Concept and Unintended Consequences of Weather Index Insurance: The Case of Mexico

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Recently, weather index insurance (WII) has received considerable attention as a tool to insure farmers against weather-related risks, particularly in developing countries. Donor organizations, local governments, insurance companies, development economists, and agricultural economists are discussing the costs and benefits of WII. While the literature on WII has focused mainly on cases in Africa and Asia, in this article we analyze the WII program in Mexico, one of the largest in the world. In this context we discuss potentially important spillover effects on related markets that so far have not been considered in the academic literature. We argue, first, that WII creates disincentives to invest in other non-insured crops, leading to potential overspecialization and monoculture; second, that WII generates disincentives to invest in irrigation systems because farmers are insured only as long as production takes place on non-irrigated land; third, that in case of catastrophic events, food prices can potentially inflate with indemnity payments at the expense of the uninsured poor. We also suggest that in Mexico the thresholds of the weather index be (continuously) recalibrated in order to adjust for the development of drought-resistant seeds. Finally, the index could relatively easily be extended to account for precipitation variances. We argue that these factors and spillover effects should be accounted for in cost benefit analysis of WII.

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Background

The productivity of agriculture is highly influenced by the conditions of the natural environment. In particular, changes in climatic and weather conditions impact farmers' yields, and in developing countries—where a high percentage of the gross domestic product is generated by agricultural income—unfavorable conditions can severely affect the overall well-being of an entire region. Traditionally, farmers have developed several coping mechanisms to mitigate the potential negative impacts of their exposure to natural risks:

- Crop diversification (planting multiple crops with different vulnerabilities to weather events)
- Development of irrigation systems (to decrease farmers' dependence on precipitation)
- Generation of off-farm incomes
- Investments in formal and informal banking systems (either by accumulating savings or by access to credit markets)

Today, despite the existence of these risk-mitigating mechanisms, a large portion of weather shocks' negative effects in developing countries are still not entirely absorbed, which in some cases can lead to humanitarian catastrophes such as famines or civil wars over access to important resources (Alderman and Haque 2008; Barnett and Mahul 2007). More generally, the lack of tools to insure sectors against weather shocks has led to an underinvestment in the agricultural sector (Morduch 1995; Rosenzweig and Binswanger 1993).

Historically, governments have used disaster relief funds to respond quickly and stabilize areas affected by floods or droughts. However, the volatility of disaster funds over time—and the associated strains on other governmental

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budgets (e.g., education, security) from which resources are taken—pose difficulties. Furthermore, disaster relief is conceived of as an *ex post* strategy only. In recent years, efforts have increased at designing *ex ante*–oriented strategies. In theory, under the assumption of risk aversion, an optimally designed WII facilitates overcoming credit constraints, mitigates chronic underinvestment, increases productivity, and could potentially relieve poor farmers from poverty traps, as discussed by Barnett, Barrett, and Skees (2008).

Weather Index Insurance Literature and Challenges

Although WII contracts are currently considered to be an effective tool for the agricultural sector in developing countries (Barnett, Barrett, and Skees 2008; Barnett and Mahul 2007; Sakurai and Reardon 1997; Skees 1999, 2000; Skees and Ayurzana 2002), the first successful implementation was realized in the United States in 1997: after the deregulation of the U.S. energy sector, energy providers increasingly insured themselves against mild winters to compensate for potential loss of revenue due to the decreased use of energy for heating (Cao, Li, and Wei 2003). Since then, stakeholders in the sectors of tourism, agriculture, travel, and event organization have engaged in the trading of weather derivatives, which became a $40 billion business for the Chicago Mercantile Exchange alone in 2006 (Ginocchio 2008).

The basic concept of WII is simple: if a certain measured weather index (i.e., precipitation) is above (flood) or below (drought) a predefined threshold, then the insurance pays indemnity payments to the insurance holder (farmer). While we will discuss the challenges of this mechanism in more detail below, the perceived advantages of WII are that it circumvents both moral hazard and adverse selection, which are problems in traditional insurance schemes that are based on actual losses of harvest. Furthermore, it is often argued (Barnett, Barrett, and Skees 2008; Barnett and Mahul 2007) that WII is cost-effective because no harvest damage assessment has to be made.

Regarding the economics and feasibility of the insurance program, important recent insights have been gained in the case of India, Malawi, and China. The main empirical problem is the take-up rate by farmers purchasing WII, ranging (depending on the study) from 4–5% in 2004 in India as analyzed by Giné, Townsend, and Vickery (2008) to about 27% for the same sample of Indian farmers in 2006 as analyzed by Cole et al. (2008). These studies and a series of additional papers (Cai et al. 2009; Giné and Yang 2009) analyze the determinants of participation of WII and find that the higher the correlation between the weather index and the yield (basis risk), the higher the take-up rate.

Furthermore, take-up increases with household wealth and with less restrictive credit constraints. These results are consistent with the predictions of simple neoclassical models. The above studies, however, also point toward important social-psychological and peer effect–related determinants for take-up, namely trust in the insurance program, participation in village networks, and familiarity with the insurance vendors. These variables are consistently correlated with the take-up decision. Giné, Townsend, and Vickery (2008) performed experiments with farmers to measure their degree of risk aversion and found (now contrary to the theoretical predictions from the neoclassical model) that risk-averse farmers were *less* (not more) likely to participate in WII, which may have reflected their uncertainty about the WII program itself.

In an already widely cited paper, Giné and Yang (2009) study the interaction between access to credit and access to WII, which is important given that one argument in favor of WII is that it helps farmers overcome credit constraints. Their findings, in randomized field experiments in Malawi, were that farmers who were offered credit were less likely to adopt the credit if simultaneously the farmer was also offered WII (compared with the control group of farmers who were offered credit only). Giné and Yang interpret this result by saying that farmers are already implicitly insured by the limited liability inherent in the loan contract, so that bundling a loan with formal insurance (for which an insurance premium is charged) is effectively an increase in the interest rate on the loan (p. 2). Another potential interpretation that Giné and Yang offer is of a psychological nature, in the sense that by being offered both credit and WII, farmers are reminded of the risk of defaulting on the credit and hence decide to accept neither. Finally, an additional interpretation (not described in Giné and Yang 2009) is that for the "average" Malawi groundnut and maize farmer, the simultaneous offer of both credit and insurance is simply too complicated to understand.

Hence, farmers may decide to accept neither contract due to their uncertainty about the details of the various policies and the interaction of the policies in case of a default. Suggestive evidence for this hypothesis is supported by the fact that the adoption of both offers increases with education, income, and wealth.[1]

Based on these experiences, a debate has emerged as to whether WII is an efficient tool for developing countries and whether WII is self-sustainable. Due to the low take-up rates, some donor organizations are now more hesitant to further invest resources into WII. For example, after a workshop on WII at the headquarters of the Bill and Melinda Gates Foundation in Seattle, the Foundation decided not to further support and engage in WII programs (personal communication of Hendrick Wolff with a senior staff member of the Bill and Melinda Gates Foundation, 2010).

However, the design of the Mexican insurance program differs from other WII programs in several important ways. Therefore, we think it is worth looking at in greater detail in order to have a better understanding of the potential role, costs, benefits, and effectiveness of different WII design options. Below we will examine some of the main problem areas of WII. Barnett and Mahul (2007) and Barnett, Barrett, and Skees (2008) have contributed papers that conceptually discuss the main challenges, which can be categorized as (*a*) basis risk, (*b*) low data quality, and (*c*) low willingness to pay. We further discuss the problem of diversification, technology inertia, and other aggregate equilibrium effects.

Weather Index Insurance in Mexico

Agricultural Background

Mexico's WII is designed to insure against droughts in non-irrigated agricultural production. It covers four crops: maize, barley, beans, and sorghum on a total of 1.9 million hectares. The insurance targets mainly maize, to which 81% (1.5 million) of the total 1.9 million hectares insured is devoted. In Mexico, maize is the most important crop, and its relative dominance is even higher in non-irrigated agriculture: 90% of all maize is grown on rainfed land, and the remaining 10% is grown on irrigated land.[2]

Eighty percent of all agricultural catastrophes in Mexico are caused by drought. This situation is exacerbated by El Niño, in the years that this phenomenon occurs. Federal and state governments spent around a third of a billion U.S. dollars in disaster relief due to agricultural catastrophes between 1995 and 2003 (Ministry of Agriculture 2009). Moreover, access to private agricultural production insurance in Mexico is insufficient, since land fragmentation (more than 60% of farmers own less than 5 hectares), large administrative costs, and systemic risk discourage private insurers. Due to the lack of private insurers and the high budgeting uncertainty of disaster relief funds, the Mexican government, through the Ministry of Agriculture, introduced rainfall index insurance in 2003, the objective of which is to efficiently support small-scale producers—defined as owning no more than 20 hectares—in the case of adverse droughts.

Regional Enrollment versus Private Take-up

While in 2003 rainfall index insurance was available in only five counties, in 2008 the insurance covered over 656 counties with a total of 1.9 million hectares. In particular, every year since 2003, state-level officials suggest to their federal counterparts the area to be insured (number of hectares and counties considered) within the first three months of the year and before the beginning of the season. The federal government pays 70% of the cost of the insurance premiums and state governments cover the remaining 30%. However, for counties that have high poverty levels (defined by the National Population Council), costs are split 90–10% between federal and state governments, respectively. The Agroasemex federal agency has provided exclusive coverage since its formation in 2001. An important aspect of the WII in Mexico is that although it provides production insurance for small-scale farmers, Agroasemex essentially insures the federal government budgets. In other words,

[1] While writing this paper, we became aware that Osgood (2010) offers an additional interpretation of the results by Giné and Yang. Farmers who are concerned about income thresholds might be more interested in production increases than risk reduction and, consistent with the Malawi insurance implementation strategy, may value the insurance more for making credit possible than for risk reduction per se.

[2] In Mexico non-irrigated farming still clearly dominates. In 2008, agricultural production accounted for up to 20.5 million hectares, of which 73.6% depended exclusively on rain. Maize production covered 7.8 million hectares, of which more than 6.9 million (90%) was non-irrigated land (Ministry of Agriculture 2009).

it serves as a budget risk management tool that allows annual budget planning, minimizing catastrophic *ex post* expenditure due to droughts. Agroasemex itself reinsures its risk with the U.S. reinsurance company Partner RE, thereby spreading the covariate risk on an international level, where reinsurers can regard a country's risk as idiosyncratic if they themselves invest in multiple countries.

Importantly, in Mexico individual producers do not pay premiums to obtain coverage under WII. Instead, WII is jointly contracted by federal and state governments, which provide resources from their annual budgets to purchase insurance premiums. The automatically insured farmers get informed about their coverage status through state officials.[3] However, whether this information channel is effective and farmers are truly aware of this insurance coverage is an open question. In order to evaluate the information channels, the Ministry of Agriculture requires that the program be externally evaluated. In particular, during the latest external evaluation of 2009 it was demanded that a subset of randomly selected farmers be surveyed to determine their awareness of and willingness to pay for the insurance. According to the Ministry of Agriculture (2009), this external evaluation proved that (*a*) almost 100% of the farmers knew about the existence of the insurance, and (*b*) over 80% of the farmers revealed a positive willingness to pay for the premium (in order to obtain the insurance in case the government would not provide it for free). However, it is important to point out that this study—although classified as external to the interests of the government—was contracted by the Mexican government and may not satisfy strict scientific criteria. In particular, the result that there exists a positive willingness to pay among Mexican farmers is in stark contrast to the results found by Giné, Townsend, and Vickery (2008) and Cole et al. (2008) in India, by Giné and Yang (2009) in Malawi, and by Cai et al. (2009) in China. Given the importance and academic interest of this issue, this problem should be analyzed further.

Data Quality

The Mexican WII program takes advantage of existing and publicly available weather data. Although there are more than 5,000 weather stations in the country, Agroasemex uses only a subset, since few of these stations attain international standards and have more than twenty-five years of daily weather information. The twenty-five–year requirement was introduced because it was regarded as important to obtain a long enough time series to statistically predict the rain-yield correlation pattern.

Basis Risk Modeling and the Problem of Nonmoving Thresholds

"Basis risk"—which describes how well the index is correlated with crop yields—is often viewed as the most significant problem with WII design. To model the relationship between weather conditions and crop yields, the Mexican Agricultural Insurance Simulation Model was developed. This model is important, as it is used to determine the critical threshold index values below which indemnity payments are triggered (Agroasemex 2006). The model consists of a system of equations representing the crop-soil-weather relationship, taking into account the specifics of each agronomic climate region. As a result, the growing season is separated into three phases: seeding, flowering, and harvest. Different thresholds are established for each of these three phases, for each crop, and for each agroclimatic unit, the Agro-Climatic Zone of Homogeneous Response (ACZHR). Indemnity payments are provided if rainfall is below the preestablished threshold, as measured in millimeters by weather stations in the ACZHR.

For example, we look at the case of a zone in the state of Guanajuato in figure 1 corresponding to the rainfall of the year 2005. Agroasemex offers the following contract for insuring maize in the county of Apaseo el Alto. The first period, known as the sowing period, runs from May 15 to July 5; the second period, or flowering period, runs from July 6 to August 20; and the third, or harvesting period, runs 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 mm for the first, second, and third periods, respectively. As can be seen from figure 1, there were no indemnity payments in Apaseo el Alto, since cumulative rainfall was higher than the minimum thresholds in each of the three periods. Figure 2 shows the rainfall pattern for the county of Leon in 2005. Indemnity payments were provided in 2005

[3] The announcements are made through the regional offices of the Program for Direct Assistance in Agriculture or through the Ventanillas Autorizadas, depending on plots, location, and county.

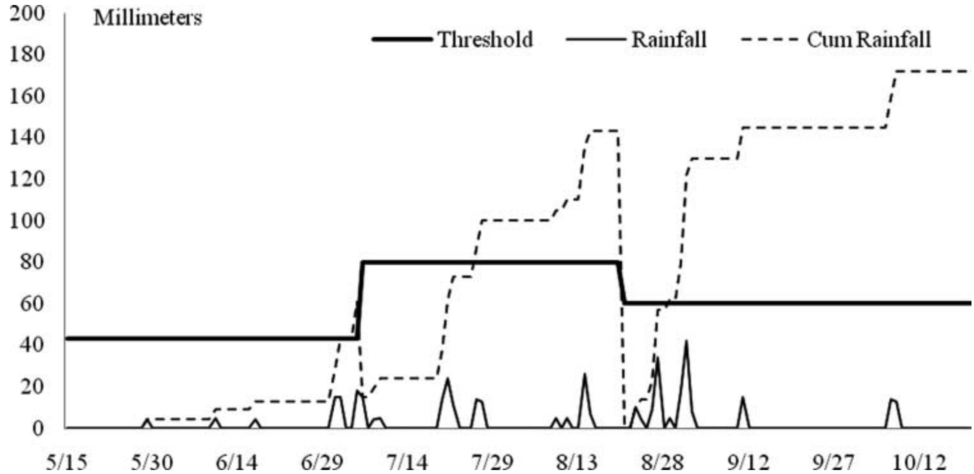

Figure 1. Weather insurance thresholds and actual rainfall: Apaseo el Alto, 2005

for maize production in Leon because cumulative rainfall was lower than the sowing-period minimum threshold.

In our opinion, given the importance of the thresholds for WII, it is problematic for these thresholds to stay constant over time. In Mexico, since the start of the program in 2003, the defined thresholds were not readjusted, although currently a substantial amount of research has been devoted to the development of drought-resistant corn and maize types (Ribaut et al. 2009). Nonmoving thresholds can inhibit important incentives to invest in research and development of drought-resistant seeds. Hence we suggest a model recalibration and the consideration of appropriately moving thresholds over time.

In addition, we consider that not only the minimum amount of cumulative rain in each period is important, but also its variance within that period. In other words, attaining the minimum amount of cumulative rainfall in one or two days (potential flood) has very different consequences on the growing conditions of maize compared with the same amount of cumulative rainfall dispersed over a larger number of days. Therefore, we suggest an additional index, which counts the number of days with a positively measured rainfall minimum. If a minimum number of days of rainfall is not reached, then the indemnity payment is triggered.

Risk of Nondiversification: Monoculture and Inertia in Technology

In Mexico 22% of all rainfed maize production is currently insured, and it is intended that

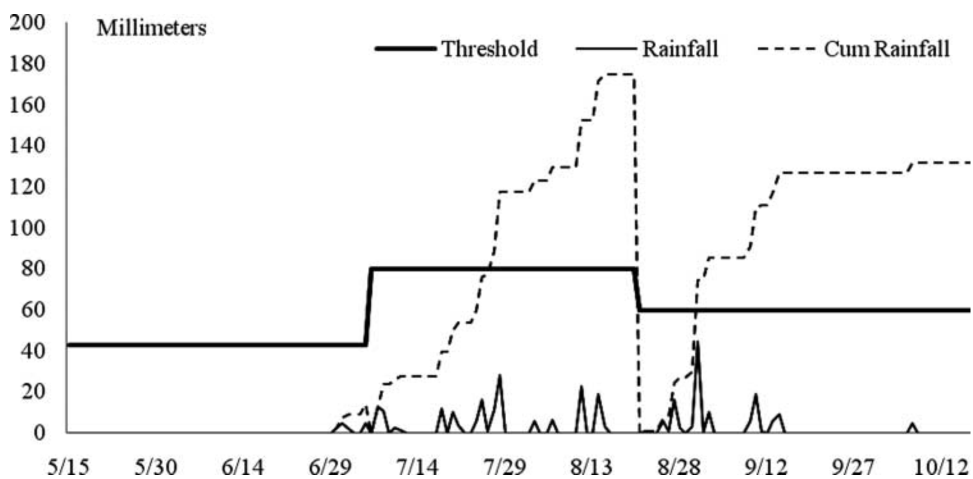

Figure 2. Weather insurance thresholds and actual rainfall: Leon, 2005

the program will be scaled up to the entire nation. In rolling out the program over larger regions, however, incentives to the farmers are lacking to diversify (i.e., into crops that are not insured), and so we see the risk of crop overspecialization. Maize monoculture has potential negative effects on the environment and long-term sustainability (Berzsenyi, Györffi, and Lap 2000).

More generally, a strong WII creates disincentives to invest in other important agricultural technologies. For example, WII may decrease efforts to invest in the development of irrigation systems because farmers are insured only if crops are planted on rainfed land. Irrigation, however, is widely accepted to be the main technology responsible for crop yield increases in arid areas, especially in developing countries. Similarly, due to the nationwide rollout of WII, the structure of the rural workforce can be affected by reducing off-farm income, which prior to the WII program was one of the major risk-coping mechanisms in Mexico.

Aggregate Equilibrium Effects of Disaster Prevention

The Mexican WII program was initially designed by the government for budget planning purposes to produce an *ex ante* disaster prevention strategy that has no volatility in budget size. There is considerable work on WII as a tool to prevent disasters and famines (Barnett, Barrett, and Skees 2008; Chantarat et al. 2007). For a WII program with such large coverage as in Mexico, however, the problem is that during food shortages, sudden indemnity payments can lead to rapid food price increases. This may be particularly true in rural areas, which are not well integrated into larger markets and where maize is a necessity with very low own-price elasticity of demand. Households not covered under WII would be especially vulnerable due to inflation (poor nonfarming population or firms that produce other crops than those that are insured).[4] This perverse price effect is likely even more important in less developed countries and in WII programs that cover perishable commodities of livestock or vegetables.

[4] In less developed African countries, the effect of a local price increase may be even larger because a larger portion of the population directly depends on farm income (and a larger percentage of the population would be hence insured) and because the agricultural markets are likely to be even less well integrated compared with the case of Mexico.

Conclusion

In this paper we outline the rapidly growing Mexican weather index insurance program and discuss some associated challenges. In particular we suggest, first, that the thresholds of the weather index be (continuously) recalibrated in order to adjust for the development of drought-resistant seeds. Second, the index could relatively easily be extended to account for precipitation variances. Third, we point out potential spillover effects on related markets: WII creates disincentives to invest in other non-insured crops, leading to potential overspecialization and monoculture. WII further generates disincentives to invest in irrigation systems because farmers are insured only as long as production takes place on non-irrigated land. Finally, in case of catastrophic events, food prices can inflate with indemnity payments at the expense of the uninsured poor. Clearly further research is necessary in order to evaluate the magnitude and the potential importance of these various side effects of WII. For preliminary results, see Fuchs and Wolff (2010).

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