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Climate change, agriculture, and poverty: A household level analysis for rural Mexico

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Abstract

This note presents results of the relationship between climate change and household level poverty via changes in agricultural income. A Mexican household level data set for the year 2002 is used. Results show that national level analysis can mask significant geographic differences that should be taken into account in the design of policies that aim to decrease rural households' vulnerability to climate change. These findings are a valuable contribution to the limited literature on climate change impacts at the household level.

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1 Introduction

Poverty tends to be concentrated in rural areas, and rural households, particularly in developing countries, rely on agriculture and natural resources for at least some of their income (Cavendish, 2000; Bank, 2002; WRI, 2005). This dependence on climate sensitive sectors has led to a growing concern about the possibility that poverty might increase as a result of climate change (Skoufias *et al.*, 2011). Therefore, understanding the link between climate change and poverty is vital for the formulation of both adaptation and mitigation public policies (Ahmed *et al.*, 2009; Hertel and Rosch, 2010). Nevertheless, in contrast to the widely analyzed potential impacts of climate change on the global economy (e.g., Stern (2007) and Nordhaus (2008)), its impact on income distribution and poverty have received limited attention (Hertel and Rosch, 2010; Mideksa, 2010).

Mendelsohn *et al.* (2006) and Tol *et al.* (2004) present some of the first efforts to analyze the impact of climate change on income distribution across countries. Both studies provide evidence supporting the hypothesis that the poor may bear most of the burden of economic damages from climate change. Similarly, using data for each country in the world from 1950 to 2003, Dell *et al.* (2008) find that, for poor countries, there is evidence of a negative effect of higher temperatures on growth. Nevertheless, although this kind of studies, which make comparisons between countries, can be insightful, they provide an incomplete picture since it is likely that different socioeconomic groups and different regions within a country will experience different effects (Mendelsohn *et al.*, 2006; Dell *et al.*, 2009). As a way to overcome this limitation, Mendelsohn *et al.* (2007) use the Ricardian method to draw a link between climate change and per capita rural income in a more disaggregated way. Using cross section information for the U.S (county level) and for Brazil (municipality level) they find that global warming will decrease rural income. Seo and Mendelsohn (2007) use a similar methodology to find that in South America farmers could lose up to 62% of their revenue due to severe scenarios of climate change. For Mexico, Mendelsohn *et al.* (2010) find average losses of land value between 42% and 54%. None of these studies measure poverty directly but all of them argue either that poverty will increase or that the poor will be relatively more affected by climate change.

As an alternative to the Ricardian approach Mideksa (2010), uses a computable general equilibrium model to show that in Ethiopia inequality could increase in as much as 20% as a response to climate change. Ahmed *et al.* (2009) and Hertel *et al.* (2010) look at poverty impacts of climate change in a group of developing countries using a computable general equilibrium model that includes a poverty module. More specifically, Ahmed *et al.* (2009) examine productivity shocks due to extreme adverse climate events. The largest poverty impacts that they find occur in Africa. Meanwhile, Hertel *et al.* (2010) look at graduate climate change impacts through three scenarios of crop productivity changes. Their results show poverty rates increasing by 20-50% for non-agricultural households in parts of Africa and Asia. Finally, Jacoby *et al.* (2011) use a modified Ricardian-type approach that allows for jointly changes in the prices of land, labor and food as a consequence of global warming. They find that in India the national poverty rate in 2040 will be 3.5 percentage points higher in a scenario with climate change than in one without it.

This note presents results of the relationship between climate change and household level poverty via changes in agricultural income. A Mexican household level data set for the year

2002 is used. It is relevant to analyze Mexico since even though there is evidence that it is vulnerable to climate change (Ahmed *et al.*, 2009; Mendelsohn *et al.*, 2010; Skoufias and Vinha, 2013) no studies have examined the potential poverty impacts in a disaggregated way. Furthermore, the data set used allows me to estimate the potential poverty impacts of climate change at the regional level. By doing this I can better capture the geographic heterogeneity in terms of both climate change predictions and relevance of agricultural income.

2 Methodology

The relationship between agricultural productivity and climate variables and between climate and land values or net agricultural revenues has been clearly established (Mendelsohn *et al.*, 1994, 1996, 2001). There is also evidence that shows that total rural households income is affected by climate, with agricultural income being the mechanism of transmission (Mendelsohn *et al.*, 2007). Agricultural income is by no means the only transmission mechanism between climate and income but it is the more direct and the one that has been more carefully analyzed (Mendelsohn, 2009).[1]

The present analysis looks at the impacts of climate change (increases in temperature and changes in precipitation patterns) on agricultural income (crop and livestock) following a partial equilibrium approach with no price changes. The advantage of this is that it allows me to look at potential impacts at the household level knowing exactly where the impacts are coming from. The main disadvantage of this approach is that other impacts that may arise from the effects of climate on agriculture (e.g., indirect impacts through factor markets and impacts through non-priced goods) are overlooked.

I follow the methodology known as the Ricardian method, developed by Mendelsohn *et al.* (1994). This method assumes that farmers will seek to maximize net farm revenues; its main advantage is its ability to implicitly incorporate private adaptation to climate conditions. It is worth mentioning that there is a recent series of papers (Di Falco *et al.*, 2011, 2012; Di Falco and Veronesi, 2012) that use a modified version of the Ricardian approach to explicitly model endogenous adaptation decisions at the household level. Unfortunately, the data that I have does not allow me to model adaptation in an explicit way. Therefore, following Mendelsohn *et al.* (1994, 2007, 2010) I use a reduced-form econometric specification that assumes a non-linear relationship between climatic variables (temperature and precipitation) and agricultural (crop and livestock) income. The general form of the equation estimated is the following:

$$yag_i = \alpha + \beta_1 \, temp_i + \beta_2 \, temp_i^2 + \beta_3 \, prec_i + \beta_4 \, prec_i^2 + \boldsymbol{\delta} \, \mathbf{z}_i + u_i \tag{1}$$

where yag_i is per capita household's net agricultural income, $temp_i$ and $prec_i$ refer to temperature and precipitation, $\mathbf{z}_i$ is a vector of household and geographic characteristics and u_i is an error term. This relatively simple specification has been shown to be very effective to econometrically model the relationship between agricultural income and climate change in developing countries (Mendelsohn *et al.*, 2010). Notwithstanding this, as pointed out by

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[1] Dell *et al.* (2009) and Horowitz (2009) propose to look directly at the relationship between total income and climate as a way to completely circumvent the need to rely on specific assumptions about the transmission mechanisms and how they might operate, interact and aggregate.

Deschenes and Greenstone (2007) there might be some problems with the use of cross sectional data to obtain consistent estimations of the effects of climate on land values (or net profits as in this work). In the econometric estimation I include as many control variables as possible as a way to partially overcome this problem.

Once Equation (1) is estimated, I use projected values of temperature and rainfall from two climate change models (see next section) to calculate two versions of simulated agricultural income (yag_i^{cc}) using the following equation:

$$yag_i^{cc} = \hat{\alpha} + \hat{\beta}_1\, temp_i^{cc} + \hat{\beta}_2\, (temp_i^{cc})^2 + \hat{\beta}_3\, prec_i^{cc} + \hat{\beta}_4\, (prec_i^{cc})^2 + \hat{\boldsymbol{\delta}}\, \mathbf{z}_i + \hat{u}_i \tag{2}$$

where the explanatory variables in $\mathbf{z}_i$ are taken at their current levels.

Total simulated net income (y_i^{cc}) for each household is defined as the sum of simulated agricultural income and observed non-agricultural income (i.e., $y_i^{cc} = yag_i^{cc} + ynonag_i$). For households that do not participate in agricultural activities (non-agricultural households) total simulated net income is equal to observed non-agricultural income (i.e., $y_i^{cc} = ynonag_i$).[2]

The final step to simulate the potential impacts of climate change, under the assumption that the only thing that changes are the climate variables, is to compare the estimates of current and simulated poverty. To estimate poverty I use the three main variants of the FGT poverty index proposed by Foster *et al.* (1984). The FGT index is calculated using:

$$FGT(\alpha) = \frac{1}{N} \sum_{i=1}^{N} I_i \left(1 - \frac{y_i}{q}\right)^{\alpha} \tag{3}$$

where $I_i = i$ if $y_i \leq q$ and zero otherwise. Per capita income is represented by y_i, q is the poverty line, N is the population size, and α is a weighting parameter than can be viewed as a measure of poverty aversion. When $\alpha = 0$ the formula collapses to the incidence or headcount index of poverty. The poverty gap measure corresponds to $\alpha = 1$ and when $\alpha = 2$ we obtain the poverty severity index.

3 Data

The data used in this research, with the exception of the climate data, comes from the Mexico National Rural Household Survey (ENHRUM by its acronym in Spanish). This survey provides detailed data on socio-demographic characteristics, production, and income sources from a nationally and regionally representative sample of rural households surveyed in 2003 (the information collected is for 2002). The sample is representative of more than 80% of the population that the Mexican census office (INEGI) considers to be rural and includes more than 1700 households from 80 villages in 14 states. In the analysis I use the 1567 households for which the necessary information is complete.[3] To implement the survey Mexico was

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[2] The underlying assumption is that households participation in agricultural activities is not altered in response to climate change. That is to say, households that currently participate in agricultural activities will continue to do so while those not participating will continue that way.

[3] There are no statistically significant differences between households excluded from the analysis and those included. The only difference is that households excluded had missing information for one or more of the variables used in the econometric analysis.

divided into five regions (see Figure 1), reflecting INEGIs standard regionalization of the country: South-Southeast, Center, West-Center, Northeast, and Northwest.

Temperature, precipitation and climate change data comes from Mendelsohn *et al.* (2010).[4] They use monthly climate normals (30 year averages) from each weather station in Mexico for the period 1971-2000 as well as data from United States stations close to the border to generate quarterly values for each one of the villages included in the sample.[5] Two climate change models are used to generate the climate scenarios for 2100: Center for Climate System Research (MIMR) and the Parallel Climate Model (PCM).[6] Mendelsohn *et al.* (2010) use the models to obtain temperature and rainfall predictions for each one of the 80 villages included in the sample. Their results show that the PCM model predicts a 2.3°C warming and a reduction of 1.7 mm/mo in precipitation while the MIMR model predicts an average increase of 5.1°C and a reduction of 3.6 mm/mo of rainfall.[7]

Figure 1: Regional distribution of poverty in Mexico

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[4] I thank R. Mendelsohn, J. Arellano-Gonzalez and P. Christensen for kindly sharing the climate data used in their paper.

[5] Recent work, for example Lobell *et al.* (2011), uses daily temperature and precipitation to measure climate impacts on crop yields. Unfortunately, daily measures and predictions on how they will change in response to climate change are not readily available. In particular, they are not available for the communities studied in this research.

[6] A third model, Hadley Center for Climate Prediction and Research model, was also used. All the estimations presented here were done also using that model, the results are extremely close to those reported for MIMR, therefore, I decided not to present them here.

[7] The three climate models are based on scenario A2 of Nakicenovic *et al.* (2000).

4 Estimation

In order to estimate the relationship between agricultural per capita income and climate I follow Deressa and Hassan (2009) and Mendelsohn *et al.* (2010) and estimate Equation (1) using quarterly values of temperature and precipitation. The vector $\mathbf{z}_i$ includes the gender and age of the household head, an index of household level assets created using variables that measure dwelling characteristics (number of rooms, availability of a separate room exclusively intended for cooking, presence of a bathroom, quality of construction materials, and availability of electricity and sewage) as well as dummy variables capturing ownership of durable goods (television set, refrigerator, car and agricultural equipment),[8] the distance from the community to nearest city, altitude and latitude of the community, land quality, land with irrigation as well as regional dummies.[9]

Table 1 shows the results of the econometric estimation, performed using ordinary least squares with weighted data to take into account the survey design. The dependent variable is net agricultural (crop and livestock) income for the 1002 households that participated in the activity in 2002. I estimated four specifications of the model, starting with climatic variables only and then gradually adding control variables. The results are very stable across specifications, therefore, I focus on discussing specification (4) which is the one that I use later on in the simulation. Results for the control variables show that households headed by a male, as well as those with more wealth have significantly higher agricultural incomes. Location is also an important predictor of agricultural income as being closer to a city increases income. Agricultural households have considerably higher incomes if they are located in the Northeast part of the country. Land quality, measured by the fraction of cultivated land that is reported by the household as being of good quality, as well as availability of irrigation have a positive and significant effect on agricultural income. Finally, results show that the coefficients for spring and fall temperatures as well as summer precipitation have a statistically significant effect on agricultural income.

More relevant for the purposes of this study are the marginal effects associated to the climate variables. Using regression results and the average value of temperature and precipitation for the whole country we can get a sense of the estimated marginal effects. Results show that an increase in one degree Celsius during the spring will decrease income in almost 2,500 pesos per household, while an increase during the fall will have a positive but not statistically significant effect of 347 pesos.[10] A statistically significant decrease of more than 800 pesos is found when looking at the combined effect of a one degree increase during all the seasons. On the other hand, a one millimeter decrease in precipitation per month during the summer decreases income in 35 pesos. It is important to remember that the climate predictions, as well as the climate normals, vary for each one of the communities, therefore, the estimated marginal effects will be community specific.

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[8] This index was created using principal components analysis and it captures the largest amount of information common to all the dwelling and durable goods variables. The methodology is explained in Filmer and Pritchett (2001). The Stata command pca was used to estimate the index.

[9] The assumption here, as in most of the literature is that irrigation is exogenous. An alternative will be to estimate a structural Ricardian model with irrigation as an endogenous variable as in Kurukulasuriya *et al.* (2011), but that is beyond the scope of this work.

[10] The exchange rate during the period was roughly 10 pesos/dollar.

Table 1: Econometric estimation of Ricardian model for Rural Mexico

	(1)		(2)		(3)		(4)	
	Coefficient	t	Coefficient	t	Coefficient	t	Coefficient	t
Spring temp	-10661.7***	-2.8	-9929.1***	-2.7	-10289.2***	-2.6	-10305.8**	-2.6
Spring temp^2	202.6***	2.7	188.1**	2.6	185.0**	2.5	188.2**	2.6
Summer temp	-1780.0	-0.6	-2206.8	-0.8	2652.2	0.7	2915.1	0.8
Summer temp^2	45.3	0.9	50.2	1.0	-33.1	-0.5	-38.8	-0.5
Fall temp	13180.7***	2.8	13023.6***	2.8	9311.3*	1.9	8913.59*	1.79
Fall temp^2	-283.5***	-3.0	-276.2***	-3.0	-220.6**	-2.0	-214.6**	-2.0
Winter temp	-961.5	-0.4	-1060.1	-0.4	-3350.6	-1.0	-3209.9	-1.0
Winter temp^2	24.9	0.4	24.8	0.4	105.0	1.2	104.2	1.2
Spring prec	-34.0	-0.6	-2.7	-0.1	74.4	0.9	72.4	0.9
Spring prec^2	0.3	0.6	0.1	0.1	-0.2	-0.2	-0.1	-0.2
Summer prec	68.4***	3.2	51.9	2.5	65.6**	2.4	54.7**	2.0
Summer prec^2	-0.1***	-3.2	-0.1**	-2.2	-0.1**	-2.0	-0.1	-1.6
Fall prec	-79.3	-2.7	-52.9*	-1.7	-56.7	-1-1	-41.0	-0.8
Fall prec^2	0.1*	1.8	0.1	0.9	0.02	0.2	-.01	-0.1
Winter prec	28.2	0.6	20.1	0.4	-12.4	-0.2	-24.8	-0.3
Winter prec^2	0.2	-0.8	-0.1	-0.4	0.2	0.5	0.2	0.6
Gender			1755.3***	3.9	1590.7***	3.5	1335.9***	3.0
Age			21.58	1.2	20.5	1.1	17.1	0.9
Indexs			3747.3***	3.3	4515.8***	3.5	4513.8***	3.5
Distance					-0.04**	-2.0	-0.04**	-2.1
South-Shouteast					1745.2	0.8	932.1	0.4
Center					38.0	0.02	-617.3	-0.3
West-Center					1382.6	0.7	992.9	0.5
Northeast					10101.4**	2.5	9991.1**	2.5
Latitude					-537.4	-1-1	-526.1	-1.1
Altitude					-1.5	-1.2	-1.2	-1.0
Good land							1379.87**	2.16
Irrigated land							48.96**	2.17
Constant	12345.6	1.1	7193.7	0.6	27628.4	1.3	274240.4	1.32
Observations	1002		1002		1002		1002	
R^2	0.094		0.105		0.123		0.130	

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

What does this mean in terms of the potential implications of climate change on poverty? To answer this I follow the methodology described in Section 2 to simulate, for each one of the 1567 households, total per capita income using the climate change predictions from the two climate models.[11] The first column of Table 2 compares observed income with the two version of simulated income at the national level. Results show a significant impact of climate change with a reduction in average total per capita income between 11% and 15%. Although these national level results are informative they mask the heterogeneity in participation in agricultural activities across regions and therefore the potential heterogeneity in welfare impacts. The regions where more households are involved in agricultural activities are the South-Southeast and the Center (86% and 82%, respectively) followed by the West-Center (69%). In the Northwest only 31% of the rural households participate in agricultural activities while 46% do it in the Northeast. The regional distribution of negative impacts of climate change on total income follows a similar pattern with the South-Southeast experiencing the biggest impact (-20%) and the Northwest the smallest (-5%). These results show a clear negative effect of climate change on simulated income.

Table 2: Observed and simulated per capita income and agricultural participation rates

	National	South-SE	Center	West-Center	NW	NE
Observed income						
y^{observed}	12,195	8,537	12,720	14,274	22,291	18,108
Simulated income						
y^{PCM}	10,894	7,261	11,287	12,935	21,224	17,022
y^{MIMR}	10,418	6,861	10,715	12,432	20,704	16,460
HHs in agricultural activities	75%	86%	82%	69%	31%	46%

Using the information on observed per capita income we have that 45% of rural households in Mexico are below the poverty line.[12] Figure 2 shows that according to the two climate models and their corresponding income simulations, climate change can have considerable impacts on poverty. Simulated poverty headcount is above 50% for both climate models. The highest value (54%), corresponding to the MIMR model, implies that in a scenario with climate change an additional 240,000 rural households will be below the poverty line compared to the baseline scenario.[13] The relative increases in poverty incidence and severity are even bigger, reflecting the fact that those already below the poverty line are significantly affected in the simulations.

On the other hand, as Figure 1 shows, poverty is not homogeneously distributed across the country; more than 60% of rural households in the South-Southeast are below the poverty line while only 20% have the same status in the Northwest. Figure 3a shows an heterogeneous

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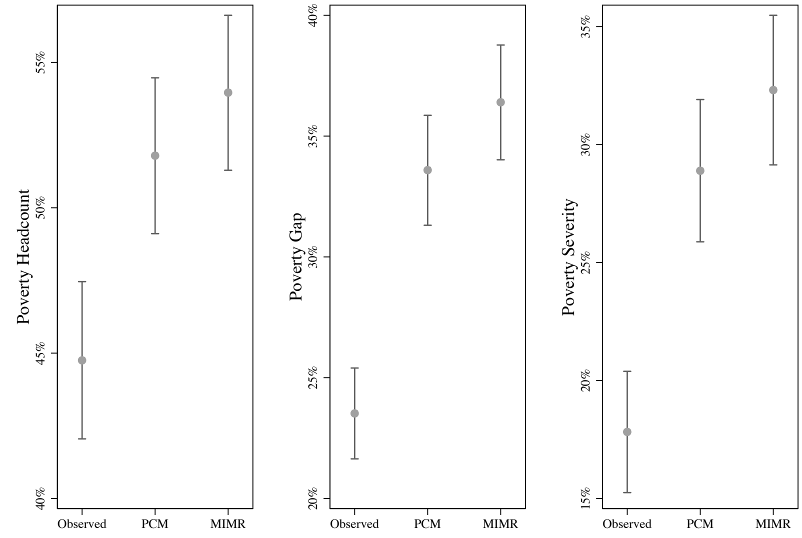
[11] For the 565 non-agricultural households total simulated income is equal to total observed income.

[12] For the measurement of poverty we use the official food poverty line for rural Mexico for the year 2002, 5,937.36 pesos per year (CONEVAL, 2006).

[13] The expansion factors used in the survey design and incorporated in the estimations presented here imply that the households in the sample represent 2,726,805 rural households.



90% confidence intervals shown

Figure 2: Poverty impacts of alternative climate scenarios. (National Level)

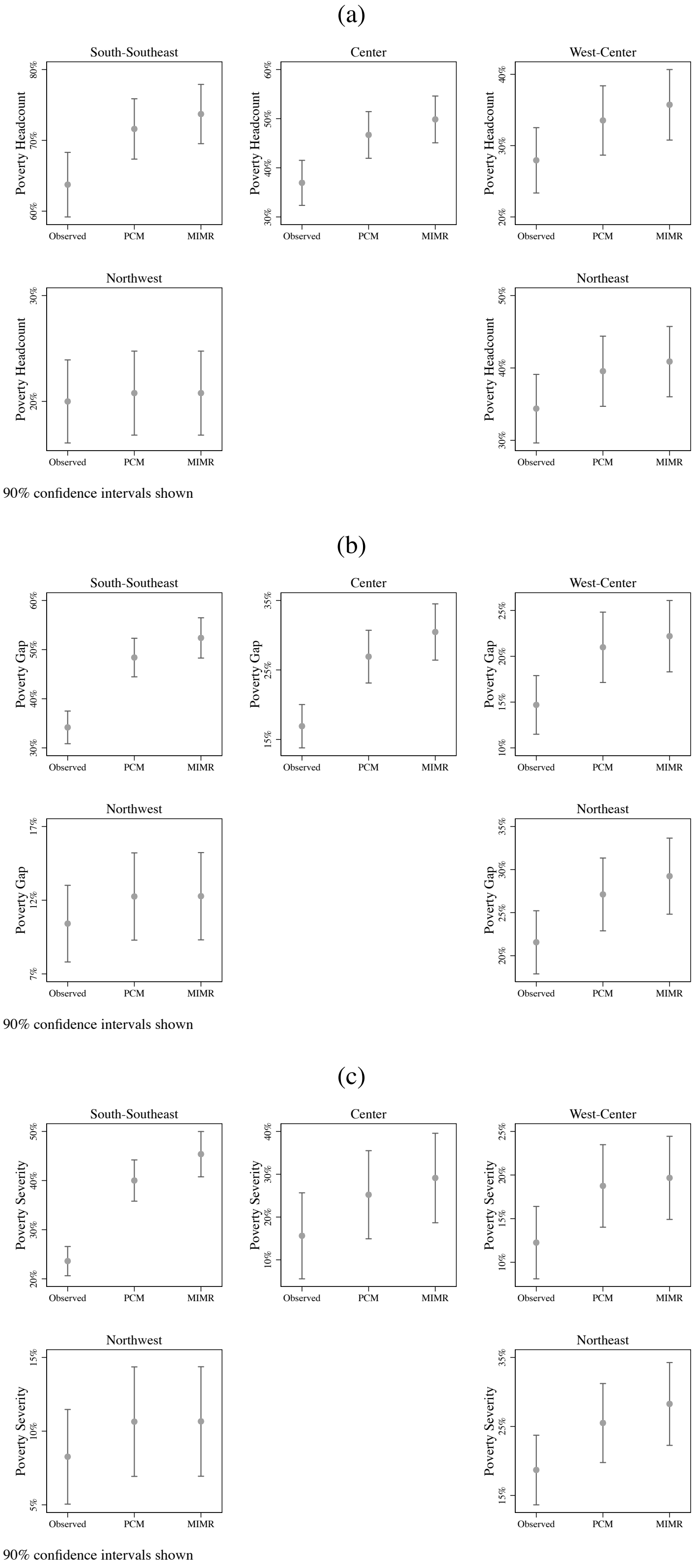
impact of climate change on poverty at the regional level. For the South-Southeast the simulated poverty rates are between 72% and 74%, although the estimates for the PCM model are not statistically different from the poverty estimated with observed income. The region with the highest relative changes in simulated poverty is the Center, where poverty can increase in as much as 13 percentage points, equivalent to 65,000 additional households below the poverty line. For the West-Center and the Northeast the changes in poverty are high as well (in relative terms) but the poverty levels estimated using simulated income are not statistically different from those obtained with observed income. Not surprisingly, given the low levels of participation, the Northwest is the region were poverty levels are less affected. Figures 3b and 3c show similar patterns for poverty gap and severity.

5 Final remarks

In the economics literature it has been frequently mentioned that climate change can have an important impact on welfare, however quantitative estimates of impacts at the household level are very scarce. The results presented in this note show that, given the current levels of participation in the agricultural sector, a change in climate could lead to an additional 240,000 households below the poverty line in rural Mexico. Of those households almost 50% will be located in the South-Southeast and more than 25% in the Center. It is important to emphasize that these results are not forecasts, they are simply indicative of the magnitude and geographical distribution of the potential climate change impacts given the current conditions. This is due to the fact that the methodology used has some important limitations (e.g., extreme climatic events are not included and prices are taken as given and constant, indirect impacts through factor markets are not included, and participation in the agricultural sector is kept constant) and to the intrinsic uncertainty about how will the world look like by the end of the century. A particularly strong assumption in this sense is that farms in the future remain essentially as they are today. Of course, technology adoption and increased capitalization is likely to happen in rural Mexico and this will have an impact on the sensitivity of income to climate.

Notwithstanding these limitations, the results presented are a valuable contribution to the limited literature on climate change impacts that uses disaggregated data. Of special relevance is the result that highlights that national level analysis can mask significant geographic differences that should be taken into account in the design of policies that aim to decrease rural households' vulnerability to climate change. For example, the results imply that most of the efforts to promote adaptation should focus on the center and south of the country.

Further research is necessary to better understand the way in which farmers might adapt over time to a changing climate that has persistent and potentially generalized effects. In particular, the results presented here are based on a model that allows for adaptation to climate change in a partial equilibrium model with no price changes. Nevertheless, climate change is likely to lead to changes in prices of agricultural products and inputs and might have impacts that cannot be anticipated with the framework used here. Considering this, a promising next step in this research agenda is to combine econometric estimations with a disaggregated rural economywide model. This will allow me to incorporate general equilibrium effects in the simulation of poverty impacts and to simulate some of the implications that different policies (e.g., agricultural subsidies and promotion of off-farm employment) or households' responses (e.g., migration or adoption of irrigation) might have under different climate change scenarios.



90% confidence intervals shown

90% confidence intervals shown

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Figure 3: Poverty impacts of alternative climate scenarios. (Regional Level)

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