.009 | | | -0.045 | |
| | | (0.08) | | | (0.08) | | | (0.07) | |
| Rain $_{t-1}$ X quartile 2 of agri share - dry season | | 0.011 | | | 0.055 | | | -0.031 | |
| | | (0.04) | | | (0.04) | | | (0.04) | |
| Rain $_{t-1}$ X quartile 3 of agri share - dry season | | -0.077 | | | 0.072 | | | -0.127** | |
| | | (0.05) | | | (0.08) | | | (0.05) | |
| Rain $_{t-1}$ X quartile 4 of agri share - dry season | | -0.131** | | | -0.013 | | | -0.122*** | |
| | | (0.05) | | | (0.06) | | | (0.04) | |
| Temp $_{t-1}$ X quartile 1 of agri share - rainy season | | 0.080 | | | 0.181 | | | -0.025 | |
| | | (0.09) | | | (0.12) | | | (0.07) | |
| Temp $_{t-1}$ X quartile 2 of agri share - rainy season | | 0.242*** | | | 0.091 | | | 0.175** | |
| | | (0.09) | | | (0.07) | | | (0.07) | |
| Temp $_{t-1}$ X quartile 3 of agri share - rainy season | | 0.217** | | | 0.104 | | | 0.198*** | |
| | | (0.09) | | | (0.08) | | | (0.06) | |
| Temp $_{t-1}$ X quartile 4 of agri share - rainy season | | 0.101 | | | 0.038 | | | 0.046 | |
| | | (0.08) | | | (0.09) | | | (0.05) | |
| Temp $_{t-1}$ X quartile 1 of agri share - dry season | | -0.120 | | | -0.137 | | | -0.054 | |
| | | (0.11) | | | (0.12) | | | (0.07) | |
| Temp $_{t-1}$ X quartile 2 of agri share - dry season | | 0.021 | | | -0.111 | | | 0.096 | |
| | | (0.07) | | | (0.07) | | | (0.07) | |
| Temp $_{t-1}$ X quartile 3 of agri share - dry season | | -0.042 | | | 0.017 | | | -0.020 | |
| | | (0.05) | | | (0.06) | | | (0.05) | |
| Temp $_{t-1}$ X quartile 4 of agri share - dry season | | -0.098 | | | -0.138* | | | 0.021 | |
| | | (0.06) | | | (0.08) | | | (0.06) | |
| Positive rain deviations $_{t-1}$ - rainy season | | | -0.061 | | | -0.054 | | | -0.044 |
| | | | (0.06) | | | (0.05) | | | (0.05) |
| Negative rain deviations $_{t-1}$ - rainy season | | | -0.017 | | | -0.157 | | | 0.087 |
| | | | (0.10) | | | (0.12) | | | (0.09) |
| Positive rain deviations $_{t-1}$ - dry season | | | -0.034 | | | 0.023 | | | -0.035 |
| | | | (0.04) | | | (0.05) | | | (0.04) |
| Negative rain deviations $_{t-1}$ - dry season | | | -0.165* | | | -0.002 | | | -0.170** |
| | | | (0.08) | | | (0.10) | | | (0.07) |
| Positive temp deviations $_{t-1}$ - rainy season | | | 0.131* | | | 0.094 | | | 0.085 |
| | | | (0.08) | | | (0.09) | | | (0.06) |
| Negative temp deviations $_{t-1}$ - rainy season | | | 0.158* | | | 0.157 | | | 0.047 |
| | | | (0.10) | | | (0.13) | | | (0.07) |
| Positive temp deviations $_{t-1}$ - dry season | | | -0.097 | | | -0.165** | | | -0.023 |
| | | | (0.06) | | | (0.08) | | | (0.06) |
| Negative temp deviations $_{t-1}$ - dry season | | | 0.016 | | | -0.022 | | | 0.100† |
| | | | (0.08) | | | (0.09) | | | (0.06) |
| N | 384 | 384 | 384 | 384 | 384 | 384 | 384 | 384 | 384 |

Standard errors corrected for autocorrelation and spatial correlation in parentheses
† $p < 0.11$, * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$
Controls not shown: log GDP per capita in $t-1$, unemployment rate in $t-1$, log share of homicides in $t-1$, number of hurricanes in $t-1$, and hurricane intensity in $t-1$.

Table 8: Climatic factors and Mexico-US migration flows : impact of public policies, Fonden in log - 2001-2011

| Cube root dependent variable | Total male flows (1) | Documented male flows (2) | Undocumented male flows (3) |
|---|---|---|---|
| Predicted share of PROCAMPO for non irrigated ejido $_{t-1}$ | -12.020** | -14.277* | -10.843* |
| | (5.79) | (7.92) | (6.55) |
| Log amount Fonden $_{t-1}$ | 0.001 | 0.013 | -0.011 |
| | (0.01) | (0.01) | (0.01) |
| Rain deviations $_{t-1}$ - rainy season | -0.064 | -0.102** | -0.032 |
| | (0.05) | (0.05) | (0.05) |
| Rain deviations $_{t-1}$ - dry season | -0.085** | 0.023 | -0.089*** |
| | (0.03) | (0.05) | (0.03) |
| Temp deviations $_{t-1}$ - rainy season | 0.153** | 0.142* | 0.042 |
| | (0.07) | (0.08) | (0.05) |
| Temp deviations $_{t-1}$ - dry season | -0.109* | -0.178** | -0.008 |
| | (0.06) | (0.08) | (0.05) |
| Rain deviations $_{t-1}$ - rainy season X Log amount Fonden $_{t-1}$ | 0.008 | 0.010 | 0.006 |
| | (0.01) | (0.01) | (0.01) |
| Rain deviations $_{t-1}$ - dry season X Log amount Fonden $_{t-1}$ | 0.028*** | 0.005 | 0.027*** |
| | (0.01) | (0.01) | (0.01) |
| Temp deviations $_{t-1}$ - rainy season X Log amount Fonden $_{t-1}$ | 0.011 | 0.006 | 0.011* |
| | (0.01) | (0.02) | (0.01) |
| Temp deviations $_{t-1}$ - dry season X Log amount Fonden $_{t-1}$ | 0.015 | 0.007 | 0.007 |
| | (0.01) | (0.01) | (0.01) |
| N | 352 | 352 | 352 |

Standard errors corrected for autocorrelation and spatial correlation in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$
Controls not shown: log GDP per capita in $t-1$, unemployment rate in $t-1$, log share of homicides in $t-1$, number of hurricanes in $t-1$, and hurricane intensity in $t-1$.

Table 9: Climatic factors and Mexico-US migration flows : impact of public policies, 2001-2011 - Log dependent variables

| Log dependent variable | Total male flows | | | Documented male flows | | | Undocumented male flows | | |
|---|---|---|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) |
| Cube root amount Fonden $_{t-1}$ | 0.002 | 0.023 | 0.021 | 0.020 | 0.028 | 0.033 | -0.010 | 0.012 | 0.009 |
| | (0.03) | (0.02) | (0.02) | (0.05) | (0.06) | (0.06) | (0.04) | (0.03) | (0.02) |
| Pred. sh. PROCAMPO non irrig. *ejidos* $_{t-1}$ | -7.664 | -7.648 | -9.317 | -28.492$^{*}$ | -30.423$^{*}$ | -32.803$^{**}$ | -19.915$^{**}$ | -17.788$^{**}$ | -21.228$^{**}$ |
| | (6.86) | (6.54) | (6.67) | (16.09) | (16.03) | (15.73) | (8.70) | (8.10) | (8.53) |
| 1 - Gini pred. PROCAMPO amount $t-1$ | -1.464 | -1.261 | -2.084 | -20.884$^{*}$ | -22.227$^{*}$ | -22.645$^{*}$ | -8.601 | -7.794 | -9.655 |
| | (6.16) | (6.28) | (5.93) | (12.52) | (12.02) | (11.64) | (7.04) | (7.82) | (6.77) |
| Rain deviations $_{t-1}$ - rainy season | -0.083 | 0.020 | -0.088 | -0.252 | -0.095 | -0.024 | -0.078 | 0.141 | -0.043 |
| | (0.06) | (0.30) | (0.12) | (0.21) | (0.70) | (0.24) | (0.09) | (0.48) | (0.21) |
| Rain deviations $_{t-1}$ - dry season | -0.090$^{*}$ | -0.378 | -0.396$^{***}$ | 0.141 | -0.684 | -0.570$^{**}$ | -0.125$^{*}$ | -0.488 | -0.415$^{*}$ |
| | (0.05) | (0.32) | (0.11) | (0.19) | (0.66) | (0.28) | (0.07) | (0.37) | (0.23) |
| Temp deviations $_{t-1}$ - rainy season | 0.067 | 0.260 | 0.019 | 0.182 | 0.778 | 0.285 | 0.081 | -0.204 | 0.062 |
| | (0.07) | (0.43) | (0.12) | (0.15) | (0.79) | (0.23) | (0.11) | (0.46) | (0.22) |
| Temp deviations $_{t-1}$ - dry season | -0.108$^{*}$ | -0.767 | -0.442$^{***}$ | -0.472$^{**}$ | -1.506 | -0.825$^{**}$ | -0.055 | -0.910 | -0.535 |
| | (0.06) | (0.50) | (0.16) | (0.22) | (1.07) | (0.39) | (0.09) | (0.65) | (0.34) |
| Rain deviations $_{t-1}$ - rainy season X Cube root amount Fonden $_{t-1}$ | 0.004 | | | -0.007 | | | 0.010 | | |
| | (0.02) | | | (0.04) | | | (0.03) | | |
| Rain deviations $_{t-1}$ - dry season X Cube root amount Fonden $_{t-1}$ | 0.035$^{***}$ | | | -0.001 | | | 0.043$^{***}$ | | |
| | (0.01) | | | (0.05) | | | (0.01) | | |
| Temp deviations $_{t-1}$ - rainy season X Cube root amount Fonden $_{t-1}$ | 0.015 | | | 0.019 | | | 0.011 | | |
| | (0.02) | | | (0.08) | | | (0.02) | | |
| Temp deviations $_{t-1}$ - dry season X Cube root amount Fonden $_{t-1}$ | 0.018 | | | 0.026 | | | 0.009 | | |
| | (0.02) | | | (0.05) | | | (0.03) | | |
| Rain deviations $_{t-1}$ - rainy season X 1 - Gini pred. PROCAMPO amount $_{t-1}$ | | -0.206 | | | -0.392 | | | -0.415 | |
| | | (0.57) | | | (1.49) | | | (0.86) | |
| Rain deviations $_{t-1}$ - dry season X 1 - Gini pred. PROCAMPO amount $_{t-1}$ | | 0.690 | | | 1.546 | | | 0.823 | |
| | | (0.59) | | | (1.33) | | | (0.64) | |
| Temp deviations $_{t-1}$ - rainy season X 1 - Gini pred. PROCAMPO amount $_{t-1}$ | | -0.373 | | | -1.210 | | | 0.565 | |
| | | (0.83) | | | (1.47) | | | (0.86) | |
| Temp deviations $_{t-1}$ - dry season X 1 - Gini pred. PROCAMPO amount $_{t-1}$ | | 1.296 | | | 2.049 | | | 1.601 | |
| | | (0.93) | | | (2.01) | | | (1.16) | |
| Rain deviations $_{t-1}$ - rainy season X Pred. sh. PROCAMPO non irrig. *ejidos* $_{t-1}$ | | | 0.018 | | | -0.395 | | | -0.024 |
| | | | (0.15) | | | (0.45) | | | (0.25) |
| Rain deviations $_{t-1}$ - dry season X Pred. sh. PROCAMPO non irrig. *ejidos* $_{t-1}$ | | | 0.504$^{***}$ | | | 0.928$^{**}$ | | | 0.498$^{*}$ |
| | | | (0.15) | | | (0.44) | | | (0.27) |
| Temp deviations $_{t-1}$ - rainy season X Pred. sh. PROCAMPO non irrig. *ejidos* $_{t-1}$ | | | 0.094 | | | -0.215 | | | 0.050 |
| | | | (0.15) | | | (0.35) | | | (0.25) |
| Temp deviations $_{t-1}$ - dry season X Pred. sh. PROCAMPO non irrig. *ejidos*$_{t-1}$ | | | 0.461$^{**}$ | | | 0.563 | | | 0.638 |
| | | | (0.19) | | | (0.53) | | | (0.40) |
| Dummy for zero total male flows | -7.246$^{***}$ | -7.241$^{***}$ | -7.162$^{***}$ | | | | | | |
| | (0.41) | (0.35) | (0.38) | | | | | | |
| Dummy for zero documented male flow | | | | -2.987$^{***}$ | -2.958$^{***}$ | -2.887$^{***}$ | | | |
| | | | | (0.34) | (0.33) | (0.34) | | | |
| Dummy for zero undocumented male flows | | | | | | | -4.185$^{***}$ | -4.136$^{***}$ | -4.108$^{***}$ |
| | | | | | | | (0.56) | (0.57) | (0.58) |
| N | 352 | 352 | 352 | 352 | 352 | 352 | 352 | 352 | 352 |

Standard errors corrected for autocorrelation and spatial correlation in parentheses
$^{*}$ $p < 0.10$, $^{**}$ $p < 0.05$, $^{***}$ $p < 0.01$
Controls not shown: log GDP per capita in $t-1$, unemployment rate in $t-1$, log share of homicides in $t-1$, number of hurricanes in $t-1$, hurricane intensity in $t-1$, and log predicted PROCAMPO amount per capita in $t-1$

Table 10: Climatic factors and Mexico-US migration flows : impact of public policies, 2001-2011 - GDP with two lags, without unemployment and homicides

| Cube root dependent variable | Total male flows | | | Documented male flows | | | Undocumented male flows | | |
|---|---|---|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) |
| Cube root amount Fonden $_{t-1}$ | 0.036** | 0.035** | 0.018 | 0.044** | 0.045** | 0.028 | 0.007 | 0.008 | -0.010 |
| | (0.01) | (0.01) | (0.02) | (0.02) | (0.02) | (0.02) | (0.01) | (0.01) | (0.02) |
| Rain deviations $_{t-1}$ - rainy season | -0.062 | -0.060 | -0.073 | -0.101** | -0.009 | -0.107* | -0.024 | 0.024 | -0.049 |
| | (0.05) | (0.10) | (0.05) | (0.04) | (0.10) | (0.06) | (0.04) | (0.09) | (0.05) |
| Rain deviations $_{t-1}$ - dry season | -0.042 | -0.382*** | -0.125*** | 0.027 | -0.215** | 0.014 | -0.044 | -0.289*** | -0.129*** |
| | (0.03) | (0.09) | (0.04) | (0.04) | (0.11) | (0.05) | (0.03) | (0.11) | (0.04) |
| Temp deviations $_{t-1}$ - rainy season | 0.095 | 0.061 | 0.081 | 0.083 | 0.028 | 0.064 | 0.028 | 0.090 | 0.012 |
| | (0.07) | (0.13) | (0.07) | (0.07) | (0.15) | (0.07) | (0.05) | (0.09) | (0.06) |
| Temp deviations $_{t-1}$ - dry season | -0.057 | -0.358** | -0.090 | -0.119* | -0.248 | -0.140* | 0.018 | -0.261** | 0.005 |
| | (0.06) | (0.16) | (0.06) | (0.07) | (0.20) | (0.08) | (0.05) | (0.11) | (0.05) |
| Pred. sh. PROCAMPO non irrig. *ejidos* $_{t-1}$ | | -13.897*** | | | -13.415** | | | -12.386** | |
| | | (4.81) | | | (6.71) | | | (5.52) | |
| Rain deviations $_{t-1}$ - rainy season X Pred. sh. PROCAMPO non irrig. *ejidos* $_{t-1}$ | | -0.001 | | | -0.130 | | | -0.072 | |
| | | (0.12) | | | (0.13) | | | (0.11) | |
| Rain deviations $_{t-1}$ - dry season X Pred. sh. PROCAMPO non irrig. *ejidos* $_{t-1}$ | | 0.442*** | | | 0.320** | | | 0.317** | |
| | | (0.11) | | | (0.13) | | | (0.13) | |
| Temp deviations $_{t-1}$ - rainy season XPred. sh. PROCAMPO non irrig. *ejidos* $_{t-1}$ | | 0.026 | | | 0.061 | | | -0.114 | |
| | | (0.15) | | | (0.17) | | | (0.12) | |
| Temp deviations $_{t-1}$ - dry season X Pred. sh. PROCAMPO non irrig. *ejidos* $_{t-1}$ | | 0.376** | | | 0.154 | | | 0.363*** | |
| | | (0.18) | | | (0.23) | | | (0.13) | |
| Rain deviations $_{t-1}$ - rainy season X Cube root amount Fonden $_{t-1}$ | | | 0.003 | | | 0.003 | | | 0.009 |
| | | | (0.01) | | | (0.01) | | | (0.01) |
| Rain deviations $_{t-1}$ - dry season X Cube root amount Fonden $_{t-1}$ | | | 0.032*** | | | 0.004 | | | 0.033*** |
| | | | (0.01) | | | (0.01) | | | (0.01) |
| Temp deviations $_{t-1}$ - rainy season X Cube root amount Fonden $_{t-1}$ | | | 0.009 | | | 0.014 | | | 0.007 |
| | | | (0.01) | | | (0.02) | | | (0.01) |
| Temp deviations $_{t-1}$ - dry season X Cube root amount Fonden $_{t-1}$ | | | 0.017 | | | 0.010 | | | 0.008 |
| | | | (0.01) | | | (0.01) | | | (0.01) |
| N | 352 | 352 | 352 | 352 | 352 | 352 | 352 | 352 | 352 |

Standard errors corrected for autocorrelation and spatial correlation in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$
Controls not shown: log GDP per capita in $t-1$, unemployment rate in $t-1$, log share of homicides in $t-1$,
number of hurricanes in $t-1$, hurricane intensity in $t-1$, and log predicted PROCAMPO amount per capita in $t-1$

Table 11: Climatic factors and Mexico-US migration flows : impact of public policies, 2001-2011 - Group fixed-effects

| Cube root dependent variable | Total male flows | | Documented male flows | | Undocumented male flows | |
|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) |
| Cube root amount Fonden $_{t-1}$ | 0.059** | 0.063*** | 0.010 | 0.015 | -0.003 | 0.003 |
| | (0.02) | (0.02) | (0.02) | (0.02) | (0.02) | (0.02) |
| Log pred. PROCAMPO per cap $_{t-1}$ | -0.027 | -0.166 | -0.037 | -0.153 | -0.241 | -0.328 |
| | (0.40) | (0.44) | (0.39) | (0.59) | (0.28) | (0.45) |
| Rain deviations $_{t-1}$ - rainy season | 0.039 | -0.123 | -0.080 | -0.059 | 0.210 | 0.063 |
| | (0.24) | (0.15) | (0.28) | (0.20) | (0.16) | (0.08) |
| Rain deviations $_{t-1}$ - dry season | -0.116 | -0.309*** | -0.173 | -0.213** | -0.021 | -0.214** |
| | (0.13) | (0.07) | (0.16) | (0.09) | (0.16) | (0.08) |
| Temp deviations $_{t-1}$ - rainy season | 0.345 | 0.033 | 0.300 | 0.077 | -0.086 | 0.093 |
| | (0.28) | (0.13) | (0.35) | (0.15) | (0.18) | (0.11) |
| Temp deviations $_{t-1}$ - dry season | -0.465** | -0.308** | -0.402* | -0.200 | -0.470 | -0.267** |
| | (0.22) | (0.15) | (0.22) | (0.16) | (0.31) | (0.13) |
| 1 - Gini pred. PROCAMPO amount $_{t-1}$ | -6.581 | | -6.430 | | -9.286* | |
| | (6.30) | | (9.53) | | (5.44) | |
| Rain deviations $_{t-1}$ - rainy season X 1 - Gini pred. PROCAMPO amount $_{t-1}$ | -0.313 | | -0.076 | | -0.488 | |
| | (0.43) | | (0.50) | | (0.33) | |
| Rain deviations $_{t-1}$ - dry season X 1 - Gini pred. PROCAMPO amount $_{t-1}$ | 0.104 | | 0.403 | | -0.123 | |
| | (0.24) | | (0.30) | | (0.30) | |
| Temp deviations $_{t-1}$ - rainy season X 1 - Gini pred. PROCAMPO amount $_{t-1}$ | -0.519 | | -0.466 | | 0.300 | |
| | (0.53) | | (0.65) | | (0.35) | |
| Temp deviations $_{t-1}$ - dry season X 1 - Gini pred. PROCAMPO amount $_{t-1}$ | 0.804** | | 0.635 | | 0.784 | |
| | (0.40) | | (0.40) | | (0.58) | |
| Pred. sh. PROCAMPO non irrig. *ejidos* $_{t-1}$ | | -0.628 | | -1.323 | | -1.493 |
| | | (3.25) | | (6.09) | | (2.86) |
| Rain deviations $_{t-1}$ - rainy season X Pred. sh. PROCAMPO non irrig. *ejidos* $_{t-1}$ | | 0.002 | | -0.081 | | -0.144 |
| | | (0.17) | | (0.23) | | (0.12) |
| Rain deviations $_{t-1}$ - dry season X Pred. sh. PROCAMPO non irrig. *ejidos* $_{t-1}$ | | 0.321*** | | 0.327*** | | 0.186* |
| | | (0.09) | | (0.11) | | (0.11) |
| Temp deviations $_{t-1}$ - rainy season X Pred. sh. PROCAMPO non irrig. *ejidos* $_{t-1}$ | | 0.059 | | -0.042 | | -0.075 |
| | | (0.15) | | (0.20) | | (0.13) |
| Temp deviations $_{t-1}$ - dry season X Pred. sh. PROCAMPO non irrig. *ejidos* $_{t-1}$ | | 0.362*** | | 0.201 | | 0.364** |
| | | (0.14) | | (0.17) | | (0.16) |
| Observations | 352 | 352 | 352 | 352 | 352 | 352 |

Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$
Controls not shown: log GDP per capita in $t-1$, unemployment rate in $t-1$, log share of homicides in $t-1$, number of hurricanes in $t-1$, and hurricane intensity in $t-1$.

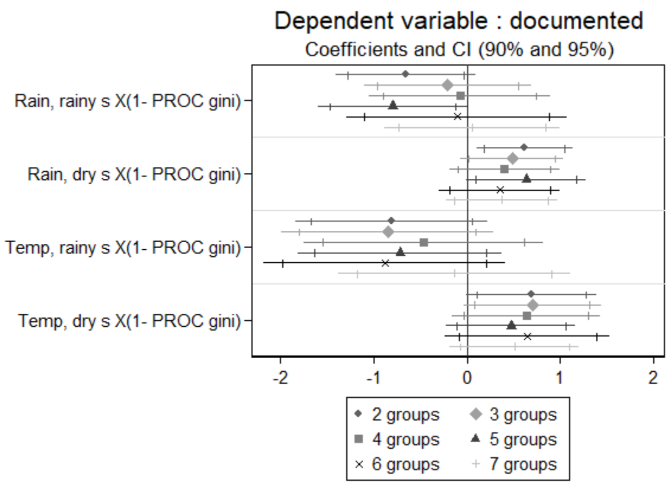


Figure 12: GFE coefficients for PROCAMPO (1-Gini), documented flows

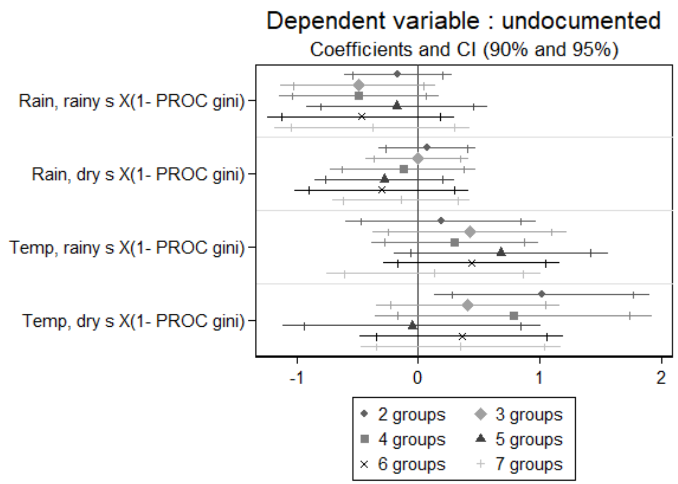


Figure 13: GFE coefficients for PROCAMPO (1-Gini), undocumented flows

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.

Table 12: Climatic factors and Mexico-US migration flows : impact of public policies, 2001-2011 - Without bottom 5 percent

| Cube root dependent variable | | male flows | | | Documented male flows | | | Undocumented male flows | |
|---|---|---|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) |
| Log pred. PROCAMPO per cap $_{t-1}$ | 1.430* | 1.027 | 1.479* | 0.599 | 0.365 | 0.758 | 1.481** | 1.324** | 1.525** |
| | (0.76) | (0.85) | (0.76) | (0.76) | (0.79) | (0.77) | (0.62) | (0.61) | (0.64) |
| Pred. sh. PROCAMPO non irrig. *ejidos* $_{t-1}$ | | -6.760 | | | -14.661* | | | -3.212 | |
| | | (5.77) | | | (7.87) | | | (6.56) | |
| Cube root amount Fonden $_{t-1}$ | 0.035** | 0.032** | 0.010 | 0.043** | 0.041* | 0.032 | -0.004 | -0.002 | -0.033* |
| | (0.02) | (0.02) | (0.02) | (0.02) | (0.02) | (0.02) | (0.02) | (0.02) | (0.02) |
| Rain deviations $_{t-1}$ - rainy season | -0.055 | -0.042 | -0.073* | -0.113** | -0.044 | -0.112* | 0.000 | 0.110 | -0.047 |
| | (0.05) | (0.10) | (0.04) | (0.05) | (0.10) | (0.06) | (0.05) | (0.09) | (0.05) |
| Rain deviations $_{t-1}$ - dry season | -0.064* | -0.378*** | -0.156*** | 0.022 | -0.231** | 0.010 | -0.056* | -0.240** | -0.135*** |
| | (0.03) | (0.10) | (0.05) | (0.04) | (0.11) | (0.06) | (0.03) | (0.09) | (0.04) |
| Temp deviations $_{t-1}$ - rainy season | 0.152** | 0.154 | 0.147** | 0.131 | 0.103 | 0.119 | 0.005 | 0.100 | -0.007 |
| | (0.07) | (0.14) | (0.07) | (0.08) | (0.16) | (0.08) | (0.05) | (0.08) | (0.05) |
| Temp deviations $_{t-1}$ - dry season | -0.130** | -0.401** | -0.177** | -0.156* | -0.317 | -0.181** | -0.026 | -0.210** | -0.033 |
| | (0.06) | (0.18) | (0.07) | (0.08) | (0.21) | (0.09) | (0.05) | (0.10) | (0.06) |
| Rain deviations $_{t-1}$ - rainy season X Pred. sh. PROCAMPO non irrig. *ejidos* $_{t-1}$ | | -0.027 | | | -0.094 | | | -0.166 | |
| | | (0.12) | | | (0.14) | | | (0.12) | |
| Rain deviations $_{t-1}$ - dry season X Pred. sh. PROCAMPO non irrig. *ejidos* $_{t-1}$ | | 0.424*** | | | 0.342** | | | 0.234* | |
| | | (0.12) | | | (0.14) | | | (0.12) | |
| Temp deviations $_{t-1}$ - rainy season X Pred. sh. PROCAMPO non irrig. *ejidos* $_{t-1}$ | | -0.027 | | | 0.011 | | | -0.152 | |
| | | (0.16) | | | (0.20) | | | (0.11) | |
| Temp deviations $_{t-1}$ - dry season X Pred. sh. PROCAMPO non irrig. *ejidos* $_{t-1}$ | | 0.355* | | | 0.193 | | | 0.257** | |
| | | (0.21) | | | (0.24) | | | (0.11) | |
| Rain deviations $_{t-1}$ - rainy season X Cube root amount Fonden $_{t-1}$ | | | 0.006 | | | -0.001 | | | 0.021** |
| | | | (0.01) | | | (0.01) | | | (0.01) |
| Rain deviations $_{t-1}$ - dry season X Cube root amount Fonden $_{t-1}$ | | | 0.040*** | | | 0.004 | | | 0.033*** |
| | | | (0.01) | | | (0.01) | | | (0.01) |
| Temp deviations $_{t-1}$ - rainy season X Cube root amount Fonden $_{t-1}$ | | | 0.003 | | | 0.012 | | | 0.008 |
| | | | (0.02) | | | (0.03) | | | (0.01) |
| Temp deviations $_{t-1}$ - dry season X Cube root amount Fonden $_{t-1}$ | | | 0.028* | | | 0.013 | | | 0.007 |
| | | | (0.02) | | | (0.01) | | | (0.01) |
| N | 335 | 335 | 335 | 335 | 335 | 335 | 335 | 335 | 335 |

Standard errors corrected for autocorrelation and spatial correlation in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$
Controls not shown: log GDP per capita in $t-1$, unemployment rate in $t-1$, log share of homicides in $t-1$, number of hurricanes in $t-1$, and hurricane intensity in $t-1$.

# Appendix B: Marginal effects

We compute the marginal effects of our variables of interest as follows.

Let us note $Y$ the migration rate, $X$ a climate shock, $Z$ a policy variable, $\mathbf{V}$ the vector of other control variables and $\Omega$ their coefficient. Our model can be written as follows :

$$Y^{1/3} = \beta_1 X + \beta_2 X \times Z + \beta_3 Z + \mathbf{V}\Omega + \varepsilon$$

We thus have :

$$\begin{aligned}
\frac{\partial Y}{\partial X} &= 3(\beta_1 + \beta_2 Z)(\beta_1 X + \beta_2 X \times Z + \beta_3 Z + \mathbf{V}\Omega + \varepsilon)^2 \\
&= 3(\beta_1 + \beta_2 Z)(\beta_1 X + \beta_2 X \times Z + \beta_3 Z + \mathbf{V}\Omega)^2 + 3(\beta_1 + \beta_2 Z)\varepsilon^2 \\
&\quad +6(\beta_1 + \beta_2 Z)(\beta_1 X + \beta_2 X \times Z + \beta_3 Z + \mathbf{V}\Omega)\varepsilon
\end{aligned}$$

Hence, the marginal effect of $X$ on $Y$ depends on the value of the error term. We assume that the error term satisfies the standard assumptions and is homoskedastic. Thus we can neglect the third component of the expression as $\varepsilon$ expectation is zero. However, we take into account $3(\beta_1 + \beta_2 Z)\varepsilon^2$, which is expected to amount to $3(\beta_1 + \beta_2 Z)\sigma^2$ noting $\sigma^2$ the variance of the error term.

To account for $\mathbf{V}\Omega$, we use the average value of the control variables. We note $\overline{\mathbf{V}}$ the vector of the averages of the control variables. From our estimation results we compute the marginal effect as

$$3(\hat{\beta}_1 + \hat{\beta}_2 Z)(\hat{\beta}_1 X + \hat{\beta}_2 X \times Z + \hat{\beta}_3 Z + \overline{\mathbf{V}}\widehat{\Omega})^2 + 3\widehat{\sigma^2}(\hat{\beta}_1 + \hat{\beta}_2 Z)$$

Last, we have estimated a model on centered variables. We correct the prediction we obtain by adding the sample average of $Y^{1/3}$.

$$\overline{\mathbf{V}}\widehat{\Omega} = \widehat{Y^{1/3} - \overline{(Y)^{1/3}}} + \overline{(Y)^{1/3}} - \hat{\beta}_1 \overline{X} - \hat{\beta}_2 \overline{XZ} - \hat{\beta}_3 \overline{Z}$$

### Marginal effect of the interaction term

To compute the magnitude of the interaction effect, we proceed similarly, as we have

$$
\begin{aligned}
\frac{\partial Y}{\partial X \partial Z} &= 3\beta_2(\beta_1 X + \beta_2 X \times Z + \beta_3 Z + \mathbf{V}\Omega + \varepsilon)^2 \\
&\quad +6(\beta_1 + \beta_2 Z)(\beta_2 X + \beta_3)(\beta_1 X + \beta_2 X \times Z + \beta_3 Z + \mathbf{V}\Omega + \varepsilon) \\
&= 3\beta_2(\beta_1 X + \beta_2 X \times Z + \beta_3 Z + \mathbf{V}\Omega)^2 + 3\beta_2\varepsilon^2 \\
&\quad +6(\beta_1 + \beta_2 Z)(\beta_2 X + \beta_3)(\beta_1 X + \beta_2 X \times Z + \beta_3 Z + \mathbf{V}\Omega) \\
&\quad +6(\beta_2(\beta_1 X + \beta_2 X \times Z + \beta_3 Z + \mathbf{V}\Omega) + (\beta_1 + \beta_2 Z)(\beta_2 X + \beta_3))\varepsilon
\end{aligned}
$$

As above, we neglect the third component of the expression, and compute the marginal effect of the interaction between $X$ and $Z$ as :

$$
\begin{aligned}
&= 3\hat{\beta}_2(\hat{\beta}_1 X + \hat{\beta}_2 X \times Z + \hat{\beta}_3 Z + \overline{\mathbf{V}}\widehat{\Omega})^2 + 3\hat{\beta}_2\widehat{\sigma^2} \\
&\quad +6(\hat{\beta}_1 + \hat{\beta}_2 Z)(\hat{\beta}_2 X + \hat{\beta}_3)(\hat{\beta}_1 X + \hat{\beta}_2 X \times Z + \hat{\beta}_3 Z + \overline{\mathbf{V}}\widehat{\Omega})
\end{aligned}
$$