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Effects of Climate Change on Corn and Quinoa Production: Analyzing the Production of Mexico and Bolivia a Semi-Ricardian Approach

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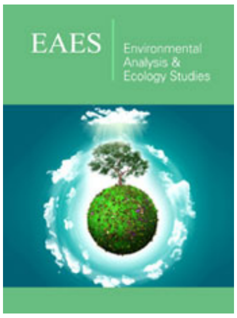

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Abstract

How does climate change affect the production of corn and quinoa in Mexico and Bolivia? There is an impact of climate change on rain-fed crop productivity and its association with alimentary security. This study analyzes how events such as global warming, unsustainable agriculture or intense droughts caused by lack of water, affects the production of quinoa in Bolivia and maize in Mexico. Our estimates suggest that climate variability will modify agriculture yields (of maize and quinoa) per hectare depending on the agricultural season, the municipality and the ensemble model used to project climate change scenarios. The study indicates tremendous heterogeneity in areas and regionally. Based on the cobweb phenomena approach, it is suggested that the producers base their decisions for their future production on the assumption that present prices will continue. If this is not the case, rigid price expectations may produce irreversible supply conditions in the short run. These prices are set by the available supply of grains. Their production is completely determined by the producers' response to price, under conditions of pure competition.

Introduction

Global warming will increase temperature and rainfall variability, with the consequent increase in extreme weather events. According to the Intergovernmental Panel on Climate Change-IPCC, droughts will intensify during this century in some seasons and areas of central Europe, North, Central and South America, and southern Africa [1]. In response, economic research has quantified the possible impacts of climate change on society. Without ignoring the sizable impacts that this climate variability could have on other economic activities, the discussion so far has centered on agriculture, which is highly susceptible to climatic conditions. Developing countries are particularly vulnerable to climate change. Large segments of their populations still rely on agriculture and have restricted the ability to adapt given their low-income. Indeed, a growing body of country level studies has confirmed that changes in precipitation patterns and warmer temperatures have negative impacts on agriculture, with the most severe losses occurring in Africa, Latin America and India [2-5]. The classical economic theory rests upon the assumption that price and production if disturbed from their equilibrium, tend to gravitate back toward that normal; the cobweb theory demonstrates that, even under static conditions, this result will not necessarily follow" [6,7]. The conditions under which the cobweb theorem was supposed to apply were:

A. Where production is completely determined by the producers' response to price, under conditions of a pure competition (where the producer bases plans for future production on the assumption that present prices will continue, and that his production plans will not affect the market).

B. Where the time needed for production requires at least one full period before production can be changed, once the plans are made.

C. Where the price is set by available supply [8].

Rain fed agriculture is vital in Mexico and Bolivia. Even though the participation of agriculture in the economy has shrunk over the past decades, rain-fed agriculture is a dominant source of livelihood for the poor. Maize is the core staple in the Mexican diet, and about 2.94 million small holders grow corn, mainly for subsistence. In the last few years, quinoa productivity has become an important source for the live hood in Bolivia, since it was declared a "superfood", most of the quinoa´s production in Bolivia is exported to other countries.

Methods and Estimations

A semi-Ricardian approach using farmland net revenues as a reflection of net productivity has been proposed [9-12]. An alternative strategy to estimate the impact of climate change is through panel data methods (fixed or random effects) to control for unobserved determinants of agricultural productivity (soil quality, farmer's ability) [13-15]. The impact of climate change on maize yields is then estimated from the predicted weather parameters and predicted changes in climate [6-16]. Linear precipitation and temperature increase yields, but their squares (extreme temperature and rainfall) decrease yields. In quinoa´s yields case, there is only one production season, and rainfall and temperature decrease. Such estimations overstate the impact of climate change on stunting because households can mitigate the consequences of climate change migrating to more amenable municipalities or move across sectors within the same municipality [17-21].

Consider a production function for an average farmer (rural household) as follows: Yieldcrop=f (Tmt, Pmt, G, L, K), where T and P represent temperature and precipitation, respectively, G stands for inputs largely immutable such as geographical characteristics and soil type, L represents an input that can vary in the short run, which we shall call labor for concreteness, and K represents capital, an input that can only vary in the long run, and m represents our core unit of analysis the municipalities [15]. The farmer, taking prices, rain, and temperature as given, solves the following program, see equation 1.

Prices, rain, and temperature-related with costs:

$$\max Yielcrop = f\left(Tmt, Pmt, K, L, G\right) subject\,to\,c\left(m1, ..., mn\right)\left(1\right) xm\,\varepsilon\mathbf{R} \quad (1)$$

Total costs c(.) are a function of maize produced, which in turn depends on the weather, w because precipitation and temperature affect yields directly [2,15]. Solving this optimization problem would let us know for a given level of temperature and precipitation, soil and prices, the combination of labor and agricultural inputs chosen by the farmer that maximizes its corn or quinoa yield. Also, changes in agricultural productivity affect rural income in our simplified model and, consequently, food security. Without full adaptation in the short run, the impact of weather shocks on maize and quinoa yields in a regression framework becomes nonlinear; Other plausible determinants of agricultural yields such as soil quality and municipal location need to be included to avoid misattributing the impacts of climate shocks on yields. Overall, we assess the historic effects of temperature and rainfall (and their projections due to climate change) on rain-fed maize yields (in Mexico). We propose the following econometric model to estimate variations in yield for a municipality (county) m, at year t.

Estimated variations in yield for the municipality:

$$yeild(w, hm, t) = \int_{h}^{\overline{h}} g)(\phi w_{mt})\phi_{mt}(h)dw + \delta z_{mt} + c_m + \varepsilon_{mt} \quad (2)$$

In equation 2 our dependent variable is average yields per hectare. Yield estimates were constructed as follows. Equation 2g(w) represents cropping growth, which depends on climatic variables w (temperature, precipitation) and fmt (w) is the average of rainfall for each growing season in municipality m and year t, and δ the behavior regarding production costs [22-24]. The matrix zmt includes average temperature and technologies employed (seed type, manual or mechanical rooter, and fertilizers and agrochemicals used) in municipality m and year t. The term cm represents municipal characteristics (i.e., soil type, latitude, longitude, and height above sea level). Overall, the regression includes climatic, geographic and economic variables affecting maize productivity. As part of the geographic variables, we include location coordinates (latitude, longitude, altitude) and soil quality Cm and Ɛmt an error term that follows a stochastic process or white noise. For the economic variables influencing agricultural productivity, we consider costs; and the climatic variables comprise linear and quadratic terms for seasonal precipitation and temperature means.

Yield estimates: $yield(w, m, t) = {}^{\pi xmt}\!/_{Hxmt}$ (3)

Where πxmt is total production (in tons) of grains in county m, at year t and Hxmt are rainfed maize and quinoa hectares initially sowed.

Result

As expected, linear precipitation and temperature increase yields, but their squares (extreme temperature and rainfall) decrease them. This confirms the existence of a non-linear relationship between temperature/rainfall and maize yields, where the lack of rain reduces agricultural productivity, as do heavy rains. This finding is consistent across specifications. According to our preferred specification, estimates show that a 1mm increase in precipitation raises gross productivity by 81 kilograms per hectare on average; and a 1 Celsius degree increase boosts productivity per hectare by 80 kilograms on average, in the maize case. The ensemble models predict increases in temperature and drops in precipitation. The ensemble models predict increases in temperature and drops in precipitation, see (Figures 1 & 2). Both phenomena will occur simultaneously. Moderate increases in temperature under current rainfall levels improve yields; but drops in precipitation will invariably reduce maize, despite maintaining current average temperature. For the main Spring-Summer season, estimates suggest that climate change will change rain fed maize yields in 2030-2039 by about 15.25% for about 48.83% of the municipalities; the rest would experience declines of about 3.14% on average. In the case of quinoa, the changes show a drop of 9.13% in the agricultural season, see (Figure 3).

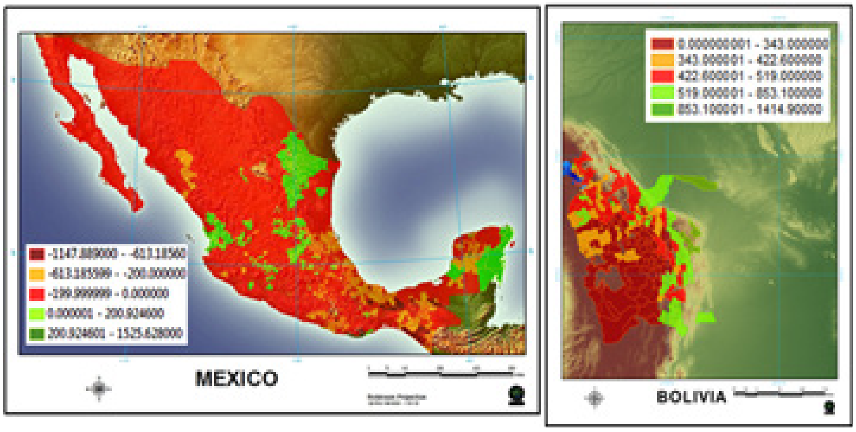

Figure 1: Future rain scenarios in the analysis region, Mexico and Bolivia. Figure 1 displays the geographical alteration on the future raindrop because climate change. Both Mexico (left panel) and Bolivia (right panel) show a general rainfall decrease, except for some municipalities in which winter storms and extreme events will provoke a rainfall increase, but in general, less precipitation is expected.

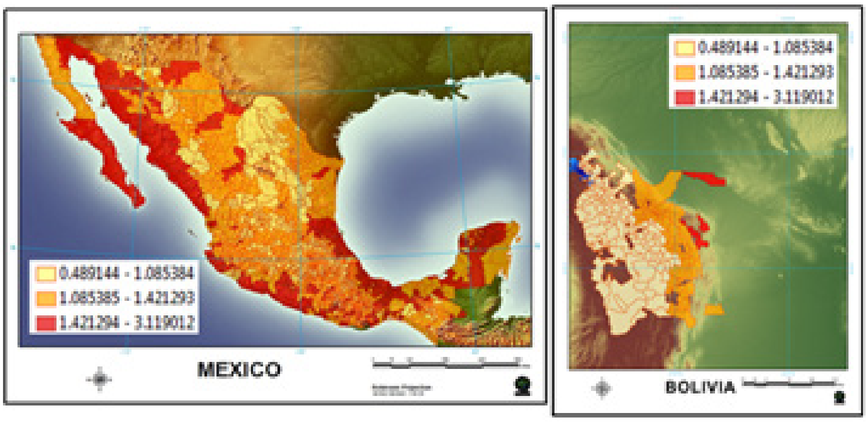

Figure 2: Future temperature scenarios in the analysis region, Mexico and Bolivia. Figure 2 displays the future temperature alterations due to climate change. In Bolivia, three regions are clearly defined: El Altiplano, the valleys and the tropical area, in which they are temperature increase but in a differenced way (right panel). In Mexico, the heat is concentrated on the coasts (left panel).

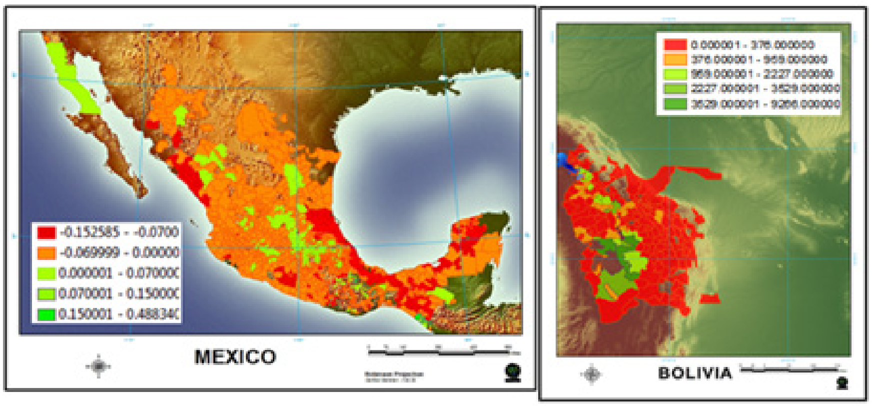

Figure 3: Changes in the production of corn and quinoa from the application of climatic scenarios. Figure 3 as a whole, and in combination, rainfall changes and temperature predictions estimate a fall in the production of maize and quinoa, but as we mentioned before, some municipalities will have marginal increases in production, mainly due to the contribution of the moisture provoked by rains and winter storms. These two elements are significant in the prediction models of maize and quinoa.

Conclusion

As we can see, our future needs to develop more advanced and ecological techniques and knowledge to take advantage of these two grains production, optimizing its process and reducing the environmental impacts resulting from these activities, and also to create and apply more effective politic policies regarding farmers adaptation to help them to make the correct long-term decisions and face the impacts of climate change and it's also necessary to adapt to the future conditions. Lower yields can imperil subsistence farmers and increase maize or quinoa prices. So, a lot will depend on whether rural households are net consumers or producers of food. Well-functioning markets can also help if there is enough food in the country. Averages can be deceiving. There will be winners and losers, both regionally and across/rural areas. The study indicates tremendous heterogeneity in impacts (differentiated by urban and regionally). Climate change will benefit some areas and regions but affect others. The adaptive capacity of households is very heterogeneous, and we account for some of this adaptive capacity through spatial mobility. The global production is determined by the producer's response to the price, under the conditions of pure competition, if present prices will continue or won't differ too much, unaffecting their plan production, and prices are set by the available stock. Governments can also improve adaptation through economic growth, prices, transfers, and insurance. More food could be grown with better policies and incentives, and recent initiatives to revamp agricultural research and develop higher yield drought resistant maize varieties are needed.

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