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Drought and Retribution

Evidence from a Large-Scale Rainfall-Indexed Insurance Program in Mexico

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Abstract

Although weather shocks are a major source of income fluctuation, most of the world's poor lack insurance coverage against them. Absence of formal insurance contributes to poverty traps, as investment decisions are conflicted with risk management ones: risk-averse farmers tend to underinvest and produce lower yielding yet safer crops. In the past few years, weather index insurance has gained increasing attention as an effective tool to provide small-scale farmers coverage against aggregate shocks. However, there is little empirical evidence about its effectiveness. This paper studies the effect of the recently introduced rainfall-indexed insurance on farmers' productivity, risk management strategies, as well as per capita income and expenditure in Mexico. The identification strategy takes advantage of the variation across counties and across time in which the insurance was rolled-out. The analysis finds that the presence of insurance in treated counties has significant and positive effects on maize productivity. Similarly, there is a positive association between the presence of insurance in the municipality and rural households' per capita expenditure and income, although no significant relation is found between the presence of insurance and the number of hectares destined for maize production.

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Drought and Retribution: Evidence from a Large-Scale Rainfall-Indexed Insurance Program in Mexico

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JEL Q11, Q14, O13, G22

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Introduction

Weather shocks are a major source of income fluctuation that usually translate into consumption interruptions and destroy assets accumulated through years of limiting consumption (Barnett and Mahul 2007). These can be catastrophic, triggering famine, displacing families, and transmitting poverty across generations by introducing malnutrition and school dropout (Alderman and Haque 2008). This is accentuated in rural settings where survival depends on stochastic factors like weather, crop disease, and personal illness. Yet, the majority of the world's poor have limited access to formal insurance (Barnett, Barrett and Skees 2008).

As a result, an ample array of informal mechanisms has developed to prevent or mitigate the effects of weather shocks on consumption. Some of these successfully reduce risk exposure, though frequently do so by imposing trade-offs. For example, farmers may choose low-risk yet low-profit investments as alternatives to riskier yet higher-yielding ones (Rosenzweig and Binswanger 1993), keeping producers trapped in extreme poverty (Barnett, Barrett and Skees 2008). Additionally, risk coping mechanisms such as asset depletion and risk sharing arrangements are mainly effective to mitigate idiosyncratic risks. Since generalized shocks --such as those caused by weather-- usually enhance highly correlated individual losses, risk sharing is partially obstructed and durable assets lose their value in case of massive sales (Barnett and Skees 2009).

In the last few years, weather index insurance (WII) has raised attention as an effective tool for providing coverage to a large number of farmers. In agriculture, these contracts provide indemnity payments if the realization of a weather event that is highly correlated with losses exceeds a pre-established threshold. There is neither need for actual loss estimation nor individual visits for verification, as these contracts rely on publicly available information from weather stations. Similarly, they potentially reduce information problems like adverse selection and moral hazard (Giné et al. 2005). Moreover, it has been argued that WII could be useful to address some insurance market failures that contribute to the persistence of poverty among rural households (i.e. poverty traps (Barnett, Barrett and Skees, 2008)). For example, WII could lead to increased investments in fertilizers and higher quality seeds or production of cash crops (Giné and Yang, 2009), though it could also lead to specialization or monoculture, depending on the insured crop (Fuchs and Wolff, 2011). Nonetheless, there is still little empirical evidence of their effects. Despite the recent increase in the number of studies related to WII, the vast majority focuses on small sample sizes and reduced geographic locations. For example, Giné and Yang (2009) implement a randomized field experiment to test whether drought insurance in Malawi induces farmers to take loans for investment in new crop varieties, but their sample consists of roughly 800 maize and groundnut farmers. Similarly, Giné, Townsend and Vickery (2007) study drought insurance implications on farmers in the Indian state of Andhra Pradesh using a sample of 752 households.[2]

With this paper, we intend to fill this gap in the literature by analyzing the effect of a large-scale WII: in 2008, the Mexican WII covered over 1.9 million hectares in 656 counties, corresponding to more than 15% of rain-fed agricultural land. Introduced in 2003, it takes advantage of existing weather stations to measure rainfall on insured regions. If precipitation within a certain period of time is below a pre-established threshold, the insurance disburses the corresponding indemnity payments. It is supplied by Agroasemex --a national insurance company-- and co-financed by the Ministry of Agriculture and state governments. Moreover, it provides coverage for production of four of Mexico's main crops of which maize is by far the most important. In 2008, agricultural production in Mexico added up to 20.5 million hectares, of which 73.6% depended exclusively on rain (Ministry of Agriculture 2009).[3] Maize production covered 7.8 million hectares, of which more than 6.9 million was rain-fed sowed land.

The paper studies the link between the recently introduced WII on farmers' productivity and risk management strategies in Mexico. We use a unique panel data set that we collected and constructed,

[2] A recent World Bank document (Arias et al 2014) seeks to evaluate whether the CADENA weather-index-based insurance product (WII) improved poverty of farmers living in insured municipalities between 2000 and 2010 and find that "…does seems to reduce moderate poverty."

[3] http://www.siap.sagarpa.gob.mx/

combining municipality level agricultural production (for more than 300 different species in more than 2,300 counties from 2002 to 2008) with WII administrative data, weather data (daily rainfall and minimum and maximum temperatures from 1990 to 2008) and the full set of PROCAMPO beneficiaries from 1994 to 2008 (a federal government program that provides cash transfers to farmers). In our identification strategy, we take advantage of the variation across time and space in which WII was introduced and expanded. WII's treatment effect on yield is identified through the time and space in which it was rolled out. We use municipality fixed effects to control for time invariant characteristics, year fixed effects to control for possible generalized shocks, and control for annual rainfall and temperature deviations. We measure changes in maize yields and hectares sown in counties that received insurance treatment earlier with respect to those who were later treated and those who were not treated at all. As a complementary empirical analysis, we measure weather-indexed insurance's effect at the household level using the National Household Expenditure and Income Surveys (ENIGH) for the rounds of 2002 to 2008.

We find that insurance presence at the municipality level positively and significantly affects insured counties' maize yield with respect to uninsured. In particular, we find that WII presence has a positive and significant effect of 6%, which compared to the premium that the government paid per hectare in 2008, translates into a substantial cost-benefit ratio with a magnitude of 340%. Nevertheless, the effect is insignificantly related to the number of hectares devoted to maize production. Thus, although we cannot rule out off-setting effects, there does not seem to be evidence towards diversification or specialization. Conversely, we find that insurance presence and relative coverage --with respect to total land sowed-- are positively and significantly associated with a higher average per capita household real expenditure and income. In particular, insurance presence at the municipality level is associated with a significantly higher real per capita household expenditure (and income) of 6 to 7 percent with respect to counties without coverage.

The rest of the paper is organized as follows: section I describes weather-indexed insurance and the Mexican case in more detail. Section II presents the data and empirical strategy and models we estimate. Section III discusses the results. Section IV presents robustness checks and finally, section V concludes.

I. Weather-Indexed Insurance

Weather-indexed insurance contracts (WII) in agriculture provide indemnity payments if the realization of an easily verifiable weather event that is highly correlated with agricultural losses exceeds a pre-established threshold. However, indemnity payments do not directly depend on agricultural producers' actual losses. These have several advantages relative to traditional crop insurance. First, it is simple in terms of implementation, sales and marketing (Barnett and Mahul 2007). Second, it represents low administrative and implementation costs since there is no need to estimate actual losses experienced by the policyholder; measuring the value of the underlying weather index is sufficient. Also, insurers no longer have to visit individual plots to verify losses as they rely on publicly available information from weather stations. Third, it reduces potential information problems (i.e. adverse selection and moral hazard) since it is unlikely that policyholders have better information about the underlying index, and policyholders cannot influence its realization (Giné et al. 2005).

Nevertheless, WII faces some downturns. First, it is expensive to get started. A substantial amount of reliable information is required such as weather and agricultural production information, as well as detailed studies of the relation between soil type, inputs, and production.[4] Consequently, since weather data have public goods characteristics (Barnett and Mahul 2007), they are unlikely to be collected, cleaned, archived and made publicly available by the private sector. Government meteorological bureaus provide these services. In addition, since WII design is easy to copy as it uses publicly available information, few insurance companies will have an incentive to incur development costs. Therefore, governments or non-

[4] This information must have international quality standards, be collected by a reliable and trusted institution, and be made publicly available.

governmental organizations need to provide incentives to develop products of this nature. However, one of WII's main critiques is that despite its coverage, policyholders are still subject to substantial "basis risk" or the imperfect correlation between the index and the actual experienced losses (Barnett and Mahul 2009). In other words, if the weather index and the agricultural losses are not perfectly correlated, there could be cases in which policyholders receive indemnity payments without having suffered any loss, and there could also be cases in which policyholders suffer losses and still do not receive indemnity payments. Similarly, WII could also have unintended consequences, such as potentially providing disincentives to invest in alternative agricultural technology such as irrigation or research and development of drought resisting seeds or depending on the insured crop it could lead to specialization or monoculture bringing all the economic and environmental consequences associated with it (Fuchs and Wolff 2011).

In Mexico, small-scale farmers lack access to private production insurance because land fragmentation, large administrative costs and systemic risk discourage private insurers. Consequently, the Mexican Federal Government, through the Ministry of Agriculture, introduced WII in 2003. The program's main objective is to support small-scale agricultural producers (i.e. owning no more than 20 hectares) that "suffer atypical climatic contingencies --in particular droughts-- get reincorporated into their productive activities". Individual producers pay nothing to get coverage since it is jointly contracted by federal and state governments who provide resources from their annual budgets to purchase insurance premiums. Individual farmers get automatically enrolled in the program if they live within the insured regions.

WII's coverage is exclusively provided by Agroasemex, a decentralized governmental agency that was formed in 2001. The design of WII acknowledges the relation between agricultural production, soil quality, crop and cumulative rain during the plant's growth cycle periods. Agroasemex tailors insurance policies for specific crops and regions to maximize the correlation between drought-induced harvest failure and indemnity payments. This is intended to effectively hedge weather risk associated with rain (Giné et al. 2005).[5]

Consequently, WII's coverage universe consists of crops that use rain as the main humidity input, and indemnity payments are provided if rainfall at any stage of the season is below the pre-established threshold measured in millimeters through local weather stations. As an example, we use three counties of the state of Guanajuato in Figures 1.a. to 1.h. Agroasemex offers the following contract for insuring maize in the selected counties (Apaseo el Alto, Leon and Salamanca): the first period, also known as the sowing period, runs from May 15 to July 5; the second period, or flowering period, from July 6 to August 20; and the third, or harvesting period, from August 21 to October 31. The minimum amount of cumulative rain above which Agroasemex does not provide indemnity payments – known as the trigger threshold-- equals 43, 80 and 60 millimeters for the first, second and third periods, respectively.[6] There were no indemnity payments in Apaseo el Alto, since cumulative rainfall was higher than the minimum thresholds in every period from 2003 to 2008. However, indemnity payments were provided in 2005 for maize production in the counties of Leon and Salamanca as cumulative rainfall was lower than the sowing period's minimum threshold.[7] To get this information, Agroasemex takes advantage of existing and publicly available rainfall information. Although there are more than 5,000 weather stations in the country, WII only uses a subset since only a few attain international standards and have more than 25 years of daily information, necessary to predict rain patterns.

Provided that Agroasemex has sufficient information to insure requested areas (historical rainfall patterns, soil type, crops' humidity sensibility), state level officials suggest their federal counterpart in the area to be insured (number of hectares and counties considered) within the first three months of the year (i.e. before

[5] In other words, weather coverage is characterized at a regional scale to minimize basis risk.
[6] In this case, there was no payment since cumulative rainfall was higher than the minimum thresholds.
[7] We confirmed this information using daily rainfall data from the National Water Commission. Also, note that in 2005 Apaseo el Alto insured 6,885 hectares for maize production and paid premiums of US$35,000 ($344,000 Mexican Pesos) for an insured production of US$400,000 ($3.9 million MXP). Conversely, the same year Leon and Salamanca insured 6,874 and 1,621 hectares for maize production, paid premiums of US$46,000 and US$13,000 (for insured production of US$380,000 and US$100,000) and received indemnity payments of US$380,000 and US$100,000 dollars, respectively.

the beginning of the season). For the purchase of insurance policies, the federal government pays 70% of the cost and the state governments cover the remaining 30%. However, for counties that have high poverty levels (defined by the National Population Council), costs are split by 90%-10% for federal and state governments, respectively.

Agroasemex provides insurance for government budgets, and thus WII serves as a governments' budget risk management tool since it allows annual budget planning minimizing the risk of catastrophic expenditure should severe droughts occur. Nevertheless, Agroasemex's WII affects the individual producer's behavior. Even when farmers pay nothing to get coverage (direct government subsidy), they become automatically insured and get informed about their coverage status through officials at the Program for Direct Assistance in Agriculture (PROCAMPO) regional offices (Centros de Apoyo al Desarrollo Rural (CADER) or in the “Ventanillas Autorizadas” depending on plots’ location and municipality).

Possible evidence is provided by the Ministry of Agriculture 2009 through WII's program of external evaluation. Although written by a local based university (University of Chapingo), the document was still prepared as a request of the Ministry of Agriculture and was not revised under strict academic peer review. Thus, the results and recommendations should be taken with caution. Despite of the latter, the document describes that a subset of randomly selected farmers were surveyed and asked about their knowledge and willingness to pay for the WII. Among those who were interviewed, almost all were aware of the WII’s existence, and over 80% of them said that they would be willing to pay in order to get it if the government did not provide it. This could be used as anecdotal evidence that farmers not only have knowledge of the existence of the insurance, but that they also believe it is a service worth paying for.[8]

[8] It is worth noting that WII has not been found to be the only insurance product that is cheap and useful for Mexico. In the last few years private insurance companies have been offering an agriculture insurance product that offers the same large-scale coverage, but it covers “multi risks”. The claims on losses are assessed through a “random sampling” of the affected area to determine whether the insurance will pay. This is a cheap way to assess losses (ex-post). However, this fact does not affect this paper’s identification as private insurance began expansion after 2010, which is a latter period that the one covered in this analysis.

II. Empirical Analysis

Data. We collected, combined and used six sources of data. The first one consists of rain-fed agricultural production by municipality, year and crop type from 2002 to 2008 reported by the System of Agricultural Information (SIAP) of the Ministry of Agriculture. Although we mainly focus our analysis on maize, this data set has more than 270 crops, and provides the number of hectares sowed and harvested per year, as well as tons of production at the municipality level. In 2008, agricultural production in Mexico added up to 20.5 million hectares. However, close to 73.6% was done without irrigation systems, depending exclusively on rain (Ministry of Agriculture 2009).[9] Maize is the most important crop since its production covers over 7.8 million hectares. Moreover, maize's relative importance is higher still for rain-fed agriculture as it covers more than 6.9 million hectares or 42% of sowed land as opposed to 28.3% of irrigated land. Nevertheless, maize yields are over 3 times higher under irrigated than under rain-fed production. Table 1.a. provides some descriptive statistics.

The second source consists of administrative data from the Ministry of Agriculture regarding WII's coverage. It includes municipality level coverage information in terms of weather stations used, insured crops (maize, beans, sorghum and barley), number of hectares insured, value of insured production, value of the premiums paid, and indemnity payments (in case a drought occurred). WII was first piloted in five counties of the Mexican state of Guanajuato in 2003. In the following years, it expanded to other counties and states reaching more than 15% of the country's rain-fed production land in 24 states in 2008.[10] Table 1.b. presents information on insured crops as well as the number of hectares insured, value of production, premiums paid by federal and state governments and indemnity payments. In 2003 WII had presence in only 5 counties, covering just over 107,500 hectares. Conversely, by 2008 WII covered almost 2 million hectares in 656 counties. The first year in which Agroasemex made indemnity payments was 2005, and

[9] http://www.siap.sagarpa.gob.mx/

[10] http://www.agroasemex.gob.mx. The states are Aguascalientes, Campeche, Chiapas, Chihuahua, Colima, Durango, Estado de Mexico, Guanajuato, Guerrero, Jalisco, Michoacan, Morelos, Nayarit, Oaxaca, Puebla, Queretaro, San Luis Potosi, Sinaloa, Tabasco, Tamaulipas, Tlaxcala, Veracruz, Yucatan and Zacatecas.

even when these payments corresponded to 15.6% of the value of insured production, they were larger than the premiums paid for that year. Figure 1.1 shows the geographic location of the 5 counties in the state of Guanajuato in which the insurance first started in 2003, and figure 1.2 shows that it covered 41 municipalities in both states of Guanajuato and Puebla. Figure 1.3 shows the program's rapid expansion in 2005 and figure 1.4 the coverage in 2007.

The third data set comes from the Program for Direct Assistance in Agriculture (PROCAMPO). It consists of the full program beneficiary census from 1994 to 2008. For our analysis, we only use a subset --farmers that produce under rain-fed agriculture from 2002 to 2008-- and take advantage of producer level information of total number of hectares used for production, total assistance amount received, whether the beneficiary produces in private or communal land and total land size (in hectares). We divide farmers between large (with 20 hectares or more) and small (less than 20 hectares) using WII's criteria for beneficiary selection. Figures 2.a and 2.b describe the number of rain-fed farmers that received support of the PROCAMPO program between 2002 and 2008, as well as the number of hectares destined for maize production and other crops. Between 2002 and 2008 PROCAMPO provided support to more than 2 million beneficiaries per year that produced rain-fed agriculture on almost 10 million hectares. Moreover, close to 75% of these received subsidies for maize production. However, if we analyze the extension in hectares that received PROCAMPO support, we are able to see that the extension destined for rain-fed maize production is close to 50%. In addition, table 1.c shows more information on rain-fed maize producers that received benefits from PROCAMPO between 2002 and 2008. In particular, the first column shows the total number of beneficiaries (and column 4 the total number of hectares supported), the second shows the number of "large" rain-fed maize producing beneficiaries (i.e. that own more than 20 hectares), and the third, the number of rain-fed maize producers that sow and harvest in private land. It is worth noting that although large maize producing beneficiaries are a little over 1% of the total number of beneficiaries, they produce in more than 11% of the land (measured in hectares).

The fourth source of data comes from the National Water Commission. The data consist of daily rainfall measures in millimeters for every weather station in the country from January 1990 until December 2008. Figure 2.c presents municipality average rainfall for the agricultural production season (months of April to November) for the years between 1990 and 2008. We also use temperature information of the same source since some studies have shown that temperature is highly correlated with agricultural productivity, and in particular, extremely high temperatures negatively affect maize yields (Schlenker and Roberts 2006).

The fifth source comes from the National Population Council and consists of the denominated Municipality Level Marginality Index (a poverty indicator) for 2000. The marginality index is calculated by the council for each municipality using the method of principal components. Based on the 2000 census, it uses 10 indicators[11] and takes continuous values from 3.4 (poorest municipality or highest marginality degree) to -2.5 (lowest marginality degree). Moreover, the council divides counties in groups depending on the value of their poverty index. For example, they define counties with high marginality as those whose index goes from 3.4 to 1, marginal counties as those who have indices from 1 to -0.1, and so on.

Finally, we use household level information from the 2002, 2004, 2005, 2006 and 2008 National Household Expenditure and Income Survey (ENIGH).[12] ENIGH is a repeated cross section that contains a rich set of data ranging from socioeconomic characteristics, family structure, monthly reported income and expenditure, among others. Table 1.e provides descriptive statistics of rural households in counties that will later be treated and those that we use as controls (not treated) in 2002 (a year before WII was introduced). As we can see, in 2002 there does not seem to be significant difference between households located in counties that will later be covered with respect to those that later will serve as controls.

[11] Total county population, % of illiterate older than 15 years, % without primary school older than 15 years, houses without sewage, houses without electricity, houses without running water, houses with overcrowding, houses with dirt floor, % of rural population and % of people earning less than 2 minimum wages per month.

[12] According to its methodological synthesis, the ENIGH is a cross-section survey that reports information about the “structure, volume and distribution of the Mexican household’s income and expenditure”. It was surveyed for the first time in 1984, but it was until 1992 that its periodicity was established for every two years. Furthermore, according to INEGI, the ENIGH has maintained the same conceptual framework, unit of analysis, geographic coverage and sample design in order to maintain time comparability. The “household” is its basic unit of analysis, defined as the “space delimited by roof and walls of any kind of material, in which one or more people live, sleep, cook, eat and protect themselves from the weather”.

Empirical Strategy. To measure WII's treatment effect on yields, we would ideally compare insured counties' yields with respect to their counterfactual. In other words, we would compare agricultural productivity of the same municipality had it not been covered by the insurance. Since the counterfactual is never observed, we take advantage of WII's staggered entry to compare treated counties with respect to counties to be covered in future years --and those not covered at all-- as comparison. Consequently, the identifying assumption is that, conditional on municipality characteristics and other shocks, changes in productivity would have been the same in treatment and control counties had WII not been implemented.

The results may be biased if insured counties are different from those that do not get insured. For example, if land quality differed among insured and not insured counties. Further, it could be argued that weather stations were not randomly allocated in terms of land quality. If weather stations are located in more productive land, the difference in yields could be attributed to land quality instead of insurance's effect. Fortunately, most of the weather stations used by the program were built long before WII was introduced.[13] Moreover, Mexico's weather stations are located in places of strategic importance for the National Water Commission (i.e. close to dams and rivers), not based on agricultural productivity ends.[14] In addition, we include municipality fixed effects to control for time invariant characteristics, such as land quality. Also, we control for annual rainfall deviation with respect to municipality rainfall average from 1990 to 2008, monthly average maximum temperature deviation from monthly 1990-2008 average, and include year fixed effects in order to control for common shocks.

Yield Models. In this section we present the empirical models we estimate. In particular, we start by testing the hypothesis that the introduction of WII had a positive effect on maize yields. Since we do not observe yield data at the farm or individual producer level, we base our productivity analysis at the minimum aggregation level we can observe: municipality level productivity.

[13] As mentioned above, one of Agroasemex's requirements to insure a certain crop in a given area is to have at least 25 years of daily rainfall data of good quality (i.e. more than 90% of observations).

[14] This was confirmed by members of SAGARPA that work for the weather indexed insurance in a personal interview in February 2009.

In the following, we measure WII's presence with a dummy variable that takes the value of one if at least one hectare is insured in a given municipality, and zero otherwise. Also, we repeat the analysis using land covered by WII as a proportion of total land used for maize production in the municipality.

The left hand side variable included in the model is

$$(1) \qquad Y_{ct} = \frac{\Pi_{ct}}{H_{ct}}$$

where Π_{ct} represents total maize production (in tons) in municipality *c* and year *t*, and H_{ct} is the extension of maize harvested land (in hectares) in municipality *c* in year *t*.

The equation we estimate is the following:

$$(2) \qquad \ln(Y_{ct}) = \alpha_c + \beta_1 RainDev_{ct} + \beta_2 TempDev_{ct} + \gamma Insurance_{ct} + \sum_{t=1}^{T} \delta_t \, Year_t + \mu X_{ct} + u_{ct}$$

where $Insurance_{ct}$ is an indicator variable that takes the value of one if WII has presence on municipality *c* in year *t*. Moreover, we also estimate the equations using the proportion of land within each municipality dedicated to maize production (hectares of maize sowed land) covered by WII in each year. That is, $Insurance_{ct} = \frac{(Hectares\ covered)_{ct}}{(Hectares\ sowed)_{ct}}$.

Similarly, the $RainDev_{ct}$ and $TempDev_{ct}$ variables measure average annual municipality rainfall and maximum temperature deviation using the available historic rainfall and temperature data (from 1990 to 2008) from annual rainfall and average maximum temperature for the same municipality over the growing cycle (for the months of May to November). Thus, rainfall deviation is measured as follows:

$$RainDev_{ct} = \ln\left(\frac{\sum_{t=1990}^{T=2008}[AnnualRain_c]}{(T-t)}\right) - \ln(AnnualRain_{ct})$$

$$RainDev_{ct} = \ln\left(\overline{AnnualRain_c}\right) - \ln(AnnualRain_{ct})$$

where $\overline{AnnualRain_c}$ is average annual rainfall of municipality *c* for the 1990-2008 period, and $AnnualRain_{ct}$ is average annual rainfall of municipality *c* for year *t* (where *t* is 2002 to 2008). Maximum temperature deviation is measured the same way.

Also, in addition to including municipality and year fixed effects, we control for municipality level characteristics that change over time, X_{ct}, like the number of PROCAMPO beneficiaries, number of PROCAMPO beneficiaries that produce on private land, number of PROCAMPO beneficiaries that are small (i.e. less than 20 hectares), and PROCAMPO per beneficiary subsidy in each municipality. Finally, we include the error term u_{ct}, and to correct for serial correlation, we cluster the standard errors at the state level and we use robust standard errors.

Finally, we follow a similar exercise but using as left hand side variable the number of maize hectares sowed in order to test whether WII presence and coverage lead towards diversification (destination of less hectares for maize production) or specialization (the opposite).

Household level analysis using ENIGH data. In this section we describe the empirical model used to estimate the relationship between WII's presence in the municipality and household level variables such as per capita real income and expenditure. To achieve the latter, we combined WII's administrative data, PROCAMPO beneficiary data aggregated at the municipality level and municipality level weather information. Although ENIGH is a household survey conformed by a series of repeated cross sections, we take advantage of detailed household level information to identify correlations between WII presence at the municipality level and rural households characteristics. The identifying assumption is that conditional on rainfall deviation and maize yields at the municipality level, government transfers --such as PROCAMPO and Oportunidades programs-- and household level characteristics, the difference in the variables of interests (i.e. poor rural household real per capita income and expenditure) should be negligible had WII not been introduced in the municipality. In addition to controlling for rainfall, PROCAMPO and household characteristics, in our most complete estimation we include year and municipality fixed effects. The main equation we estimate is the following:

$$(3) \qquad \ln(\mathrm{Y}_{ict}) = \alpha_c + \beta RainDev_{ct} + \gamma Insurance_{ct} + \sum_{t=1}^{T} \delta_t \, Year_t + $$
$$+ \eta ln(Y_{ct}) + \mu X_{ct} + \tau H_{ict} + \varepsilon_{ict}$$

where $\ln(Y_{ict})$ is the log of either real per capita household income or expenditure for household *i* in municipality c in year t. α_c and $\sum_{t=1}^{T} \delta_t \, Year_t$ are municipality and year fixed effects, respectively. $RainDev_{ct}$ is rain deviation (as defined above) in municipality *c* at year *t*. $Insurance_{ct}$ is either a dummy variable that takes the value of one if WII is present in municipality *c* at year *t*, zero otherwise, or it is the proportion of land destined for agricultural production covered by WII in municipality *c* in year *t*. We also include the natural logarithm of municipality level maize yield, $\ln(Y_{ct})$, as defined in equation (2). Similarly, X_{ct} are municipality level characteristics, such as those obtained from the PROCAMPO beneficiaries' data set. Finally, H_{ict} are household level characteristics such as household head's years of formal education, and whether the household receives Oportunidades and PROCAMPO benefits.[15]

III. Results

Table 2.a shows estimates of the relation between the log of maize yield on WII insurance presence (in the odd numbered columns) and WII coverage (in the even numbered columns), as well as municipality level PROCAMPO variables, rain deviation, maximum temperature deviation, municipality and year fixed effects from equation (2). The first two columns present estimates of the simplest specifications, and then we add more controls as we move towards the end of the table from left to right (columns (7) and (8)). Thus, the first two columns show the effect of WII (presence in column (1) and coverage in column (2)) on the log of maize yield using only municipality fixed effects. The coefficient is significant (at the 10% level) and substantial in magnitude (5.9% and 6.6% for presence and coverage variables, respectively).

Columns (3) and (4), in addition to municipality fixed effects, include rain deviation and maximum temperature as controls. The coefficients on WII presence and coverage are still significant, with similar orders of magnitude. Moreover, the coefficient on rain deviation is positive and significant, implying that

[15] This information is from ENIGH. The survey asks the household whether they are Oportunidades, PROCAMPO and or other government program's beneficiaries.

good rainfall (above average) will be positively associated with higher yield, and bad rainfall will be associated with lower yields. Similarly, the coefficient on maximum temperature deviation is also significant, negative and important in magnitude. This would imply that maximum temperatures above average will have a negative effect on yields. This finding is in line with Schlenker and Roberts' (2006), not only in the fact that higher temperatures are negatively related to maize yields, but also on the relative importance of temperature on yields.

Columns (5) and (6) include year dummies, excluding 2008. Finally, columns (7) and (8) present the most complete estimation, including municipality fixed effects, year dummies, rainfall and maximum temperature deviation and PROCAMPO variables at the municipality level. According to these estimates, WI's presence has a positive and statistically significant relation with maize yield productivity once we control for municipality fixed effects, year dummies, precipitation, temperature and the set of controls. Similarly, the coverage variable is also significant (though at the 10% level) and of similar magnitude as before. It is worth noting that having a large number of PROCAMPO beneficiaries that produce in private land is strongly and significantly associated with higher maize yields. This could be related to the literature of property rights and agricultural productivity. For example, Besley (1995 bis) finds a link between property rights and investment incentives in Ghana. Similarly, Jacoby and Mansuri (2008) use detailed plot level data from rural Pakistan to show that non-contractible investment is underprovided on tenanted land.

Table 2.b show results of the relation between the log of maize cultivated hectares and WII presence and coverage in the municipality following similar specifications as that of table 2.a. The hypothesis behind these models is to see whether WII presence at the municipality level has an effect on farmers' decision towards diversification (in which case we would expect a negative coefficient) or towards specialization (positive coefficient). Although we cannot rule out that there might have been a combination of both effects, we argue that there is not a clear pattern (the coefficients of both WII presence and coverage go from negative and significant to positive, small in magnitude and statistically insignificantly different from zero

as we include the full set of covariates). However, it is worth noting that as the proportion of PROCAMPO small maize producing beneficiaries increase, the log of maize cultivated hectares decrease. Similarly, the coefficient on land destined for maize production covered by PROCAMPO is negative significantly different from zero.

Tables 3.a and 3.b show household-level cross-sectional relationships between WII presence and coverage at the municipality level and the log of real per capita household expenditure and income, respectively. The odd numbered columns show the relationship between the variable of interest and the insurance presence at the municipality as well as the full set of covariates, and the even numbered columns show the relation between the variable of interest and the insurance coverage as a proportion of land sowed in each municipality. Both tables show that the relationship between the insurance presence/coverage and both the log of real per capita expenditure and income is positive, statistically and significantly different from zero and robust to the inclusion of the full set of municipality and household level covariates. Moreover, the coefficients of the insurance presence on household expenditure and income are similar in magnitude. In these estimations, we are only considering the rural (villages of less than 10,000 people) subset of the survey. Insurance presence at the municipality is associated with a 7.83% higher real per capita household expenditure and 7.46% higher real per capita household income. Similarly, insurance coverage at the municipality level is associated with an 8.48% higher real per capita household expenditure and a 7.69% higher real per capita household income.

Cost-Benefit Analysis

Pure Premium vs. Actual Premium

Like in any competitive market, the price of agricultural insurance–or premium–depends on the demand and supply of insurance. However, market and regulatory imperfections affect the cost and the price of agricultural insurance.[16] Moreover, the price of the insurance is driven by three components: expected loss, expense load and catastrophe load (Mahul and Stutely 2010). The expected loss (also called pure premium) refers to actuarially calculated frequency and severity of the loss. The expense load is the part of the actual premium intended to compensate for administrative and operating costs. Finally, the catastrophe load, which is defined as "the amount charged to compensate the insurer for bearing risk since in any given year the actual loss can be much larger than the average loss" (Mahul and Stutley 2010 pp. 43), tends to be high in agricultural insurance since actual losses can be many times the expected loss. To get a sense of the relative magnitude of the premium paid for the Mexican Weather Indexed Insurance, we used administrative data (in particular the trigger thresholds, premiums paid and value of insured production) as well as weather information (cumulative rainfall reported by weather stations used by Agroasemex). We calculate annual expected loss to get an idea of the difference between the so called "pure premium" and the "actual premium" paid to Agroasemex in 2008. Using the 2008 weather stations' thresholds and daily rainfall data from 1990 to 2008, we calculated cumulative rainfall for each period-year and constructed the following "drought" variable D_{it}:

$$D_{it} = \begin{cases} 1 \ if \ C_{it} < T_{it} \\ 0 \ if \ C_{it} \geq T_{it} \end{cases}$$

where C_{it} is cumulative rainfall in weather station *i* and year *t*, and T_{it} is trigger threshold set for weather station *i* and year *t*, below which indemnity payment is triggered.[17] After obtaining the values of the "drought" variable, we calculated the pure premium *PP*:

$$PP = \frac{\sum_{n=1}^{N} D_{it}}{N}$$

[16] Mahul and Stutely (2010) list a series of market imperfections that justify public intervention in the provision of agricultural insurance, among which we recall systemic risk, information asymmetries, post-disaster assistance programs, limited access to international reinsurance markets, lack of infrastructure, low risk awareness.

[17] Given that the trigger thresholds and the time periods did not change between 2003 and 2008, we used the same thresholds and periods for the prior years (from 1990 to 2002) in order to calculate the variable D_{it}.

In this case, $\sum_{n=1}^{N} D_{it}$ is the sum of actual drought cases (in each station-year) over the total number of cases, N. The calculated pure premium *(PP)* for the case of maize is 3.94%.

The "actual" premium *(AP)* for 2008 can be directly obtained from the 2008 administrative data. From table 1.b we see that in 2008 the government paid US$18.33 million (MXP 192.45 million) for insuring maize. Also, the same table shows that the value of the maize insured production was US$114.06 million (MXP 1.2 billion). Thus, we could argue that the actual premium (AP) paid by the government for insuring maize production through Agroasemex's WII was about 16.07%.

Therefore, we can argue that by charging a little over 16% for premium, Agroasemex covers the expected loss (about 4%) and has enough to cover the expense and catastrophe loads (roughly 12%). As mentioned above, WII is relatively expensive to get started, but once running the cost of operation are low compared to other types of agricultural insurances as their operation is based on publicly available weather information and insures zones of similar agro-climatic conditions instead of individual farmers. Thus, we think that the expense load should not take a large chunk of the remaining 12%. On the other hand, we also believe that catastrophe load should not absorb such a large proportion of the actual premium since Agroasemex reinsures risk in international markets in which individual countries' risk (even those of the size of Mexico) are handled as idiosyncratic.

Context and magnitude of the effects

In the Results section we found that WII presence at the municipality level leads to a 6% increase in maize yield. In this subsection we analyze the magnitude of such effect in terms of the relative amount of resources invested in the program (i.e. actual premiums paid) by the government and benefits or second order effects (productivity and income/expenditure).

According to Table 1.c, approximately 99% of PROCAMPO's rain-fed maize producers have less than 20 hectares, and their share of total land destined for maize production is equivalent to 88% of the total. Thus, since the average effect found was a 6% increase in maize yields, it could be argued that the average treatment effect on the treated ranges between 6% and 7.4%.

Similarly, considering that --on average-- PROCAMPO maize producer beneficiaries produce on 3 hectares, and that under rain-fed agriculture maize production yields are around 3 tons per hectare, then the 6% increase in yields found due to WII's presence translates into an increase in production of half a ton per farmer per year. In addition, according to the Ministry of Agriculture, the average price per ton of maize in Mexico in 2008 was about US$230 (2,400 MXP), and given that under rain-fed agriculture the average annual production is 3 tons per hectare, we could argue that a 6% increase leads to an average increase of US$41.4 per hectare. This may not sound appear to be a substantial increase in production, but if we compare this number to the premium amount that the government paid per hectare in 2008--US$11.9 per hectare (125 MXP)--the relative cost-benefit ratio is closer to 350%.[18]

Regarding rural household level effects, we found that WII presence is associated with a 7.5% increase in adult equivalent per capita expenditure. According to ENIGH, average per capita monthly expenditure in 2002 was about US$107.6 (MXP 1,130), which implies an annual per capita expenditure of US$1,291.5. Consequently, a 7.5% increase in annual per capita expenditure adds to US$96.86, which compared to the US$11.9 paid for as premium, implies that WII is associated to an even larger effect on per capita expenditure than on maize yields. This may be explained through possible WII multiplying effects: for example, Barnett, Barrett and Skees (2008) underline the link between WII and credit markets, and Boucher, Carter and Guirkinger (2008) propose that WII alleviates what they call “risk constraints”, thus unleashing the possibility of further credit uptake. Though we present weak evidence of the link between

[18] Nevertheless, maize yield under irrigated farm land is closer to 10 tons per hectare. Thus, even acknowledging that irrigated and non-irrigated agricultural land are not directly comparable, the striking difference in yields may induce reconsidering the overall evaluation of irrigation projects. Moreover, agricultural insurance programs such as WII may disincentive investments on irrigation projects (Fuchs and Wolff, forthcoming). It is important to consider second order effects when evaluating the effectiveness of any program to avoid getting biased results.

WII presence and higher per capita income and expenditure in rural settings, further research is needed to understand the mechanisms under which this relation is channeled.

IV. Robustness

Test of WII's rollout exogeneity. Let y_{ct} be an outcome of interest, such as maize yield, for municipality c in year t. To test that WII's rollout was not correlated with pre-intervention characteristics, we first calculated municipality level changes in outcomes from previous year, Δy_{ct}, for all counties (that would eventually get the insurance by 2008, i.e. we exclude from the sample counties that are never treated by WII). In other words, we calculated maize yield growth for each year relative to the last one. Then, we use municipality/year changes in outcomes for all years prior to PACC's entry, Δy_{ct}, and regress on a set of year dummies δ_t and a variable T_c which gives the numerical year in which the insurance was introduced in municipality c:

$$\Delta y_{ct} = \delta_t + \beta T_c + u_{ct} \tag{4}$$

This tests whether outcomes were changing at different rates in counties that received insurance earlier relative to those that received it later, which is the identifying assumption of an impact regression using municipality fixed effect. The results of this regression for both maize and beans yields can be seen in panel A of table 4.

Then, we analyze municipality productivity more closely over periods of time before and after being insured. This can be seen in Figure 2.a. for maize productivity and 2.b. for the case of beans. In these figures we show municipality level performance before and after WII's entry.

There is no particular pattern in the years prior to entry, which would concern with a potential endogenous sequence in the rollout, either in response to lower productivity problems (i.e. Ashenfelter dip), or following an ongoing improvement in performance. The 'Ashenfelter dip' has been discussed in previous non-experimental evaluations of public programs. For example, Rouse (1998) describes this problem in the context of a public sector training program evaluation in which individuals who participate in training programs are observed to have unusually low earnings in the period in which they are selected for the program. If potential beneficiary households that actually applied for the program were having an unusually low income in the time that they were selected, then the fixed effects estimates might be biased. In our particular case, the 'Ashenfelter dip' would bias our results if WII was introduced into counties that were particularly affected by droughts in previous years.

These results can be confirmed by regressing the average municipality outcome y_{ct} on a set of year dummies δ_t, municipality fixed effects γ_c, and variables c_{-n} that denote the year before WII's entry

$$(5) \qquad y_{ct} = \delta_t + \gamma_c + \beta_1 c_{-1,ct} + \beta_2 c_{-2,ct} + \beta_3 c_{-3,ct} + \beta_4 c_{-4,ct} + u_{ct}$$

The results of these regressions for maize and beans' yields are presented in panel B of Table 4. None of the explanatory variables turned out to be statistically significantly different from zero, which provides suggestive evidence that WI's expansion was not correlated with maize and beans' yield in previous years.

Matching Estimations. As additional robustness, we used CONAPO's 2000 marginality index. Based on the 2000 national population census, the marginality index is calculated for each municipality using the method of principal components. It uses 10 indicators[19] and takes continuous values from 3.4 (poorest municipality) to -2.5 (lowest marginality degree). Moreover, CONAPO divides counties in groups depending on their marginality index. For example, they define counties with high marginality as those whose index goes from 3.4 to 1, marginal counties as those who have indices from 1 to -0.1, and so on. Although CONAPO's marginality index for 2005 at the municipality level is available (calculated using the short census or Conteo), we use the 2000 information since it is the most recent one we can get before weather indexed insurance was introduced.

[19] Total county population, % of illiterate older than 15 years, % without primary school older than 15 years, houses without sewage, houses without electricity, houses without running water, houses with overcrowding, houses with dirt floor, % of rural population and % of people earning less than 2 minimum wages per month.

We use municipality fixed effects models (similar to those used in section 3) with log of maize yield as the variable of interest, but restricting to municipality-subsamples that have similar pre-intervention characteristics (matched counties) based on CONAPO's categories. Results can be seen in table 5.a. The first two columns show the same results as those of columns (7) and (8) of table 2.a. Insurance presence and coverage does not seem to have a significant effect on the very poor (or highly marginal) counties. However, the effect is positive and significant for the group of poor and medium level counties. It is worth noting that the magnitude of the effect is larger for poor counties than for medium ones.

Fruits and other vegetables' yields. As additional robustness, we repeated the exercise of quantifying WII effect on yields (from section IV), but using as the left hand side variable fruit and other vegetables yields (produced under rain-fed agriculture). The results can be seen in tables 5.b and 5.c for fruits and vegetables, respectively. In line with our hypotheses, we find no significant effect of WII presence (and/or coverage) on fruits and other vegetables' yields.

V. Concluding Remarks

In the last few years, weather index insurance has gained increasing attention as a useful tool to manage and cope with aggregate risk. Much has been said about its advantages over other traditional agricultural insurance contracts regarding low costs and reduction of information problems. Some have argued that it could be used as an effective tool to overcome "poverty traps" by allowing low income farmers to produce higher profit yet riskier crops or increase investment in fertilizer and higher yielding crops. Conversely, others have argued that WII may induce specialization or monoculture and even divert investment in R&D of drought resistant seeds or other agricultural technology such as irrigation. Nonetheless, there is still little empirical evidence of its effects on risk taking behavior and farmers' decision making.

Using a unique data set that we collected and combined with information on Mexican agricultural production at the municipality level between 2002 and 2008, rainfall information and administrative data, and taking advantage of the Mexican WII introduction and staggered expansion over time, we identified the insurance's effect on yields and household level variables such as per capita income and expenditure. The paper provides evidence that WII's presence and coverage in treated counties was significant and positively associated with maize productivity. In particular, our results indicate that WII presence (and coverage) at the municipality level increased maize yields by approximately 6%. This may appear to be a small increase, but if we consider that on average the annual per hectare premium paid was a little over US$10, and a 6% increase in yields translates into US$36, then the back of the envelope benefit analysis provides evidence that the budget invested in the program is well spent. Similarly, using household level information from the National Household Income and Expenditure Survey (ENIGH) for the rounds of 2002 to 2008, we found that WII presence and coverage at the municipality level is positively and significantly associated with real per capita household expenditure and income. Moreover, the effects found were around the magnitude of 6% to 7%, indicating a per capita annual expenditure increase of US$65 underlying the possibility of a multiplying effect. Finally, we found that rainfall indexed insurance presence and coverage in Mexican counties was not significantly related with the number of hectares destined to sow maize. Thus, although we cannot argue that there has been a clear pattern towards specialization or diversification, we cannot rule out offsetting effects.

Although our results concentrate on a particular case –i.e. the Mexican WII– we hope that this study contributes to understanding the implications of this type of risk management instrument by studying one of the largest weather index insurance programs yet implemented. There are many questions left unanswered, but we hope that this paper leaves the door open for answering them in future research.

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Table 1.a. Agricultural Production in Mexico by Source and Product (2008)[1/]

	Irrigation			Rain-fed			Total		
	(a) Maize	**(b) Total**	**(a)/(b) %**	**(c) Maize**	**(d) Total**	**(c)/(d) %**	**(e) Maize**	**(f) Total**	**(e)/(f) %**
Sowed (Hectares)	1,590,111.2	5,612,662.3	28.33%	6,853,725.7	16,289,910.4	42.07%	8,443,836.9	21,902,572.7	38.55%
Harvest (Hectares)	1,541,559.9	5,413,056.9	28.48%	6,288,549.7	15,089,776.8	41.67%	7,830,109.6	20,502,833.7	38.19%
Production (Tons)	15,835,037.6	355,037,345.1	4.46%	20,022,737.6	118,791,025.7	16.86%	35,857,775.2	473,828,370.9	7.57%
Yield (Tons/Hectare)	10.3			3.2					
max (90%)	32.0			6.7					
min (10%)	2.2			0.7					
Counties (n)	1,523			2,303					

1/ Own elaboration using data from Sistema de Informacion Agroalimentaria y Pesquera (SIAP)

Table 1.b. PACC's Coverage by Crop, Year, Municipio, Extension, Production Value, Premium and Indemnity Payments

	Counties	Extension	Value	Premium	Indemnity
1.1 Maize Insurance					
2003	5	69,010	24,912,610	2,389,119	0
2004	39	189,742	142,306,500	17,803,054	0
2005	162	756,806	431,086,720	59,951,795	75,726,560
2006	552	1,069,670	625,505,760	68,524,501	11,596,080
2007	507	1,117,200	658,377,600	77,109,615	38,441,200
2008	633	1,532,239	1,197,676,908	192,455,049	73,061,820
1.2 Barley, Beans and Sorghum Insurance					
2003	5	38,611	13,938,571	1,336,709	0
2004	19	58,741	44,055,750	5,093,475	0
2005	126	409,515	234,898,560	41,368,288	29,357,360
2006	194	348,430	249,844,080	34,509,445	9,932,960
2007	181	401,538	249,367,200	38,361,415	1,985,200
2008	195	356,685	260,500,644	47,118,240	4,015,080
1.3 Total Insurance					
2003	5	107,621	38,851,181	3,725,828	0
2004	41	248,483	186,362,250	22,896,529	0
2005	213	1,166,321	665,985,280	101,320,083	105,083,920
2006	573	1,418,100	875,349,840	103,033,946	21,529,040
2007	527	1,518,738	907,744,800	115,471,030	40,426,400
2008	656	1,888,924	1,458,177,552	239,573,288	77,076,900

Data source: SAGARPA, own elaboration

Table 1.c. PROCAMPO Beneficiaries that produce Maize under Rain-Fed Agriculture (2002-2008)

		Beneficiaries			Hectares used for production		
		Total	Large (>20 hs)	Private	Total	Large (>20 hs)	Private
2002	Total	1,687,743	17,604	36,977	5,630,904	653,717	182,761
	Mean	714	7.44	15.64	2,381	276.41	77.28
	Standard Dev.	1,114	28.94	69.08	4,134	1,093.94	358.54
	Min (10%)	34	0	0	66	0	0
	Max (90%)	1,782	17	17	6,244	571	88
2003	Total	1,672,421	17,163	37,049	5,525,560	626,282	187,132
	Mean	705	7.24	15.62	2,329	264.03	78.89
	Standard Dev.	1,106	29.00	68.37	4,060	1,070.44	367.19
	Min (10%)	33	0	0	67	0	0
	Max (90%)	1,753	16	21	6,121	538	96
2004	Total	1,602,172	17,520	35,446	5,302,351	649,102	186,008
	Mean	675	7.38	14.92	2,233	273.31	78.32
	Standard Dev.	1,066	31.40	65.65	3,902	1,183.48	364.78
	Min (10%)	32	0	0	60	0	0
	Max (90%)	1,644	15	18	5,805	521	94
2005	Total	1,424,022	14,942	33,142	4,608,866	549,668	165,984
	Mean	599	6.28	13.94	1,938	231.15	69.80
	Standard Dev.	956	24.31	62.80	3,239	941.80	318.05
	Min (10%)	27	0	0	56	0	0
	Max (90%)	1,480	14	18	5,104	460	90
2006	Total	1,400,508	13,659	32,763	4,434,112	492,459	161,292
	Mean	589	5.75	13.79	1,866	207.26	67.88
	Standard Dev.	946	21.17	62.49	3,068	811.19	310.18
	Min (10%)	26	0	0	56	0	0
	Max (90%)	1,429	12	18	4,950	422	88
2007	Total	1,394,590	14,554	31,991	4,485,397	531,032	161,821
	Mean	587	6.12	13.46	1,887	223.40	68.08
	Standard Dev.	942	24.31	60.75	3,147	967.67	313.22
	Min (10%)	25	0	0	54	0	0
	Max (90%)	1,450	13	18	5,059	431	89
2008	Total	1,664,619	17,399	36,325	5,474,625	621,664	187,240
	Mean	699	7.31	15.26	2,300	261.20	78.67
	Standard Dev.	1,120	29.22	67.14	4,044	1,081.29	363.22
	Min (10%)	27	0	0	59	0	0
	Max (90%)	1,734	16	21	5,886	531	97

Source: Own elaboration using data from the PROCAMPO beneficiaries' data set.

Table 1.d. Pre-Weather Insurance Municipality Characteristics (2000)

Variable	Treated	Not Treated	Difference	Standard Error
Mean Population	47,743.07	28,827.12	-18,915.9***	(4,401.72)
Mean % Illiteracy	15.30	18.18	2.89***	(0.47)
Mean % No Primary	37.03	41.79	4.76***	(0.59)
Mean % No Sewage	9.14	11.47	2.32***	(0.26)
Mean % No Electricity	3.97	6.51	2.54***	(0.35)
Mean % No Running Water	16.96	18.79	1.83***	(0.87)
Mean % Dirt Floor	21.23	28.08	6.85***	(0.96)
Mean % Rural	65.08	79.48	14.40***	(1.43)
Mean % Indigenous	11.95	21.45	9.50***	(1.20)
Mean % Men Labor Force	74.43	75.16	0.73***	(0.33)
Mean % Female Labor Force	25.57	24.84	-0.73***	(0.33)

	Treated	Not Treated	Total
Number of Counties	810	1,546	2,356

Table 1.e. Pre-Weather Insurance Household Level Characteristics (ENIGH 2002)

Variable	Treated	Not Treated	Difference	Standard Error
Log of Per Cap Income	7.03	7.02	0.017	(0.06)
Log of Per Cap Expenditure	7.01	6.92	0.086	(0.06)
Head's Years of Formal Education	7.68	7.01	0.668	(0.62)
Number of elderly	3.18	3.08	0.103	(0.08)
Real Oportunidades Support	20.10	24.25	-4.147**	(2.09)
Real PROCAMPO Support	22.86	27.59	-4.729	(5.09)

	Treated	Not Treated	Total
Number of households	1,379	4,689	6,068

Table 2.a. PACC's Insurance Effect on Log of Maize Yield at the Municipality Level

VARIABLES	(1) Log Maize Yield	(2) Log Maize Yield	(3) Log Maize Yield	(4) Log Maize Yield	(5) Log Maize Yield	(6) Log Maize Yield	(7) Log Maize Yield	(8) Log Maize Yield
PACC Presence (dummy)	0.0588*		0.0564*		0.0505*		0.0504*	
	(0.030)		(0.029)		(0.029)		(0.029)	
PACC Coverage (% of land sowed)		0.0656*		0.0624*		0.0649*		0.0672*
		(0.037)		(0.036)		(0.034)		(0.034)
Rain Deviation			0.0878***	0.0878***	0.0717***	0.0716***	0.0683***	0.0681***
			(0.026)	(0.026)	(0.021)	(0.021)	(0.021)	(0.021)
Temperature Deviation			-0.491**	-0.495**	-0.404**	-0.405**	-0.401**	-0.401**
			(0.187)	(0.186)	(0.184)	(0.182)	(0.186)	(0.184)
% of PROCAMPO in Private land							1.588**	1.593**
							(0.598)	(0.600)
% of Maize Producers in <20 hectares							0.17	0.166
							(0.616)	(0.615)
% of Land covered by PROCAMPO (maize production)							-0.0895	-0.0935
							(0.058)	(0.058)
Constant	0.382***	0.384***	0.383***	0.386***	0.410***	0.412***	0.233	0.241
	(0.004)	(0.003)	(0.004)	(0.003)	(0.022)	(0.022)	(0.612)	(0.611)
Observations	14,791	14,791	14,791	14,791	14,791	14,791	14,791	14,791
R-squared	0.002	0.001	0.008	0.008	0.026	0.026	0.029	0.029
Number of Counties	2,316	2,316	2,316	2,316	2,316	2,316	2,316	2,316
Municipality Fixed Effects	YES	YES	YES	YES	YES	YES	YES	YES
Year Fixed Effects	NO	NO	NO	NO	YES	YES	YES	YES

Robust standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1. The unit of observation is the municipality or 'municipio'. The left hand side variable is "log of maize yield" defined as total production (in tons) over number per municipality harvested hectares. The first right hand side variable for the odd number regressions is PACC Presence at the municipality (a dummy variable), and for the even numbered regressions is the proportion of land devoted for maize production covered by PACC in each municipality. The 'Rain Deviation' variable is rainfall deviation defined as the difference of the log of average rainfall (in millimeters) from 1990 to 2008 minus the log of average rainfall for each year. The third to fifth right hand side variables come from the PROCAMPO beneficiaries data set whereby the first one is the proportion of PROCAMPO beneficiaries that produce maize in private land, the second one is the proportion of beneficiaries that have land smaller than 20 hectares and the third one is the proportion of total land dedicated for maize production covered by PROCAMPO program. Moreover, in addition to controlling for municipality fixed effects, we include year fixed effects in the last two specifications. Finally, we cluster at the State level.

Table 2.b. PACC's Insurance Effect on Log of Maize Cultivated Hectares at the Municipality Level

VARIABLES	(1) Log Maize Cultivated Hectares	(2) Log Maize Cultivated Hectares	(3) Log Maize Cultivated Hectares	(4) Log Maize Cultivated Hectares	(5) Log Maize Cultivated Hectares	(6) Log Maize Cultivated Hectares	(7) Log Maize Cultivated Hectares	(8) Log Maize Cultivated Hectares
PACC Presence (dummy)	-0.0442**		-0.0443**		-0.0249		-0.0229	
	(0.021)		(0.021)		(0.026)		(0.018)	
PACC Coverage (% of land sowed)		-0.124***		-0.124***		-0.102**		-0.0680**
		(0.032)		(0.032)		(0.040)		(0.027)
Rain Deviation			0.000477	0.00113	-0.00413	-0.00298	-0.00218	-0.00153
			(0.018)	(0.017)	(0.016)	(0.016)	(0.013)	(0.013)
Temperature Deviation			-0.035	-0.043	0.010	0.000	0.038	0.032
			(0.139)	(0.136)	(0.138)	(0.138)	(0.112)	(0.112)
% of PROCAMPO in Private land							-0.343	-0.341
							(0.467)	(0.473)
% of Maize Producers in <20 hectares							-4.457***	-4.468***
							(0.720)	(0.723)
% of Land covered by PROCAMPO (maize production)							-1.300***	-1.295***
							(0.122)	(0.123)
Constant	7.202***	7.206***	7.202***	7.206***	7.218***	7.223***	12.53***	12.54***
	(0.003)	(0.003)	(0.003)	(0.003)	(0.011)	(0.012)	(0.705)	(0.708)
Observations	14,791	14,791	14,791	14,791	14,791	14,791	14,791	14,791
R-squared	0.002	0.007	0.002	0.007	0.009	0.013	0.288	0.290
Number of Counties	2,316	2,316	2,316	2,316	2,316	2,316	2,316	2,316
Municipality Fixed Effects	YES	YES	YES	YES	YES	YES	YES	YES
Year Fixed Effects	NO	NO	NO	NO	YES	YES	YES	YES

Robust standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1. The unit of observation is the municipality or 'municipio'. The left hand side variable is "log of maize cultivated hectares" defined as the log of hectares of maize sowed in each municipality each year. The first right hand side variable for the odd number regressions is PACC Presence at the municipality (a dummy variable), and for the even numbered regressions is the proportion of land devoted for maize production covered by PACC in each municipality. The 'Rain Deviation' variable is rainfall deviation defined as the difference of the log of average rainfall (in millimeters) from 1990 to 2008 minus the log of average rainfall for each year. The third to fifth right hand side variables come from the PROCAMPO beneficiaries data set whereby the first one is the proportion of PROCAMPO beneficiaries that produce maize in private land, the second one is the proportion of beneficiaries that have land smaller than 20 hectares and the third one is the proportion of total land dedicated for maize production covered by PROCAMPO program. Moreover, in addition to controlling for municipality fixed effects, we include year fixed effects in the last two specifications. Finally, we cluster at the State level.

Table 3.a. Relation between PACC's Presence and Real Per Capita Household Expenditure from ENIGH 2002-2008

VARIABLES	(1) Log Per Cap Expenditure	(2) Log Per Cap Expenditure	(3) Log Per Cap Expenditure	(4) Log Per Cap Expenditure	(5) Log Per Cap Expenditure	(6) Log Per Cap Expenditure	(7) Log Per Cap Expenditure	(8) Log Per Cap Expenditure
PACC Presence (dummy)	0.00635		0.0757**		0.101**		0.0783**	
	(0.035)		(0.032)		(0.043)		(0.033)	
PACC Coverage (% of land sowed)		0.0020		0.0849**		0.0913**		0.0848*
		(0.049)		(0.040)		(0.046)		(0.043)
Log of Maize Yield	0.0870***	0.0875***	0.0389*	0.0409**	(0.042)	(0.038)	-0.0852**	-0.0859**
	(0.030)	(0.029)	(0.020)	(0.020)	(0.039)	(0.041)	(0.038)	(0.038)
% of PROCAMPO beneficiaries in Private land			0.010	0.023	0.735	0.932	1.023	1.180
			(0.375)	(0.371)	(2.603)	(2.730)	(2.682)	(2.746)
% of Maiz Producers who own < 20 hectares			-1.523***	-1.507***	-1.933***	-1.950***	-1.416**	-1.480**
			(0.570)	(0.566)	(0.664)	(0.646)	(0.681)	(0.682)
% of maize land covered by PROCAMPO			-0.047	-0.054	-0.011	-0.018	-0.093	-0.106
			(0.090)	(0.090)	(0.094)	(0.098)	(0.093)	(0.093)
Rain deviation from 1990-2008 mean			0.080	0.083	0.149***	0.155***	0.113**	0.116**
			(0.066)	(0.066)	(0.054)	(0.053)	(0.050)	(0.050)
PROCAMPO Real per Capita Transfers			0.000352***	0.000351***	0.000455***	0.000454***	0.000453***	0.000453***
			(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
OPORTUNIDADES Real per Capita Transfers			-0.00199***	-0.00197***	-0.00074***	-0.00071***	-0.00078***	-0.00077***
			(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Years of formal education			0.0642***	0.0641***	0.0578***	0.0577***	0.0579***	0.0579***
			(0.004)	(0.004)	(0.003)	(0.003)	(0.003)	(0.003)
Constant	6.980***	6.981***	8.295***	8.288***	8.660***	8.617***	8.246***	8.276***
	(0.051)	(0.050)	(0.546)	(0.544)	(0.989)	(0.994)	(0.995)	(1.005)
Municipality Fixed Effects	NO	NO	NO	NO	YES	YES	YES	YES
Year Fixed Effects	NO	NO	NO	NO	NO	NO	YES	YES
Observations	34,440	34,440	34,440	34,440	34,440	34,440	34,440	34,440
R-squared	0.01	0.01	0.156	0.156	0.344	0.343	0.347	0.347

Robust standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1

Note: We use household level information from the National Household Income and Expenditure Survey (ENIGH) for 2002, 2004, 2005, 2006 and 2008. However, we only take into account households that live in rural settings. We use OLS to estimate the relationships. We include municipality fixed effects and year fixed effects, as well as a set of controls. The left hand side variable is the log of per adult equivalent real household expenditure. The first right hand side variable for the odd regressions (PACC Presence) is a dummy variable that takes the value of 1 if PACC has presence on the municipality where the household is located, and zero otherwise. The first hand side variable for the even regressions (PACC coverage) is the proportion of land destined for maize production covered by the PACC program. The second variable is the natural logarithm of maize yield in the municipality (same as defined above). The third one is a variable that takes the value between zero and 1 and is the proportion of PROCAMPO beneficiaries that produce in private land (as opposed to communal land or 'Ejidos'). The fourth one is the proportion of PROCAMPO beneficiaries that produce maize and have less than 20 hectares (proportion of small-scale producers), and the fifth is a variable that describes the proportion of land dedicated for maize production in each municipality covered by PROCAMPO. The sixth variable is yearly rain deviation (in millimeters) from mean rainfall between 1990 and 2008. The seventh and eighth are PROCAMPO and OPORTUNIDADES real per capita transfers received by each beneficiary household and finally, years of formal education is the number of years that the head of household reported having received of formal education. Finally, we cluster at the State-Rural level.

Table 3.b. Relation between PACC's Coverage and Real Per Capita Household Income from ENIGH 2002-2008

VARIABLES	(1) Log Per Capita Income	(2) Log Per Capita Income	(3) Log Per Capita Income	(4) Log Per Capita Income	(5) Log Per Capita Income	(6) Log Per Capita Income	(7) Log Per Capita Income	(8) Log Per Capita Income
PACC Presence (dummy)	0.0375		0.118***		0.145***		0.0746**	
	(0.037)		(0.033)		(0.046)		(0.036)	
PACC Coverage (% of land sowed)		0.0333		0.128***		0.141***		0.0769*
		(0.050)		(0.042)		(0.045)		(0.043)
Log of Maize Yield	0.0903***	0.0918***	0.034	0.0375*	(0.037)	(0.031)	-0.0720**	-0.0725**
	(0.034)	(0.033)	(0.023)	(0.022)	(0.031)	(0.033)	(0.031)	(0.031)
% of PROCAMPO beneficiaries in Private land			-0.013	0.007	-0.297	-0.031	0.434	0.592
			(0.372)	(0.367)	(1.939)	(2.093)	(2.126)	(2.184)
% of Maiz Producers who own < 20 hectares			-2.030***	-2.006***	-1.428	-1.469*	-1.657*	-1.717**
			(0.549)	(0.542)	(0.865)	(0.850)	(0.851)	(0.850)
% of maize land covered by PROCAMPO			-0.066	-0.077	-0.044	-0.055	-0.105	-0.117
			(0.096)	(0.096)	(0.092)	(0.095)	(0.089)	(0.091)
Rain deviation from 1990-2008 mean			0.064	0.068	0.132***	0.139***	0.102**	0.104**
			(0.066)	(0.066)	(0.049)	(0.049)	(0.046)	(0.046)
PROCAMPO Real Transfers			0.000617***	0.000614***	0.000737***	0.000736***	0.000740***	0.000739***
			(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
OPORTUNIDADES Real Transfers			-0.00241***	-0.00237***	-0.00100***	-0.00097***	-0.00108***	-0.00107***
			(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Years of formal education			0.0680***	0.0677***	0.0579***	0.0577***	0.0575***	0.0574***
			(0.003)	(0.003)	(0.002)	(0.002)	(0.002)	(0.002)
Constant	7.003***	7.006***	8.826***	8.815***	8.601***	8.563***	8.761***	8.784***
	(0.055)	(0.054)	(0.528)	(0.524)	(0.979)	(0.978)	(0.970)	(0.973)
Municipality Fixed Effects	NO	NO	NO	NO	YES	YES	YES	YES
Year Fixed Effects	NO	NO	NO	NO	NO	NO	YES	YES
Observations	34,440	34,440	34,440	34,440	34,440	34,440	34,440	34,440
R-squared	0.01	0.01	0.17	0.168	0.356	0.355	0.36	0.359

Robust standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1, we are cluster at the State and Rural levels

Note: We use household level information from the National Household Income and Expenditure Survey (ENIGH) for 2002, 2004, 2005, 2006 and 2008. However, we only take into account households that live in rural settings. We use OLS to estimate the relationships. We include municipality fixed effects and year fixed effects, as well as a set of controls. The left hand side variable is the log of per adult equivalent real household income. The first right hand side variable for the odd regressions (PACC Presence) is a dummy variable that takes the value of 1 if PACC has presence on the municipality where the household is located, and zero otherwise. The first hand side variable for the even regressions (PACC coverage) is the proportion of land destined for maize production covered by the PACC program. The second variable is the natural logarithm of maize yield in the municipality (same as defined above). The third one is a variable that takes the value between zero and 1 and is the proportion of PROCAMPO beneficiaries that produce in private land (as opposed to communal land or 'Ejidos'). The fourth one is the proportion of PROCAMPO beneficiaries that produce maize and have less than 20 hectares (proportion of small-scale producers), and the fifth is a variable that describes the proportion of land dedicated for maize production in each municipality covered by PROCAMPO. The sixth variable is yearly rain deviation (in millimeters) from mean rainfall between 1990 and 2008. The seventh and eighth are PROCAMPO and OPORTUNIDADES real per capita transfers received by each beneficiary household and finally, years of formal education is the number of years that the head of household reported having received of formal education. Finally, we cluster at the State-Rural level.

Table 4. Test of Exogeneity of the Weather Indexed Insurance rollout

	Municipality level annual performance	
	Maize	Beans
Panel A: Yearly average yield growth		
Year PACC was introduced	-0.032	-0.0131
	(0.027)	(0.019)
Observations	2,146	2,146
R-squared	0.084	0.029
Panel B: Yearly average yield		
Year prior to PACC	-0.033	-0.025
	(0.217)	(0.038)
2 years prior to PACC	-0.107	0.009
	(0.244)	(0.033)
3 years prior to PACC	-0.206	0.018
	(0.331)	(0.039)
4 years prior to PACC	-0.304	0.013
	(0.305)	(0.045)
5 years prior to PACC	-0.409	0.021
	(0.316)	(0.023)
Observations	2,146	2,146

Robust standard errors in parentheses

Significance *** p<0.01, ** p<0.05, * p<0.1

Panel A: Municipality/year growth weighted regression with year fixed effects, for pre-treatment period 2002 2007. "Year PACC was introduced" gives numerical year PACC was introduced in each municipality.

Panel B: Municipality/Year growth (level) regression with year fixed effects, for pre-treatment period, 2002 to PACC’s entry.

Table 5.a. Matching using CONAPO's Marginalty Index at the Municipality Level 2000: PACC's Insurance Effect on Log of Maize Yield at the Municipality Level

VARIABLES	(1) Log Maize Yield	(2) Log Maize Yield	(3) Log Maize Yield	(4) Log Maize Yield	(5) Log Maize Yield	(6) Log Maize Yield	(7) Log Maize Yield	(8) Log Maize Yield	(9) Log Maize Yield	(10) Log Maize Yield
PACC Presence (dummy)	0.0504*		0.0298		0.0453		0.0686***		0.0638**	
	(0.029)		(0.063)		(0.057)		(0.020)		(0.029)	
PACC Coverage (% of land sowed)		0.0672*		0.0746		0.0851		0.0832***		0.0481
		(0.034)		(0.062)		(0.069)		(0.025)		(0.047)
Rain Deviation	0.0683***	0.0681***	0.0820*	0.0801*	0.0257	0.0248	0.0848*	0.0851*	0.0970**	0.0967**
	(0.021)	(0.021)	(0.040)	(0.040)	(0.019)	(0.019)	(0.044)	(0.044)	(0.043)	(0.044)
Temperature Deviation	-0.401**	-0.401**	-0.460*	(0.440)	(0.304)	(0.308)	-0.479*	-0.469*	(0.359)	(0.367)
	(0.186)	(0.184)	(0.260)	(0.253)	(0.240)	(0.235)	(0.258)	(0.254)	(0.433)	(0.432)
% of PROCAMPO in Private land	1.588**	1.593**	0.987***	0.979***	-0.231	-0.255	3.587**	3.595***	2.034**	2.056**
	(0.598)	(0.600)	(0.138)	(0.129)	(0.405)	(0.397)	(1.296)	(1.296)	(0.904)	(0.882)
% of Maize Producers in <20 hectares	0.17	0.166	0.757***	0.719***	-0.325	-0.353	1.263**	1.251**	-0.117	-0.144
	(0.616)	(0.615)	(0.193)	(0.178)	(2.284)	(2.277)	(0.592)	(0.582)	(1.004)	(1.014)
% Land covered by PROCAMPO (maize)	-0.0895	-0.0935	-0.000415	-0.00355	-0.201**	-0.203**	0.0928	0.0815	-0.0857	-0.0912
	(0.058)	(0.058)	(0.045)	(0.046)	(0.079)	(0.078)	(0.111)	(0.111)	(0.089)	(0.090)
Constant	0.233	0.241	-0.641***	-0.601***	0.655	0.685	-0.937	-0.914	0.905	0.942
	(0.612)	(0.611)	(0.189)	(0.174)	(2.290)	(2.282)	(0.641)	(0.631)	(0.973)	(0.983)
Observations	14,791	14,791	2,465	2,465	5,730	5,730	3,094	3,094	3,502	3,502
R-squared	0.029	0.029	0.044	0.045	0.035	0.036	0.045	0.044	0.028	0.027
Number of Counties	2,316	2,316	384	384	897	897	477	477	558	558
Matching Group	ALL	ALL	VERY POOR	VERY POOR	POOR	POOR	MEDIUM	MEDIUM	OTHER	OTHER

Marginality Index is presented by the National Population Council (CONAPO in Spanish). It is calculated for each municipality using the 2000 national population census using the method of principal components based on 10 indicators: population, % illiterate older than 15 years, % with no primary school older than 15, no sewage in the house, no electricity in the house, no running water in the house, overcrowding, dirt floor, % rural population in the municipality and % earning less than 2 minimum wages. The result is an index that takes continuous values from 3.4 (municipality with highest marginality) to -2.5 (municipality with lowest marginality). Similarly, CONAPO divides counties in groups depending on their marginality index. For example, the first group is the very poor or counties with "high marginality" (with indices that go from 3.4 to 1), poor counties or "marginal" ones (from 1 to -0.1), medium (from -0.1 to -0.69), low level of marginality (from -0.7 to -1.27) and very low level of marginality (from -1.28 to -2.44). In this table we present fixed effect models that uses the full set of counties (in columns (1) and (2)), and subsets, like only very poor counties (columns (3) and (4)), poor counties (columns (5) and (6)) and medium counties (columns (7) and (8)). Robust standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1

Table 5.b. PACC's Insurance Effect on Log of Fruit Yield at the Municipality Level

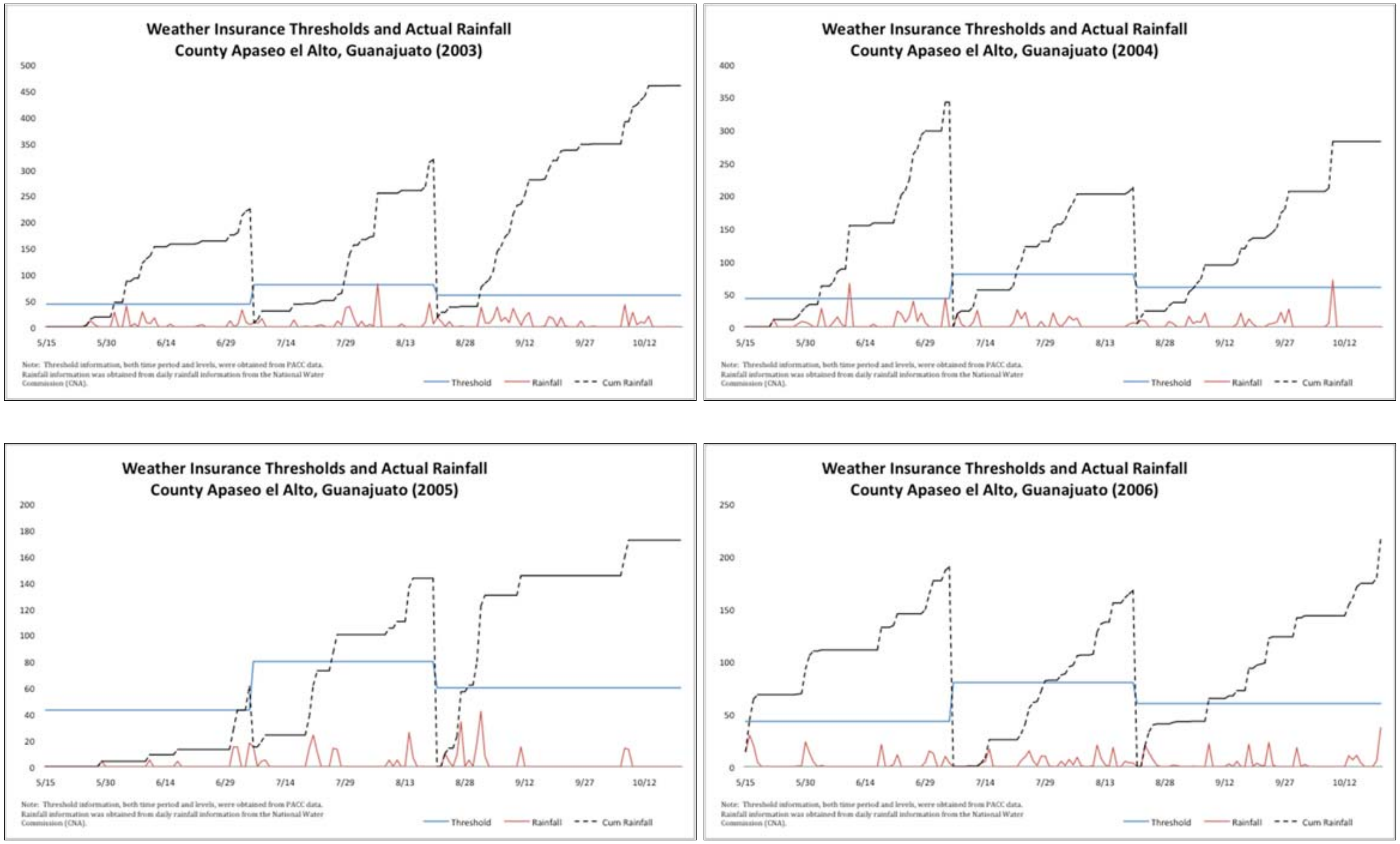
VARIABLES	(1) Log Fruits Yield	(2) Log Fruits Yield	(3) Log Fruits Yield	(4) Log Fruits Yield	(5) Log Fruits Yield	(6) Log Fruits Yield
PACC Presence (dummy)	0.0136		0.0136		0.025	
	(0.024)		(0.024)		(0.023)	
PACC Coverage (% of land sowed)		0.0258		0.0259		0.0385
		(0.027)		(0.028)		(0.026)
Rain Deviation			-0.00507	-0.00527	-0.00445	-0.00468
			(0.017)	(0.017)	(0.017)	(0.017)
Temperature Deviation			-0.027	-0.029	-0.009	-0.014
			(0.099)	(0.099)	(0.097)	(0.096)
Constant	1.787***	1.787***	1.787***	1.787***	1.782***	1.783***
	(0.003)	(0.002)	(0.003)	(0.002)	(0.013)	(0.013)
Observations	8,153	8,153	8,153	8,153	8,153	8,153
R-squared	0.000	0.000	0.000	0.000	0.002	0.002
Number of Counties	1,390	1,390	1,390	1,390	1,390	1,390
Municipality Fixed Effects	YES	YES	YES	YES	YES	YES
Year Fixed Effects	NO	NO	NO	NO	YES	YES

Table 5.c. PACC's Insurance Effect on Log of Vegetables Yield at the Municipality Level

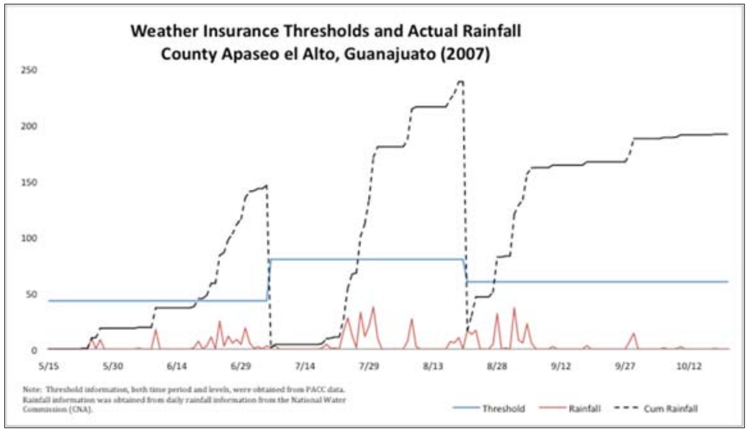
VARIABLES	(1) Log of Vegetables Yield	(2) Log of Vegetables Yield	(3) Log of Vegetables Yield	(4) Log of Vegetables Yield	(5) Log of Vegetables Yield	(6) Log of Vegetables Yield
PACC Presence (dummy)	0.101		0.0997		0.0813	
	(0.074)		(0.073)		(0.059)	
PACC Coverage (% of land sowed)		0.126		0.124		0.103
		(0.083)		(0.083)		(0.066)
Rain Deviation			-0.0134	-0.0119	-0.025	-0.0238
			(0.044)	(0.044)	(0.044)	(0.044)
Temperature Deviation			0.355	0.336	0.240	0.216
			(0.474)	(0.475)	(0.540)	(0.541)
Constant	-0.175***	-0.171***	-0.173***	-0.169***	-0.154***	-0.152***
	(0.018)	(0.014)	(0.019)	(0.015)	(0.024)	(0.025)
Observations	1,008	1,008	1,008	1,008	1,008	1,008
R-squared	0.014	0.013	0.016	0.014	0.037	0.037
Number of Counties	264	264	264	264	264	264
Municipality Fixed Effects	YES	YES	YES	YES	YES	YES
Year Fixed Effects	NO	NO	NO	NO	YES	YES

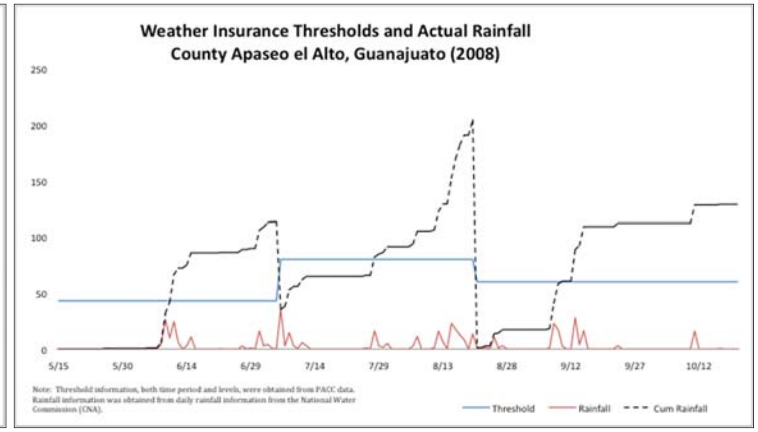
Figures

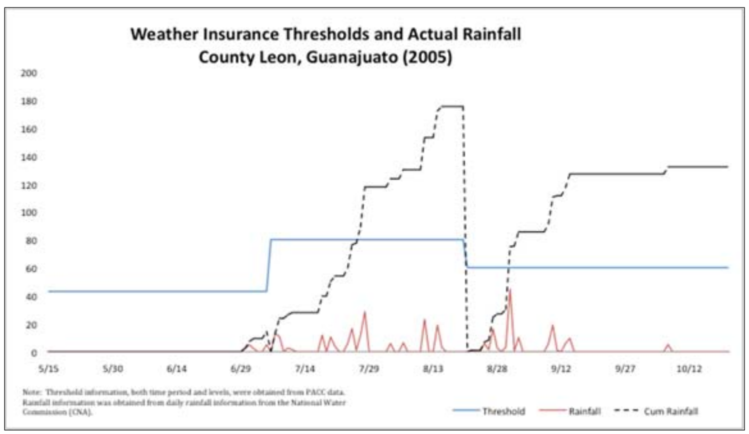
Figure 1.a., 1.b., 1.c and 1.d.



Figures 1.e., 1.f., 1.g. and 1.h.







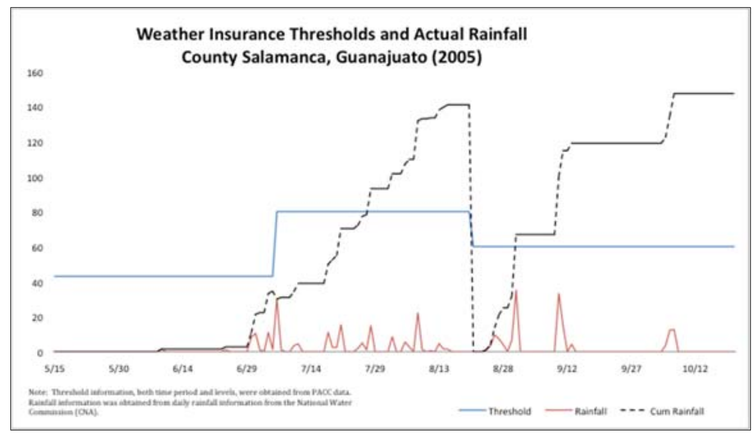


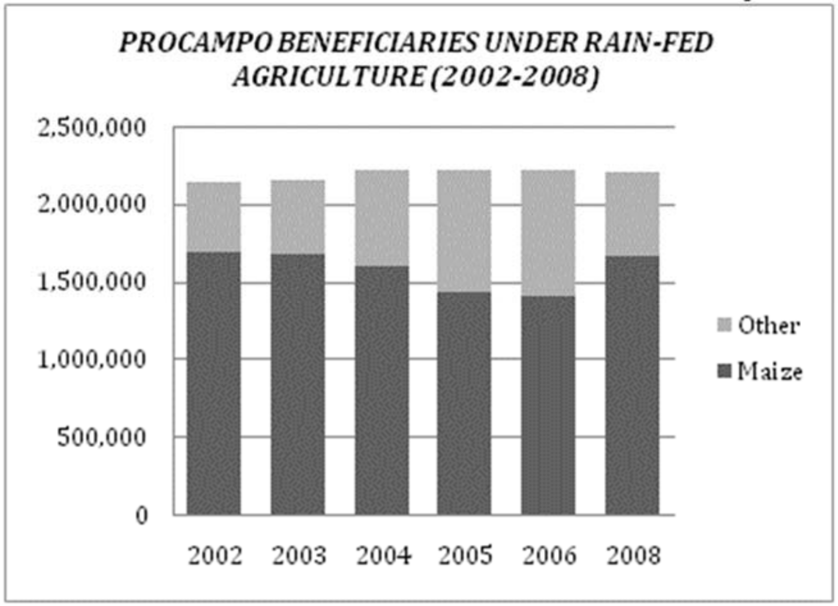
Figure 1.1

Figure 1.2

Figure 1.3

Figure 1.4

Figures 2.a and 2.b



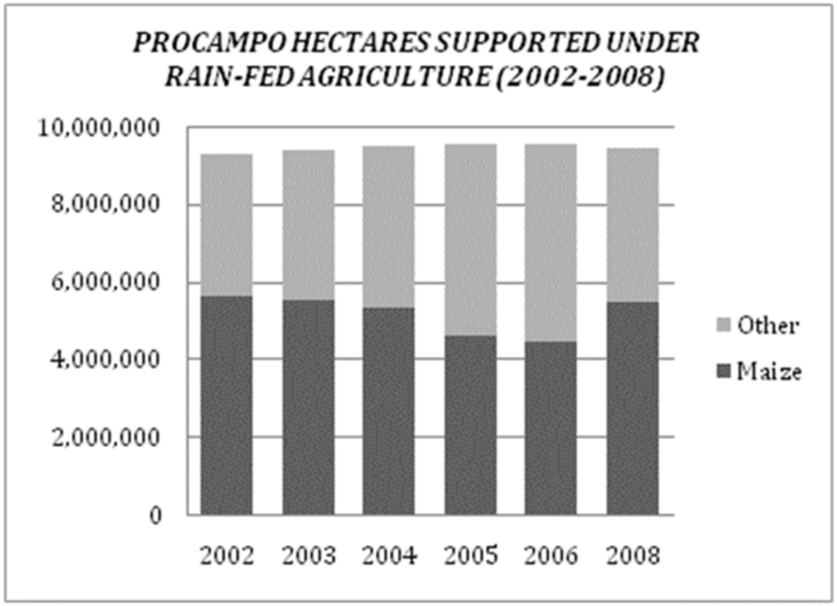


Figure 2.c

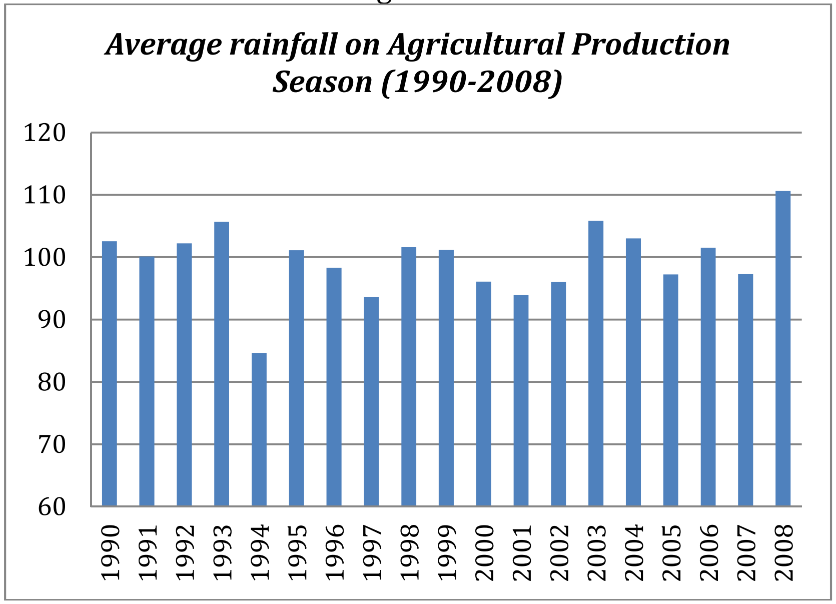


Figure 3.a. Maize Productivity Yield Growth

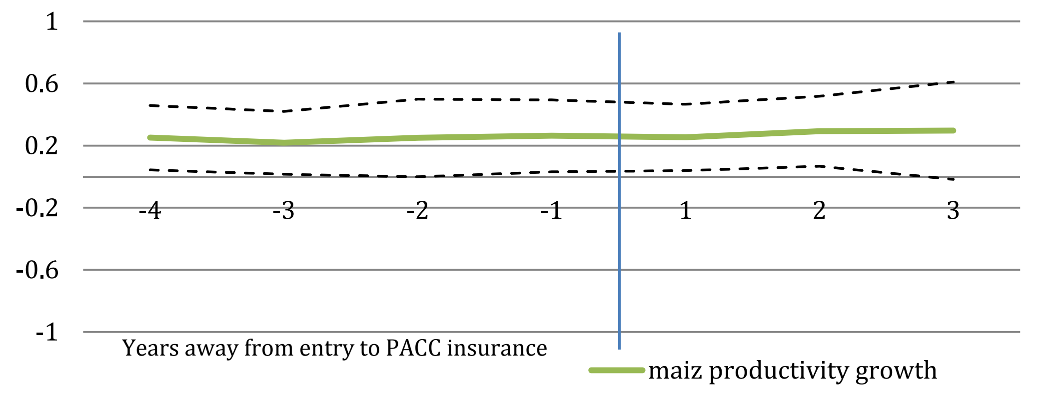


Figure 3.b. Bean Productivity Yield Growth