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The Effect of Rainfall Variation on Agricultural Households: Evidence from Mexico

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This paper presents results of the rainfall impact on agricultural production and net income for rural households in Mexico using a two-year panel data set. We construct a metric on rainfall variation using historical data from weather stations across Mexico. The relationship between our rainfall measure and agricultural production indicates a consistent negative effect on maize production, specially for rain-fed and small farmers. Moreover, there is mixed evidence for non-maize crops production and non-significant rainfall impact for household's net income.

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1. Introduction

Extreme rainfall conditions characterized by droughts and floods can have devastating impacts on rural household's engaged in agricultural production, especially in low-income regions around the world. The absence of access to financial services by these households implies that they cannot mitigate the short-run effects of adverse weather conditions.[1]

Under these circumstances, rural households use informal strategies for coping with weather related risk (Chen and Chang, 2005; Lewin et al., 2012; Skees et al., 2002). However, relying on informal insurance to deal with weather variations from others in the same village or rural region is likely to be unavailable since bad weather conditions affect other neighboring households (Gudiño, 2013). Poor households in the rural economy are susceptible to natural disasters, even if households are not directly involved in agricultural production, this is due to that many of the rural poor have income sources that are tied to the success of agricultural production or are otherwise susceptible to extreme weather events (Barnett and Mahul, 2007, and Dyer et al. 2005).

The crucial role of rainfall in the livelihoods of agricultural households in low-income regions is widely recognized in recent literature; any irregularity in its timing and/or fluctuation in amount results in adverse consequences. There is a growing literature that studies the impact of weather conditions on agricultural production (Levine and Yang, 2006; Riha, et al., 1996); migration (Lewin et al., 2012; Mueller and Osgood, 2009); poverty (Miguel, 2005; Barnet and Mahul, 2007); health and education (Maccini and Yang, 2009; Hoddinott and Kinsey, 2001); food security (Birhanu and Zeller, 2009), among others. These studies have focused on developing countries where risk is part of life in households highly exposed to individual-specific impacts which makes them extremely vulnerable (Macours et al, 2012).

The study of the effects of rainfall variation on Mexican rural households is relevant for several reasons. 1) In Mexico, poverty has prevailed and has increased during the last years, a

1 "...wheather refers to temperature and precipitation at a given time and place. Climate or climate normals refer to a locations weather averaged over long periods of time." Deschenes and Greenstone, 2007.

process that began in 2008 as compared to 2006, in part because of the rise in food international prices, and poverty incidence is much higher for rural households. 2) Higher food prices has not lead to a significant rise in agricultural production by rural households, because of rural subsistence households producing staples are low or nil price elastic (Dyer and Taylor, 2011) and probably because of bad weather conditions. 3) Mexico has an heterogeneous agro-ecological and weather conditions, and so, the effects of global warming (and on agricultural production) differ from region to region.

With respect to the latter fact, data from a survey, representative of rural house holds in Mexico (called ENHRUM, Spanish acronym of National Survey of Rural Households of Mexico, see below) shows that around 22% of households suffered rainfall impacts in 2007. These events were mainly droughts (63%) and floods (37%), depending upon the region (south Mexico is prone to floods while north to droughts). Besides, during the last century, there is evidence of at least 63 severe droughts and floods and 17 events of extreme temperature in Mexico (www.emdat.be). Rainfall variation have devastating effects in areas where agriculture is predominantly rainfed and hence any irregularity in weather conditions has adverse welfare implications (Birhanu and Zeller, 2009).

In consistency with the long-run effects in Mexico of climate change, several measures indicate that droughts have been one on the main problems affecting rural areas. Severe and sustained drought began in 1994 and continued for the past 15 years with only limited relief. Drought during this period equaled some aspects of the 1950s drought, which is the most severe drought evident in the instrumental climate record for Mexico from 1900 to 2008 (Cook, 2007; Cortez, 2006; Stahle et al., 2009).

The objective of this paper is to evaluate empirically the influence of rainfall variation on crop production and income of rural households in Mexico for a two-period panel in 2002-2007. We separate by maize, bean production in physical terms since these are the main crop produced by almost all rural households in Mexico as well as the major crop consumed by its people. We also aggregate other annual crops value of production. In the second part of the paper we add to the study estimations on the effect of rainfall variation on farm household's net income to evaluate if results on the impacts of rainfall variation on agricultural production are consistent with those of net income.

Econometrically, we separate the sample by characteristics such as rainfed-irrigated land and small-medium size household producers in the crop production equation. Since net income may depend on the household decisions about the variety of activities they make, we also separate by off-farm work and household members outside in the net income equation. Besides, since regions in Mexico are remarkably different in levels and variation of rainfall, we also analize the results by regions in the net income equation.

Our study is different from other research on meteorological phenomena for Mexico in two aspects. First, most studies have discussed climate change scenarios for the long-run, rather than its short run-implications for rural households (see Jessoe, Manning, and Taylor, 2014). Instead of the conventional study of climate change on agriculture using the standard production function or a Ricardian approach, we analyze rainfall variations to estimate its effect on rural household's crop production and their total income in years that are dryer or wetter with respect to historical trends.[2] In this sense, while climate change may represent no surprise for a farmer and a possibility to adaptation in the long term, rainfall short-run variations provide an accurate measurement of the effects on the most households exposed to weather: the rural ones. Second, previous research has focused in cross-sectional data, limiting the potential benefits from a panel data structure. Instead, we use an innovative rainfall measure and panel data approach in line with Lewis et al. (2012) and Birhanu and Zeller (2009). As these authors, our goal is to find if there are significant damages to a household's crop production and total earning potential arising to

2 Mendelsohn et al. (1994) suggest a Ricardian approach to econometrically estimating the effect of climate on farm productivity. The central idea of these authors is to measure the differences in land values across the United States, inferring that land value differences are due to endowed soil quality and climate. References to Mexico includes Mora and Yúnez-Naude, 2008; Mendelsohn, et al., 2009; Lopez-Feldman, 2013.

large rainfall events. Using panel data, this paper analyzes the effect of rainfall variation on Mexican rural household's crop and total net income over time while controlling for a range of factors.

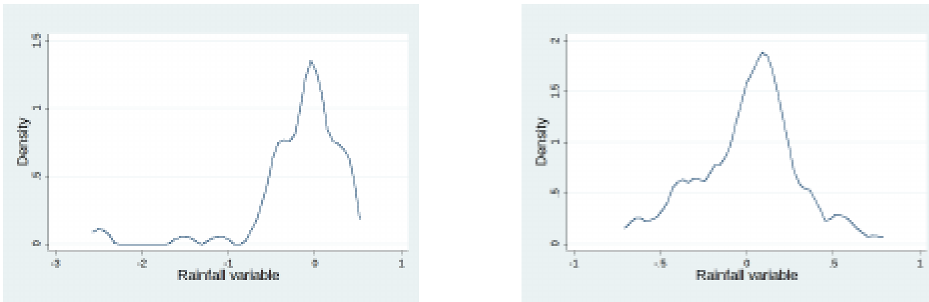
In addition to this introduction, the paper consists of the following. Part 2 presents the data used, part 3 the model applied for the empirical analysis. Results are presented in part 4, and we end the paper in part 5, where the main conclusions are discussed.

2. Data sources and summary statistics

The present study examines how household crop output and net total income are associated with rainfall variation over time controlling for a variety of factors. In assessing the effect of rainfall the traditional approach is based on qualitative information given by respondents related to extreme events. This information may be useful; however, it could be biased due to attrition resulting from non-response[3], and because people tend to overestimate the effect of extreme events in order to receive financial aid. An alternative approach consists in using quantitative measures of rainfall over time provided by meteorological data available from different weather stations. The latter is the approach taken in the present research since in Mexico rainfall time series information is updated, reliable and matched with each locality of the survey we used in our estimations.[4]

3 Attrition results from migration caused by extreme weather conditions.

4 Data were interpolated for precipitation using the Inverse Distance Weighting method for each weather station.



(a) 2002 (b) 2007

Figure 1: Kernel density plots of rainfall.

The data on precipitations we used is from National Meteorological Service of Mexico (Servicio Meteorólogico Nacional). Rainfall levels and variation in Mexico are quite different between regions and over time; for example, the south-southeast has high levels of precipitation while northern regions are much dryer. In addition, more rainfall was registered during 2007 with respect to 2002 in all regions, as well as higher variations in the central regions of Mexico (Figure 1, see also maps in the Appendix).

Following Levine and Yang (2014), we construct the deviation of annual rainfall from the norm for every locality covered by the survey used in the present research. Specifically, the variable is the natural log of average annual rainfall during 2002 and 2007 minus the natural log of historical rainfall mean annual rainfall in each locality (according to the available information, the historical data range between the years of the decades from the 1950s and the 1980s).[5]

The economic and socio-demographic data for rural individuals, rural households and communities in Mexico to estimate the models come from ENHRUM (www.das-ac.mx).

5 In order to calculate the norm, we use available historical data on weather stations across Mexico.

ENHRUM is representative of rural households living in localities from 500 to 2,500 inhabitants, and provides detailed panel data in 2002 and 2007 on assets, socio demographic characteristics, agricultural and other household's production activities, income of household members from waged work, remittances, and other private and government transfers (www.das-ac.mx).

The original representative sample of ENHRUM includes 1,765 households in 2002 and 1,543 for households in 2007 covering 80 villages and 14 States of Mexico. This originates an unbalanced panel data for two years. However, we restrict our attention to households who are active farmers and present agricultural activities in the period of study (779 in 2002 and 696 in 2007).

ENHRUM data allowed us to perform the estimations of rainfall variation on farm-households total net income for the whole data and for the five rural regions of Mexico, a procedure that is relevant because the regional agro-ecological and socioeconomic heterogeneity of rural Mexico.

As mentioned, we conducted two sets of regressions for the study of the effects of rainfall variation in the economy of rural households in Mexico. The first one focuses on crop production and the second is for total net income of Mexican rural households.[6]

In what follows we describe the variables included in the model and our prior expectations about their relationship with crop output and total income of rural households. Table 1 presents the definitions and descriptive statistics of the variables used in the different empirical specifications, as well as other relevant information. Although the focus is to estimate the effect of rainfall variation on output and net income, we controlled for other factors that we hypothesized to be associated with our dependent variables (output and total net income). Thus, a number of variables, such as demographic, social, and economic variables are included in the analysis. One characteristic of rural household heads is their relatively high age, most of them

6 It is important to note that here net crop income is sales plus self-consumption derived from household's crop production minus their monetary costs. So net income captures value added of family inputs (land, labor and capital).

being men, having low education (less than the six years of primary education), and a considerable portion of them speaks an indigenous language. Rural household's average size is high and increased from 2002 to 2007, although the number of family members that migrated also increased during the period and so, the average size of rural households remained practically unchanged (around 6 members per household). Maize production and value of production of other annual crops raised but bean volume of production fell during the period, whereas cropping land characteristics experienced no major changes. The exception is average plot size that sharply decreased from 2002 to 2007. Table 1 also shows that a low proportion of households producing field crops have access to irrigation. Income wise and in 2002 pesos, income increased, as well as government income transfers to farmers producing basic crops (including maize and bean) and agricultural wages. Diversification into off-farm activities has increased over time, and remittances and access to credit increased. With respect to historical trends annual rainfall dropped during 2002 and 2007, and the variation was higher during the first year, whereas the standard deviation in the second year was almost the same. Finally, around 45% of rural households are dedicated to field crop production, and between 64% and 69% of them produced maize during 2002 and 2007, respectively.

The expected signs of the estimated parameters are the following. We hypothesize that a rainfall variation (high deviation respect to historical data) does affect agricultural output in a statistical significant manner, especially so for maize and bean and rain-fed crop farmers since most of them are entirely rain dependent. Based on rural household models and previous empirical research we introduced several controls. A group of them relates to demographic and education characteristics play a role in determining crop production and total net income. For example, if crop production is labor intensive, the number of household members is expected to have a positive effect on agricultural production, whereas more years of education of family members could have the opposite effect since maize and bean and field crop production does not necessarily require formal education. With respect to land assets, we expect that size of plots to have a positive impact on maize and bean production and total net income, and we expect the same effect of irrigated lands. Off- farm work may have a negative effect on total net income since work outside the farm reduces family labor availability for agricultural production. However, by increasing household's income, off-farm work can be a way to finance crop production, especially maize subsistence production. Income transfers as remittances and government income supports to farmers, as well as access to credit, could also have a positive impact on crop production and total income.

3. Econometric model

We perform the present analysis using two rounds of household panel data set spaced five years apart. The panel nature of the data allows capturing both changes over units (households) and over time. We have what is called a short panel, it means data on many individuals and few time periods. Given the detailed data provided by ENHRUM, we apply models appropriate to the richness of the data. Accordingly, in the econometric estimations we apply the two prominent panel data models: fixed effects and random effects models. By virtue of their capacity to account for inter-temporal as well as individual differences, these models provide a better control for the influence of missing or unobserved variables as well to estimate key marginal effects; they also allow for causal interpretations (Cameron and Trivedi, 2010). We consider a simple panel data model with individual-specific effects:

$$Y_{it} = \alpha_i + \beta X_{it} + u_{it} \tag{1}$$

where:

Y_{it} is the dependent variable observed for household *i* at time *t*, in our case it is the logarithm of maize and bean production in physical terms or the net income accruing to households producing field crops.

X_{it} is a vector o regressors for household i at time t.

β is a vector of coefficients.

α_i are random-specific unobserved household effects which are assumed to be fixed over time and vary across household i.

u_{it} is an idiosyncratic error.

A fundamental issue concerns with the assumption behind the relationship between the X_{it} and α_i since it makes fixed effects and random effects models different. The fixed effects approach treats α_i as nonrandom and hence makes possible the correlation between the observed explanatory variables (X_{it}) and α_i (this allows for a limited form of endogeneity). On the other hand, the random effects approach is applicable under the assumption that αi is random and not correlated with X_{it} and includes it into the error term (Cameron and Trivedi, 2010). We used a Hausman test to check whether there is such a correlation between the observed explanatory variables and αi to select the suitable model specification. In addition, we use cluster-robust standard errors because of the well-known failure assumption of homoscedasticity in panel data.

4. Results

We present here the results of the estimations of the baseline models of the logarithm of total crop production, logarithm of maize and bean physical production and the logarithm of other crops value of production (section 4.1), and results for total net income (section 4.2) using equation 1. In particular, using alternative specifications we tested the statistical significance of the rainfall variation, controlling for a range of factors.

4.1. Crop production

The results from our baseline regression are in Table 2. The experiment variable (the rainfall parameter) is negative and significantly different from zero in the fixed effects estimation for maize production, supporting our hypothesis that large short-term impacts have negative consequences. The magnitude of the rainfall parameter is significant at 1%, implying that small wet and/or dry events have some measurable effect on household's maize production, suggesting that these farmers may not be able to cope with unanticipated rainfall changes. On the other side, we found no evidence of a negative rainfall shock for other crops, including a positive sign and not statistically significant estimator in the rainfall parameters.[7]

In the following, we emphasize fixed effects estimator results on maize production and other crops value of production, because, applying the Hausman test, we rejected the null hypothesis that the coefficients estimated by the efficient random effects estimator are the same as the ones estimated by the consistent fixed effects estimator (Prob>chi2 of 0.0010 and 0.0058, respectively). However, we analyze random effects estimator results for bean production (Prob>chi2 of 0.3503).

For the fixed effects estimations in the maize production equation, most parameters present the expected signs, and, in addition to the rainfall variable, the statistical significant ones are sex, plot size, and irrigated land.[8] Whereas the positive and significant sign of plot size, irrigated land, and transfers are expected, the positive sign of wages is not. The latter result may come from the possibility that waged labor is more productive than family labor in agricultural production. Using ENHRUM data for 2007, Stabridis (2014) presents evidence for field crop production supporting this interpretation.

It is worth noting the impact for maize production, we find that deviations from mean local rainfall are negatively associated with maize output: 10% higher rainfall variation leads metric tons of output to be 0.8% lower on average. On the other hand, positive impacts are associated for bean production (6%) and no significant effect for other crops. To improve identification we split

7 Panel data estimations are more reliable since they control for unobserved features, while OLS use data as independent cross-sectional units.

8 The variables not presented in the fixed effects estimation are those characterized by their constant nature. Also it is interesting to note the U-shape in age of household head, suggesting that maize and bean production is lower for farmers above 50 years old.

the sample in irrigated and rain-fed production and distinguished medium from small farmers or plots. The results of the former specifications are in table 3 and 4. As expected, the results show that production of maize and other crops under rain-fed conditions are negatively affected by rainfall variations, whereas the effect of the later variable on maize production with irrigation is not statistically significant (tables 3 and 4, respectively). In addition, we found a negative and statistically significant of rainfall variations on the production of other crops under rain-fed conditions. It is worth noting that we found a no significant rainfall estimate for producers for bean. In general, the control variables have the expected sign.

Tables 5 and 6 present the results for the second specification (as before, we control for all other explicative variables including irrigation).[9] Medium-size farmers are affected by rainfall variations only with respect to bean production (the effect is positive and significant, Table 5), whereas small farmers production of maize is affected in a significant and negative manner y rainfall variations; in addition their production of other crops is affected positively (Table 6).

4.2. Total net income

Amongst others, a relevant question in the study of rural poverty and food security is to inquire on the effects of weather on net income for rural households which have agricultural activities. In this section we rely on evidence found that rainfall variation has adverse effects on agricultural production, specially on maize production cultivated under rain-fed conditions and by small household farmers to focus on household's total net income.

Based on Hausman test we focus on fixed effects estimator (Prob>chi2 of 0.0003). Results from our baseline model (except remittances and PROCAMPO's government transfers) show no evidence about rainfall impact on rural household's net income independently of the panel model applied. In both cases, this effect is negative but not statistically significant (Table 7). In contrast, family size, irrigated land and wages resulted to have a significant impact on household's income.

9 Based on ENHRUM data, small-sized crop farmers produce in plots with an extension of up to 5 hectares, and medium size farmers have more than 5 hectares of cropping land.

There is no evidence of an inverse U shaped curve in age explained by high frequency of household head with more than 50 years of age. Unlike the results for crop production, only family size, irrigated land and wages have a significant impact on income. Finally, contrary to production equation, there are no expected signs in household education and there are no results for indigenous, land quality and time because their constant nature.

Notwithstanding the above results, recent research suggest household's prone to diversify out of farming, but still remain part of the local rural activities. When we distinguish off-farm work and households dedicated only to agricultural activities, we found no evidence of a significant impact of rainfall variations on income of pure agricultural households, although the rainfall estimate is, as expected, negative (last two columns of Table 8). Households focused on agricultural activities are affected by sex of the household, family size, irrigation, plot area, and wages, with expected signs. An unexpected result is noteworthy: again there is no evidence of a significant impact on income by rainfall variation, although the rainfall estimate is negative in both equations. Latter result suggests an unforeseen rainfall impact on farmers who are prone to diversify in activities and income.

5. Conclusions

In this paper we inquire on a theme with little attention in the literature related to rural development and food security: the impacts of weather variations on agricultural production and incomes of Mexico's rural households. We focus on the likely effects of high variation in rainfall with respect to historical trends on crop production of maize, bean and other crops, as well as on rural household's net income.

The empirical research we conducted comes from the use of panel data provided by a survey representative of rural households of Mexico for 2002 and 2007. The study uses a simple panel data model with individual-specific effects and focused on households dedicated to field crops production while controlling for a range of relevant factors. The estimations are for the whole sample of households producing maize and bean, and field crops, as well as dividing the sample according to households with access to irrigation and producing under rain-fed conditions and distinguishing producers according to their plot size.

We found strong evidence of a negative and significant impact of rainfall variation for maize production and mixed results with respect to the impact on net income of rural households. In the case of maize production, we find that deviations from mean local rainfall are negatively associated with maize output: 10% higher rainfall variations leads metric tons of output to be 0.8% lower on average. On the other hand, positive impacts are associated for bean production (0.6%) and we find mixed results for and other crops.

Our study suggests that rainfall variations with respect to historical rainfall trends can be harmful for crop production, in particular for farmers producing maize and other crops under rain-fed conditions (-1% for maize and -0.7% for other crops) and for farmers with small plots (-0.7% and -0.8%, respectively).

However, we found no clear empirical evidence of negative impacts of rainfall variation on net income of Mexican rural households.

The result of the present research about a not significant change on household's income of rainfall variation asks for future research. In this respect, we are building disaggregated rural economy-wide model for Mexico to estimate the direct and indirect effects of rainfall variations, as well as of other climate change variables, on agricultural production and on other activities of Mexican rural households.

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Appendix A

Table 1: Summary Statistics of Households and Communities: 2002-2007

Variable	Description	Mean	Std. Dev.	Mean	Std. Dev.
Age	Age of the hh in years	51.74	14.96	55.64	14.50
Sex	Sex of the hh (1=men; 0 women)	0.89	0.30	0.91	0.29
Indigenous	hh speaks an indigenous language (1=indigenous; 0 otherwise)	0.29	0.45	0.31	0.46
Household education	Education of the household in years	5.52	2.56	6.09	2.56
Family size	Number of members in the family	6.91	3.15	7.94	3.55
Members outside	Members who lived outside for at least 3 months (1=yes; 0=no)	0.49	0.50	0.69	0.46
Maize production	Amount of maize produced (kilograms)	3,964.8	22,760.9	5,529.5	19,754.8
Bean production	Amount of bean produced (kilograms)	4,067.21	26,268.3	626.0	1,263.5
Other crops	Production values of other crops ($)	41,918	149,285.9	263,816.9	3,433,251
Land quality	Quality of land (1=good,...,3=bad)	1.70	0.55	1.70	0.55
Land time	Avg. time from the household to the plot	28.98	27.39	29.15	27.16
Sowed area	Sowed area (hectares)	7.19	57.52	3.69	6.68
Irrigated	Land irrigated (1=irrigated; 0=rainfed)	0.23	0.42	0.26	0.44
Total net income	Total net income in pesos ($)	48,441.6	118,608.0	47,454.7	85,904.4
Remittances	Income from US remittances ($)	3,849.0	15,491.1	6,657.4	28,373.2
Transfer	Income transfers from PROCAMPO ($)	2,406.8	5,611.9	1,939.38	3,860.60
Off-farm activities	Off-farm work, including livestock (1=yes; 0=no)	0.21	0.41	0.29	0.45
Wages	Agricultural wages paid	2,060.9	9,996.9	1,146.3	5,217.8
Credit	Access to credit (1=yes; 0=no)	0.06	0.23	0.21	0.41
Rainfall	Log annual rainfall less historical rainfall	-0.10	0.30	0.006	0.29
Crop producers	779 in 2002 and 696 in 2007				

Sources: own calculation using data from ENHRUM and NMS from Mexico.

Table 2: Model results for crop production

Variable	Coefficient (Maize)	(Std. Err.)	Coefficient (Bean)	(Std. Err.)	Coefficient (Other crops)	(Std. Err.)
Age	-0.0442	(0.0698)	0.0481	(0.0536)	0.1674*	(0.0856)
Age2	0.0005	(0.0005)	-0.0004	(0.0004)	-0.009	(0.0007)
Sex	0.4208***	(0.1118)	0.8087**	(0.3433)	-0.2791	(0.7781)
Indigenous	N.A.	N.A.	-0.6382**	(0.2503)	N.A.	N.A.
Household educ.	-0.0579	(0.0660)	0.0150	(0.0525)	-0.0356	(0.0678)
Family size	0.0261	(0.0469)	-0.0104	(0.0267)	0.0002	(0.0734)
Land quality	N.A.	N.A.	-0.5660***	(0.1716)	N.A.	N.A.
Land time	N.A.	N.A.	-0.0021	(0.0040)	N.A.	N.A.
Sowed area	0.0007**	(0.0003)	0.0001	(0.0009)	0.0206	(0.0182)
Irrigated	0.4075*	(0.2286)	0.3320	(0.2507)	0.3993	(0.3905)
Remittances	1.39e-06	(4.59e-06)	3.53e-06	(3.65e-06)	2.37e-06	(2.57e-06)
Transfers	9.96e-06	(0.000)	0.0001***	(0.0000)	0.0000	(0.0000)
Wages	5.40e-06	(0.000)	9.84e-06	(0.0000)	0.0000***	(0.0000)
Credit	0.1465	(0.1827)	-0.4275	(0.2826)	0.0059	(0.2033)
Rainfall	-0.8244***	(0.2388)	0.5956*	(0.3408)	0.2931	(0.3642)
Intercept	7.2095***	(1.9186)	4.1041***	(1.5117)	3.0713	(2.4463)

Note: Unbalanced panel. Fixed and random effects estimations. Own computations from ENHRUM and NMS. $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$. All calculations using robust standard errors.

Table 3: Model results for irrigated farmers

Variable	**Coefficient (Maize)**	**(Std. Err.)**	**Coefficient (Bean)**	**(Std. Err.)**	**Coefficient (Other crops)**	**(Std. Err.)**
Age	0.0637	(0.2336)	N.A.	N.A.	0.1666	(0.1582)
Age2	6.61e-06	(0.0020)	N.A.	N.A.	-0.0010	(0.0014)
Sex	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
Household educ.	-0.2192	(0.053)	N.A.	N.A.	-0.2142*	(0.1195)
Indigenous	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
Family size	-0.0248	(0.1372)	N.A.	N.A.	0.0766	(0.1391)
Land quality	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
Land time	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
Sowed area	0.0383	0.0628	N.A.	N.A.	0.0854**	(0.0374)
Remittances	-2.39e-06	(7.55e-06)	N.A.	N.A.	-4.08e-06	(0.0000)
Transfers	-2.87e-06	(0.0000)	N.A.	N.A.	-5.03e-06	(0.0000)
Wages	-1.87e-06	(0.0000)	N.A.	N.A.	0.0000***	(0.0000)
Credit	-0.0811	(0.5027)	N.A.	N.A.	0.0450	(0.3005)
Rainfall	0.3263	(0.6228)	N.A.	N.A.	1.1317***	(0.4268)
Intercept	5.8412	(6.3524)	N.A.	N.A.	4.6956	(4.3344)

Note: Unbalanced panel. Fixed and random effects estimations. Own computations from ENHRUM and NMS. $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$. All calculations using robust standard errors.

Table 4: Model results for rain-fed farmers

Variable	**Coefficient (Maize)**	**(Std. Err.)**	**Coefficient (Bean)**	**(Std. Err.)**	**Coefficient (Other crops)**	**(Std. Err.)**
Age	-0.0288	(0.0826)	0.0172	(0.0559)	0.1909*	(0.1108)
Age2	0.0003	(0.0006)	-0.0002	(0.0004)	-0.0010	(0.0009)
Sex	0.3206**	(0.1323)	0.9973***	(0.3414)	-0.1636	(0.6869)
Indigenous	N.A.	N.A.	-0.4704*	(0.2435)	N.A.	N.A.
Household educ.	0.0544	(0.0836)	0.0279	(0.0619)	0.1942***	(0.0742)
Family size	0.0108	(0.0514)	-0.0142	(0.0290)	-0.0118	(0.1016)
Land quality	N.A.	N.A.	-0.4148**	(0.1841)	N.A.	N.A.
Land time	N.A.	N.A.	-0.0018	(0.0042)	N.A.	N.A.
Sowed area	0.0008***	(0.0003)	0.0001	(0.0008)	0.0288	(0.0187)
Remittances	-2.19e-06	(5.24e-06)	6.31e-06	(5.20e-06)	3.12e-06***	(1.13e-06)
Transfers	0.0000	(0.0000)	0.0001***	(0.0000)	-0.0000	(0.0001)
Wages	8.08e-06	(0.0000)	0.0000***	(0.0000)	0.0000**	(0.0000)
Credit	0.1496	(0.2557)	-0.9609***	(0.3343)	-0.0634	(0.3046)
Rainfall	-1.0049***	(0.2894)	0.6522*	(0.3537)	-0.7259*	(0.4131)
Intercept	6.2970***	(2.2792)	4.4138***	(0.5871)	0.2202	(3.1059)

Note: Unbalanced panel. Fixed and random effects estimations. Own computations from ENHRUM and NMS. $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$. All calculations using robust standard errors.

Table 5: Model results for medium farmers

Variable	Coefficient (Maize)	(Std. Err.)	Coefficient (Bean)	(Std. Err.)	Coefficient (Other crops)	(Std. Err.)
Age	-0.2646	(0.1607)	-0.0270	(0.1069)	0.1339	(0.1280)
Age2	0.0029**	(0.0014)	0.0001	(0.0009)	-0.0002	(0.0011)
Sex	N.A.	N.A.	0.5276	(1.0431)	N.A.	N.A.
Indigenous	N.A.	N.A.	-0.8252	(0.5196)	N.A.	N.A.
Household educ.	0.1714	(0.1362)	0.0230	(0.0743)	-0.1053	(0.0699)
Family size	0.1441	(0.1538)	-0.0403	(0.0336)	-0.2296	(0.1582)
Land quality	N.A.	N.A.	-0.5882**	(0.2593)	N.A.	N.A.
Land time	N.A.	N.A.	-0.0182***	(0.0056)	N.A.	N.A.
Irrigated	0.0925	(0.4748)	-0.1912	(0.4444)	-0.2586	(0.6203)
Remittances	-7.69e-08	(7.16e-06)	3.75e-06	(5.88e-06)	0.0000	(0.0000)
Transfers	0.0001***	(0.0000)	0.633	(0.053)	0.0000	(0.0000)
Wages	2.24e-07	(0.0000)	1.57e-06	(0.0000)	0.0000***	(0.0000)
Credit	-0.1313	(0.2664)	-0.0841	(0.2553)	0.1656	(0.3078)
Rainfall	-0.1812	(0.6700)	1.0118**	(0.4949)	1.153	(0.7525)
Intercept	10.8140**	(4.5929)	8.1063**	(3.2931)	5.3190	(3.4611)

Note: Unbalanced panel. Fixed and random effects estimations. Own computations from ENHRUM and NMS. $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$. All calculations using robust standard errors.

Table 6: Model results for small farmers

Variable	Coefficient (Maize)	(Std. Err.)	Coefficient (Bean)	(Std. Err.)	Coefficient (Other crops)	(Std. Err.)
Age	0.0717	(0.0804)	0.0595	(0.0591)	0.2134	(0.1338)
Age2	-0.0004	(0.0006)	-0.0005	(0.0005)	-0.0013	(0.0010)
Sex	0.5003***	(0.1213)	0.7605**	(0.3652)	-0.0875	(0.6762)
Indigenous	N.A.	N.A.	-0.5079*	(0.2988)	N.A.	N.A.
Household educ.	0.1637***	(0.0622)	-0.0269	(0.0646)	-0.0440	(0.1000)
Family size	0.0586	(0.0440)	-0.0006	(0.0379)	-0.0316	(0.1205)
Land quality	N.A.	N.A.	-0.5617***	(0.1985)	N.A.	N.A.
Land time	N.A.	N.A.	0.0072	(0.0050)	N.A.	N.A.
Irrigated	0.5469*	(0.3235)	0.8898***	(0.3163)	0.1359	(0.5943)
Remittances	-1.64e-06	(3.68e-06)	-1.65e-07	(3.92e-06)	4.65e-06***	1.74e-06
Transfers	0.0000	(0.053)	-0.0000	(0.0001)	0.0000	(0.0000)
Wages	0.0000	(0.0000)	0.0001	(0.0000)	0.0000***	(0.0000)
Credit	-0.0637	(0.2768)	-0.5073	(0.4447)	-0.1799	(0.3532)
Rainfall	-0.7670***	(0.2764)	0.3300	(0.4790)	0.8196*	(0.4827)
Intercept	4.1096	(2.2308)	3.2476*	(1.6664)	2.0086	(3.5583)

Note: Unbalanced panel. Fixed and random effects estimations. Own computations from ENHRUM and NMS. $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$. All calculations using robust standard errors.

Table 7: Model results for net income

Variable	Coefficient	(Std. Err.)
Age	-467.06	(1,930.92)
Age2	-2.05	(20.66)
Sex	-56,448.77	(88,697.05)
Indigenous	N.A.	N.A.
Household educ.	-4,396.0	(4,167.72)
Family size	6,066.57***	(1,833.73)
Land quality	N.A.	N.A.
Land time	N.A.	N.A.
Sowed area	21.76	(27.64)
Irrigated	18,358.18*	(11,113.76)
Wages	1.16***	(0.38)
Credit	1,891.84	(7,811.32)
Rainfall	-5,341.03	(8,073.87)
Intercept	100,356.9	(94,524.01)

Note: Unbalanced panel. Fixed effects estimation. Own computations from ENHRUM and NMS. $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$. All calculations using robust standard errors.

Table 8: Model results for household activities

Variable	Coefficient (Off-farm)	(Std. Err.)	Coefficient (Only ag.)	(Std. Err.)
Age	4,152.44	(5,553.93)	-3,278.73	(2,282.60)
Age2	-31.19	(45.05)	12.50	(23.74)
Sex	100,513.6***	(13,758.84)	-132,262.6	(86,212.76)
Indigenous	N.A.	N.A.	N.A.	N.A.
Household educ.	6,214.10	(7,238.30)	-4,778.60	(4,893.14)
Family size	7,243.64*	(4,055.78)	7,690.34***	(2,602.87)
Land quality	N.A.	N.A.	N.A.	N.A.
Land time	N.A.	N.A.	N.A.	N.A.
Sowed area	7,799.71***	(1,769.95)	16.63	(26.56)
Irrigated	-12,575.27	(17,186.69)	30,021.88**	(13,209.55)
Wages	-2.21	(3.11)	1.06***	(0.32)
Credit	-18,468.96	(27,186.86)	8,036.21	(8,725.94)
Rainfall	-33,314.59	(30,207.18)	-5,880.77	(11,785)
Intercept	-276,289*	(157,923.6)	256,293.5**	(104,690.1)

Note: Unbalanced panel. Fixed effects estimation. Own computations from ENHRUM and NMS. $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$. All calculations using robust standard errors.

Appendix B

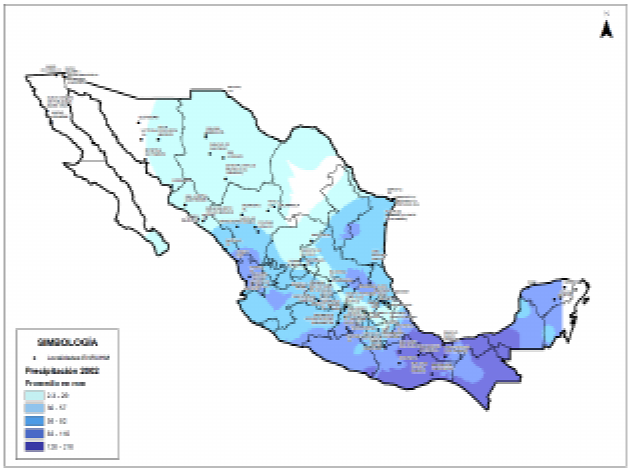

Figure 2: 2002

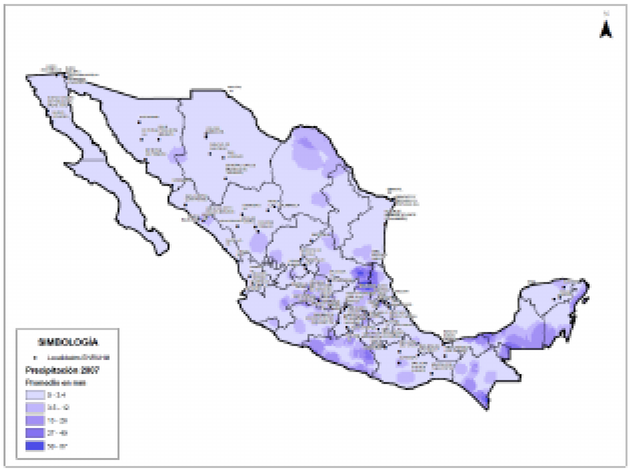

Figure 3: 2007