

PERCEIVED BASIS RISK AND THE HETEROGENEOUS DEMAND FOR WEATHER DERIVATIVES IN SOUTHERN ETHIOPIA*

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Abstract

This paper investigates the role of basis risk in decisions to buy derivatives that protect against drought risk. We conducted a discrete choice experiment on a sample of Ethiopian farmers. The results suggest that there is an inverted U-shaped relationship between the contractual frequency of severe drought and the market share of insurance. In other words, when the contractual frequency differs from the average perceived frequency, demand decreases. This relationship is not verified for moderate drought insurance. These findings point to the necessity to design insurance for moderate drought events and for risk aggregators that can diversify the idiosyncratic risk component.

Key words: *weather derivatives; basis risk; Ethiopia; microfinance.*

JEL classification: *G23; Q14; C93; G21.*

1. INTRODUCTION

In most low-income countries, formal crop insurance schemes are still undergoing feasibility study or pilot phases. Factors such as the suitability of insurance to rural household needs, the significant presence of information asymmetries, and problems in distribution systems represent major challenges as Brown (2001) explains. Asymmetric information problems are especially common among traditional crop insurance schemes: moral hazards, for example, can reduce farmer incentives to produce (Hess, Richter & Stoppa, 2002);

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this is more evident among government insurance schemes (Viganò, 2002). Index-based insurance, for which payout is related to the realization of a specific climatic index correlated with crop yields (Bryla et al., 2003), is designed to overcome shortcomings of traditional insurance and to decrease ex-post verification costs (Hill & Robles, 2011). Several theoretical and empirical studies have been conducted on this topic. Several types of indexes have been proposed, with area-yields, livestock mortality rates, weather indexes and weather derivatives being the most common (FAO, 1992, 2001; Hess, Richter & Stoppa, 2002; Skees 2003; Skees et al., 2002). Despite the numerous pilot projects and actual applications that have been dedicated to these innovative insurance schemes, take-up ratios remain very limited, accounting for roughly 5-10% of the potential demand. As a result, intended purchasers have not yet shown an overall appreciation for various reasons (Clark & Kalani, 2012; Sarris, 2013). This lack of enthusiasm is indeed rooted in different factors: basis risk exposure, high premiums, transaction costs and difficulties associated with delivering products (Hess, 2003; Skees, 2003; Varangis, Larson & Anderson, 2002). All of these obstacles affect farmers' willingness to pay for insurance.

In this study, we aim to analyze the impact of perceived basis risk on potential demand for drought insurance. Basis risk stems from the imperfect correlation between the index and losses suffered by the insured. Leblois, Quirion and Sultan (2014) argue that there are three different types of basis risk: design basis risk, spatial basis risk, and idiosyncratic basis risk. Design basis risk results when the index not perfectly correlated with observed yields at a given geographic level. Spatial basis risk occurs as a consequence of the difference between weather experienced where a weather station is located and weather effectively experienced by a farmer (Norton et al., 2014). Idiosyncratic basis risk stems from dissimilarities between farmers in terms of agricultural practices and soil features. Barnett and Mahul (2007) observed that even though basis risk is often cited as an important factor that may explain the low demand for index insurance, few empirical studies of basis risk and of the willingness to pay for index insurance have been conducted. To the best of our knowledge, no experimental studies have empirically analyzed the relationship between potential demand and the degree of perceived basis risk implied in insurance contracts. This study is concerned with this specific objective. We focus on the perceived basis risk for farmers defined as the difference between the frequency of drought at a weather station and the perceived frequency of drought at a farmer's field. The perceived basis risk can therefore be a product of both spatial basis risk and idiosyncratic basis risk. To implement this analysis, we conducted a discrete choice experiment on a sample of Ethiopian households by offering hypo-

thetical heterogeneous weather derivatives that protect against drought risk. According to Hills and Robles (2011), these contracts are more suited to adapting to customer preferences, even if they are becoming increasingly interchangeable with index-based insurance (Berg et al., 2004). The effectiveness of these contracts at helping farmers manage their revenue variability has been proven by Hill and Robles (2011) and by Hess and Hazell (2009) in reference to different countries around the world.

The paper is organized as follows. Section 2 reviews the literature on determinants of the willingness to pay for index-based insurance with a focus on Ethiopia. Section 3 discusses the results of the existing literature on basis risk and on the willingness to pay for index-based insurance. Section 4 presents a simple model on the demand for weather insurance in the presence of basis risk. Section 5 describes the surveyed area, the experimental design employed and the selected product attributes. Section 6 presents our empirical approach. Sections 7 and 8 present the results of the empirical analysis and simulations of predicted aggregate demand based on different product characteristics, respectively. Section 9 concludes.

2. DEMAND FOR WEATHER INDEX-BASED INSURANCE IN DEVELOPING COUNTRIES

According to the existing literature, the most frequently cited factors that explain household decisions to either purchase or not purchase index insurance are related to a household's socio-economic characteristics or to features of the product or insurance delivery system in question. Soil quality levels, agro-climatic zones, and types of disaster risk are listed as objective factors (Hill & Robles, 2011; Sakurai & Reardon, 1997). For example, with regards to economic characteristics, some studies show that wealth has an ambiguous effect on the WTP (Patrick, 1988); assets, while serving as a buffer against shocks, may imply the existence of a moral hazard and may push farmers to take bigger risks. Land holdings may exhibit the same contradictory trends even though some studies prove a positive relationship between this attribute and the WTP (Aker et al., 2009). Clarke and Kalani (2012) find an interesting irregular pattern where the highest take-up ratio of insurance is associated with intermediate wealth levels. Cash holdings positively affect the WTP for index insurance (Cole et al., 2009), but a negative relationship can also be found, especially when cash comes from aid. In some studies, subsidies or initial endowments are found to serve as the main motivation that induces farmers to buy insurance (Sarris, 2013). However, subsidies and

endowments distort farmers' decisions and thus mislead interpretations of such results. As Sakurai and Reardon (1997) note, public food aid may have moral hazard effects on farmers' decisions as well.

Patt et al. (2009) focus on behavioral factors such as trust in suppliers, in products and in oneself. Cole et al. (2009) and Hill and Robles (2011) find that trust is a relevant determinant. Social links also play an important role in insurance take-up, and demand increases when potential customers buy a contract as a group (Hill, Hoddinott & Kumar, 2013), especially if they are uneducated. Akter et al. (2009) and Giné, Townsend and Vickery (2008) stress the importance of customer awareness in increasing the WTP.

Customers' capacities to understand and value insurance products are related to the complexities of certain attributes: price, maturity, delivery system, index type, triggers or thresholds, indemnities, etc. Insurance terms directly affect the WTP, and quite often their effects are combined. In fact, Cole et al. (2009) find that demand for index-based insurance may not be especially reactive to price but instead to the price and suitability of the selected index and to other contract conditions. Even implied transaction costs can be identified as an attribute. In this regard, Hill, Hoddinott and Kumar (2013) discover that distribution through local risk-sharing groups is preferred by customers and increases the WTP.

Generally speaking, potential customers appear to be sensitive to how flexible a product is and to how much a product can be adapted to their situation. For example, for Hill and Robles (2011), the basic principle is that Ethiopian farmers differ in terms of agricultural production and preferences and thus need different insurance contracts. The authors maintain that offering each farmer a combination of weather derivatives is preferable to offering a standardized index insurance product because while farmers are members of the same local risk-sharing group, they may make production decisions differently. Furthermore, McIntosh, Sarris and Papadopoulos (2013), who focus on the relationship between the use of fertilizers and weather index insurance in Ethiopia, highlight the importance of appropriate insurance design and challenges associated with product fine-tuning. Volpi (2005) also stresses that farmers are aware of multiple-risk exposure and that insurance only covers a single risk category. In fact, single-risk protection may not appeal when the associated price is not low enough. This supports arguments for a compound index product (Elabed et al., 2013) or for a combination of different weather derivatives covering more than one risk category (Hill, Hoddinott & Kumar, 2013).

Along with contract flexibility levels, farmers' attitudes toward risk and alternative risk management strategy access are other key factors. Perceived risk exposure has been found to be positively associated with higher WTP for insur-

ance (Hill, Hoddinott & Kumar, 2013). A negative relationship between risk aversion and WTP has been found under specific conditions by Hill, Hoddinott and Kumar (2013) for Ethiopia. Giné, Townsend and Vickery (2008), in reference to India, find that risk-averse households are less likely to purchase if they are unfamiliar with an insurance contract or dealer. Hill and Viceiza (2010), on the other hand, through their field experiments conducted in southern Ethiopia, reveal a positive link between insurance purchases and risk aversion.

Risk exposure and attitudes towards risk affect the WTP in different ways, as households use different strategies in managing hazards both *ex ante* and *ex post*. Sakurai and Reardon (1997), for example, find that wealthier and more self-insured farmers demand less formal drought insurance. However, this is dependent on the stratum of the sample surveyed; for example, in the upper stratum, neither off-farm income nor livestock holdings have a significant effect (Sakurai & Reardon, 1997). Akter et al. (2009) also stress the role of different risk management strategies, finding that land extension, household head occupation, land ownership and farm size are all related to capacities to self-manage risk. In reference to India, Gautam, Hazell and Alderman (1994) empirically tested a joint hypothesis of risk avoidance and welfare smoothing to study latent demand due to inadequate risk management strategies. Their results prove that demand is high. Hill, Hoddinott and Kumar (2013) also confirm that those with higher risk exposure and, somewhat controversially, those who are more risk-averse purchase more insurance and that potential customers tend to optimize risk management by combining informal risk sharing and insurance depending on levels and types of risk involved.

Norton et al. (2014), through experimental games conducted in Ethiopia, allowed farmers to allocate an initial cash endowment from different options: purchase drought index insurance, invest in simulated savings accounts, participate in risk-sharing groups, or hold cash. Higher frequency payouts are recorded as a preference for liquidity but also as a consequence of insufficient self-insuring mechanisms that are likely to be more cost-effective. Insurance was also more frequently selected over savings and participation in risk sharing groups. These results refute the common belief that poor farmers minimize their expenses and related insurance coverage. Clark and Kalani (2012), through their experiments in Ethiopia, analyze determinants of the WTP for index and indemnity insurance. They find that past exposure to shocks plays a key role in positively influencing take-up rates of indemnity insurance. Generally speaking, participation in risk-sharing groups has the same effects on both types of insurance.

New insights are also found through the field research presented in this paper.

3. BASIS RISK AND DEMAND FOR WEATHER INDEX-BASED INSURANCE

Another important determinant of the demand for index-based insurance is the degree of basis risk implied in a contract. The terms and conditions of an insurance product affect the amplitude of basis risk (Fuchs & Wolff, 2011; Hill, Hoddinott & Kumar, 2013): the more a product is designed such that payouts are aligned with actual losses, the higher the preference for insurance is. Basis risk can also be expressed in terms of probability. We define a potential “false negative” as the probability that the farmer will not be indemnified when losses occur in the farmer’s field, and a potential “false positive” is defined as the probability that the farmer will be indemnified when losses do not occur. Leblois, Quirion and Sultan (2014) find that weather index-based insurance for cotton growers in Cameroon suffers from large basis risk regardless of the index considered, and so this type of insurance can hardly contribute to income smoothing. They indeed find a very high basis risk exceeding a value of 50% for most indices. In Mali, Elabed et al. (2013) also study a sample of cotton growers. They analyze demand for an average area-yield index insurance contract using data on risk distribution and risk aversion. In particular, the authors compare latent demand for a single-index insurance contract with demand for an insurance contract based on a two-scale index. For the latter, the first trigger at the district level is designed to reduce moral hazard levels while the second trigger at the village level is designed to lessen basis risk. The authors note that ambiguity and compound risk aversion further decrease demand at every level of basis risk. Demand for two-scale contracts would be roughly 40% higher than demand for a single-index contract (55% vs. 39%). In particular, the two-scale index reduces the incidence of false negatives and it completely eliminates false positives. In reference to Ethiopia, Hill, Hoddinott and Kumar (2013) find that 30% of surveyed households would not continue purchasing index-based insurance if they suffered losses but experienced no indemnity. The authors also find that one’s distance from a weather station, as a proxy of basis risk, is an important determinant of demand. For example, increasing the distance from 5 to 15 km reduces demand by roughly 20%. Clarke and Kalani (2012) also conducted a study in Ethiopia and found that selling index insurance to local informal risk-sharing groups may increase take-up levels, as households can pool idiosyncratic risk within a group. A similar approach is used by Mobarak and Rosenzweig (2012), who find that negative effects of basis risk are reduced for households in Indian sub-castes that are more able to indemnify individual losses. Furthermore, the authors discover that in villages with no

basis risk, demand for index insurance is not related to informal network capacities to cover idiosyncratic risks. Finally, Giné, Townsend and Vickery (2008) put forward that among the Indian households that they surveyed, demand for insurance is greater for those households that have historically cultivated a large share of the two crops that index-based insurance targets. Depending on the type of insured crop concerned, the probability of purchasing insurance increases by 34 or 59% when a household cultivates that crop alone. Additionally, the authors find that 24% of households do not purchase insurance due to basis risks.

This study aims to contribute to this stream of literature. In particular, we intend to determine whether perceived basis risk affects demand for index-based drought insurance, and if our hypothesis is verified, we wish to also measure changes in demand relative to changes in the degree of perceived basis risk. The few existing studies that have examined the influence of basis risk on the WTP for index insurance have attempted to address the former issue but have hardly provided an estimate of the structure and shape of the relationship between the two. Moreover, while such studies focus on real basis risk, this study is concerned with perceived basis risk.

4. THEORETICAL MODEL

The insurance contract that was offered to farmers during the field experiment provides an indemnity that is proportional to a given premium and to the probability of drought at a weather station location¹. Thus, if a premium is \$100 and if the probability level is 0.5, the indemnity is \$200. However, the probability perceived by a farmer can differ from the contractual probability that gives rise to a perceived basis risk. In this section, we present a simple framework of weather insurance demand in the presence of perceived basis risk to draw theoretical hypotheses that are to be tested in the empirical analysis. Assume that a farmer is presented with an opportunity to buy a weather derivative product that protects against drought. The index is measured at a weather station located a certain distance away from the farmer's field. When a drought occurs, the farmer receives an indemnity equal to a fixed premium times the inverse of the probability of drought at the station field location.

The insurance company offers two different products: a weather derivative with basis risk and a weather derivative without basis risk. For the latter

¹ For the sake of simplicity, we assume in the theoretical model that the premium is the fair premium.

product, the perceived probability of drought at the farmer's field $\pi(f)$, is equal to the contractual probability of drought $\pi(w)$ and these two probabilities are perfectly correlated, i.e. $\pi(w|f) = 1$. If the farmer pays a fair premium p , when a drought occurs, she receives $p/\pi(f)$. If we further assume that for the product without basis risk, the indemnity, $p/\pi(f)$ is equal to the farmer's loss when a drought occurs, L , then the expected utility can be expressed as follows:

$$\pi(f)u\left(-p + \frac{p}{\pi(f)} - L\right) + (1 - \pi(f))u(-p) = u(-p) \quad (1)$$

with $u' > 0$ and $u'' < 0$.

On the other hand, in the presence of perceived basis risk, we have following four possible outcomes:

- I. $-p + \frac{p}{\pi(w)} - L$ with probability $\pi(w)\pi(w|f) = \pi(f)\pi(w|f)$;
- II. $-p + \frac{p}{\pi(w)}$ with probability $\pi(w)\pi(nf|w) = \pi(nf)\pi(w|nf)$ where $\pi(nf)$ is the probability that no drought will occur at the farmer's field;
- III. $-p - L$ with probability $\pi(nw)\pi(f|nw) = \pi(f)\pi(nw|f)$ where $\pi(nw)$ is the probability that no drought will occur at the weather station field;
- IV. $-p$ with probability $\pi(nw)\pi(nf|nw) = \pi(nf)\pi(nw|nf)$

The farmer's expected utility in the case of perceived basis risk is then:

$$\begin{aligned} &\pi(w)\pi(f|w)u\left(-p + \frac{p}{\pi(w)} - L\right) + \pi(w)\pi(nf|w)u\left(-p + \frac{p}{\pi(w)}\right) + \\ &+ \pi(nw)\pi(f|nw)u(-p - L) + \pi(nw)\pi(nf|nw)u(-p) \end{aligned} \quad (2)$$

It follows that the farmer will prefer the product with basis risk to the product without basis risk if and only if the following condition is verified:

$$\begin{aligned} &\pi(w)\left(\pi(f|w)u\left(-p + \frac{p}{\pi(w)} - L\right) + \pi(nf|w)u\left(-p + \frac{p}{\pi(w)}\right) - u(-p)\right) \\ &> -\pi(nw)\pi(f|nw)(u(-p - L) - u(-p)) \end{aligned} \quad (3)$$

Inequality (3) states that the product with perceived basis risk is preferred when the expected utility of the positive outcome is greater than the expected utility of negative outcomes. The expression on the right side of the inequality is always positive and thus for the condition to be verified, the expression on the left side must also be positive. As p , L , and $\pi(f)$ are given, the condition is dependent on $\pi(w)$. Interpretations of the results are however not straightforward. The main issue relates to the fact that $\pi(f)$ is a perceived probability and thus even conditional probabilities with respect to $\pi(w)$ are perceived and personally interpreted by the farmer. It follows that as $\pi(w)$ changes, conditional probabilities change not only according to the new frequency of and but also according to farmer's preferences and perceptions. Only an empirical analysis can address this conundrum.

However, some preliminary considerations can be drawn. If the frequency of drought at the weather station is equal to the perceived frequency of drought at the farmer's field, i.e., $\pi(w) = \pi(f)$, then $\pi(w|f) = \pi(f|w)$ and $\pi(nf|w) = \pi(nw|f)$. In the field experiments, as understood by the surveyed farmers, this case corresponds a case without basis risk with $\pi(w|f) = \pi(f|w) = 1$ and $\pi(nf|w) = \pi(nw|f) = 0$. An increase in $\pi(w)$ with respect to $\pi(f)$ implies that $\pi(w|f) > \pi(f|w)$ and $\pi(nf|w) > \pi(nw|f)$, but this also implies a $p/\pi(w)$ that is smaller than L . This case thus implies an increase in the probability of false positives relative to the probability of false negatives, but the expected negative utility of partial protection from drought impacts may also increase. On the other hand, a decrease in $\pi(w)$ implies a greater $p/\pi(w)$ but also $\pi(w|f) > \pi(f|w)$ and $\pi(nf|w) > \pi(nw|f)$. In this case, even though the indemnity covers potential losses, the probability of suffering a loss without receiving the indemnity is greater than that when no basis risk is present.

These considerations suggest that when the farmer is sufficiently risk-averse, i.e., she gives more prominence to expected losses than to expected rewards, preferences for the product without basis risk may always be dominant. If we assume as well that the implied lottery is ambiguous for the farmer and that risk aversion is therefore compound as stated in Elabed et al. (2013), and thus, negative effects of perceived basis risk on insurance demand can be even more significant. This implies an inverted U-shaped relationship between $\pi(w)$ and the WTP. If the farmer is not sufficiently risk-averse, decreasing, increasing, or U-shaped relationships are possible.

In the following sections, which focus on our empirical analysis, we test these hypotheses on the relationship between $\pi(w)$ and the WTP for weather derivatives by considering a sample of rural Ethiopian farmers.

5. EXPERIMENTAL DESIGN AND SAMPLE DESCRIPTION

To empirically study the effect of perceived basis risk on weather derivative purchase decisions, we conducted a field experiment on a sample of rural Ethiopian farmers. The experiment was designed according to a linear random utility model. In particular, we assume that the utility that each farmer obtains from the insurance product is a linear combination of its attributes, X_i 's, and a random component, ϵ :

$$P \sum_{i=1}^J \beta_i X_i + \epsilon \quad (4)$$

Equation (4) points to a straightforward approach to both data collection and empirical analysis. Data were collected through a fractional factorial design discrete choice experiment whereby surveyed households were asked to make a selection from different choice sets (Hensher, Rose & Greene, 2005). In discrete choice experiments, each choice set is composed of two or more alternatives where one alternative may be the status quo. In our case, the non-status quo alternatives are characterized by insurance product attributes while the status quo alternative is the no-insurance case, i.e., the current farmer's status.

The experiment complies with orthogonality in the product's attributes (Hensher, Rose & Greene, 2005). Apart from the traditional advantages of choice modeling (Centre for International Economics, 2001), providing different combinations of premiums and other attributes allows one to test for heterogeneities in household preferences. The expected results of this small-scale field experiment may, however, be controversial due to the questionability of the experiments themselves as previously explained. However, bearing in mind these limitations, we can still provide interesting insights. The empirical methodology used is discussed in detail in the following section.

The experiment involved studying 205 Ethiopian farmers in the Wolayta zone (SNNP region) over a period of 3 weeks in November of 2013. The farmers were randomly selected from a larger sample of 360 households already involved in a three-year data collection project (2010-2013). The surveyed farmers were from three *Kebele*, i.e., the smallest administrative unit, which are improperly referred to as villages in this study. The villages are representative of three different agro-ecological zones of the Wolayta area that differ in terms of altitude, rainfall patterns, and household livelihood

strategies. The zones are named by the Ethiopian Ministry of Agriculture after their characteristic crops: the ginger and coffee zone, the barley and wheat zone, and the maize and root crop zone.

We decided to keep the field experiment as simple as possible. We opted for an insurance product with a limited number of attributes and attribute levels. We used this approach for two reasons. First, the percentage of illiterate individuals participating in the study was high (25%), and second, neither traditional crop insurance nor other types of formal insurance were available at the time when the survey was conducted. These two problems can limit interviewees' capacities to fully understand the insurance product and the utility that they can derive from using it. Preliminary training on the hypothetical insurance product was also provided to all farmers in groups of 10-20. The training focused on the terms of the contract (drought types, drought frequency, premiums and indemnity) and on issues of basis risk in particular. The latter term was explained as rainfall realizations were measured at the weather station located in the closest district town. In particular, the presence of basis risk was expressed in terms of the difference between the frequency of drought implied in the insurance contract and the frequency of drought at the farmer's field. In the surveyed area, the presence of basis risk is indeed relevant. For instance, Figure 1 presents the empirical distribution of the difference by village in terms of rainfall patterns between the farmer's field and the rest of the Wolayta zone as perceived by the interviewed farmers. This first suggests that variations are remarkable and second that the lower the altitude, the greater the perceived difference². Even the perceived rainfall pattern at the closest weather station differs from the perceived pattern at the farmer's field. In particular, Figure 2 shows that the lower the altitude, the greater the level of perceived performance dispersion at the closest weather station. There are thus also remarkable variations among farmers in terms of perceived drought frequency levels.

The hypothetical product offered to the farmers was not designed according to real rainfall data, but instead according to stated drought frequencies. The frequency data were retrieved from a previous experiment on weather insurance that was conducted in the same villages in March of 2013 (Castellani, Viganò & Tamre, 2014). We selected four values of empirical distributions of stated frequencies that we believe to be representative of the entire distribution: 2 and 3 years for moderate drought, and 10 and 18 years for se-

² Abala Faracho is located at an altitude of roughly 1,400 meters above sea level, Hembecchio is located at an altitude of roughly 1,600 metres above sea level, and Kutto Sorfella is located at an altitude of roughly 1,800 metres above sea level.

Figure 1: *Empirical distribution (Kernel density estimate) of the perceived difference (from 0 to 1) in rainfall patterns between the weather station location and farmer's field location.*

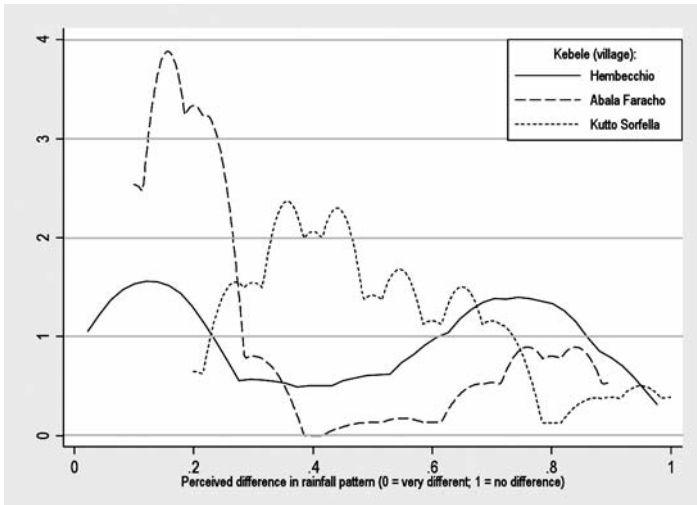
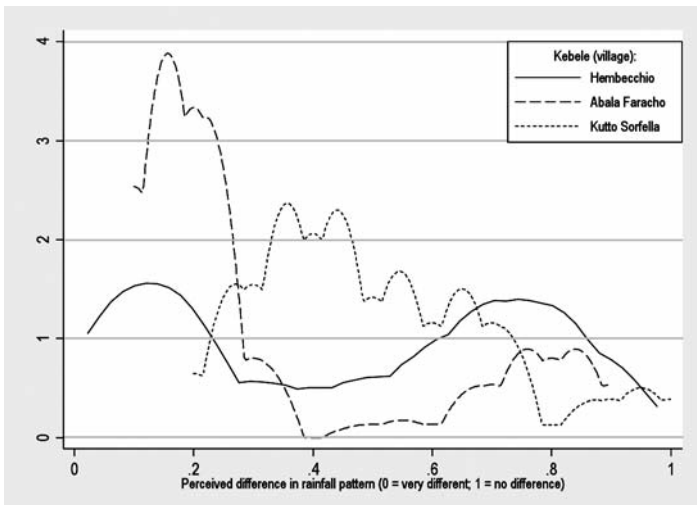


Figure 2: *Empirical distribution (Kernel density estimate) of the perceived rainfall performance (from -1 to 1) at the weather station location compared to that at the farmer's field (negative values correspond to less rainfall on average; positive values correspond to more rainfall on average).*

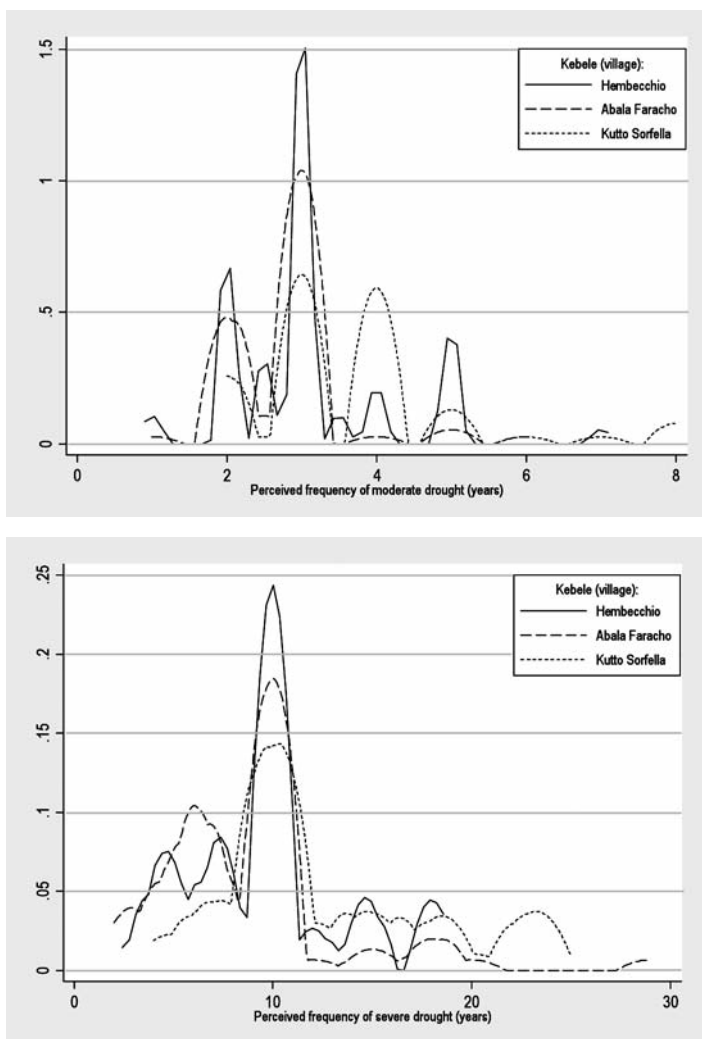


vere drought. The product pays a fixed indemnity when a moderate or severe drought occurs. We provided farmers with simple and straightforward definitions of moderate and severe drought that were agreed upon during focus group activities held one week prior to the start of the experiment. A moderate drought was defined as “insufficient rainfall that leads to a reduction of production yield and lack of grazing land”, and a severe drought was defined as “no rainfall at all that results in no agricultural production, no consumption, high levels of poverty and the death of human beings, animals and plants”. Though these definitions appear to be quite vague, the fact that they were established in collaboration with the farmers makes them relevant for the purposes of the experiment. This is further supported by values of drought frequency reported by farmers participating in the experiment. Indeed, the average perceived frequency of a moderate drought is one in roughly every 3 years (Std. Dev. 1.14), while the average perceived frequency of a severe drought is one in roughly every 10 years (Std. Dev. 4.83). Figure 3 presents the empirical distributions of the perceived frequency of moderate and severe drought. Apart from further supporting the notion that there is a potential basis risk given overall dispersion in the values, the distributions are consistent with the specific geographic characteristics of each village, and in particular with the fact that lower altitudes correspond with higher levels of perceived drought frequency.

The fair premium for each insurance product was established beforehand. The objective was to build reasonable hypothetical products that households could actually afford. The range of the fair premium was settled by using as a benchmark the premium of a drought insurance product that was already available in another area of the same region and that had proven to be somewhat successful (Hill & Robles, 2011). Fair premium levels were ETB 50 and ETB 100. The indemnity was then determined as the ratio between the fair premium and selected drought probability, i.e., the inverse of the frequency. The coverage period for the proposed insurance product ran from the start of the *Belg* or “small rains” season (March/April) to the end of the *Meher* or “big rains” season (September/October). *Belg* and *Meher* are the agricultural seasons in Ethiopia. In the surveyed area, farmers typically buy inputs such as improved seeds and fertilizers at the start of the *Belg* season and sell most agricultural products at the end of the *Meher* season.

We created four different types of questionnaires to shorten the interview period while at the same time allowing for all combinations of product attributes and attribute levels. The questionnaires were then allocated randomly to the entire sample in equal proportions. Thus, of the 205 participating farmers, roughly 50 completed to the same type of questionnaire. Each

Figure 3: Empirical distribution (Kernel density estimate) of the perceived frequency (in years) of moderate and severe drought events.



questionnaire includes eight different choice situations (or choice sets), with four pertaining to moderate drought and four pertaining to severe drought. For each choice situation, the respondent could opt for one of two different insurance products or the status quo alternative. When an insurance alternative was selected, the interviewee was asked to report the number of insur-

ance contracts of the selected insurance type he/she would be willing to purchase assuming that the total premium would be paid and assuming the total expected indemnity value.

Apart from frequency, premium and indemnity, other product attributes included the following: loading, home delivery, and deferred payment. The first attribute is critical to the sustainability of the insurance scheme. It is a non-explicit attribute, as it is only implied in the premium, and the farmers were not told whether the premium included the loading or not. This attribute only leads to an increase in the premium. In the experiment, we avoided allowing for choices between products with the same characteristics apart from loading features³. The loading consists of a 15% increase in the fair premium that is offered by the insurer to cover the operating cost. This percentage is hypothetical and does not necessarily correspond to the real cost. The loading attribute levels used are therefore referred to as “loading” and “not loading” levels. The second attribute, i.e., home delivery, was included to estimate the impact of customer transaction costs on demand. These costs can be remarkable in rural areas of developing countries. Several microfinance initiatives are successful because they have been able to dramatically reduce customer transaction costs. Home delivery implies that the insurance product is delivered and paid at the household’s doorstep as well as when the indemnity is to be redeemed. In the opposite case, the household must travel to the main district town to perform all transactions. This attribute allows for possible transaction costs that arise from the opportunity cost of time and from potential transportation costs. All main district towns are positioned between 15 and 20 km from village administration units, which are typically located at a village’s midpoint. Whereas some households in the surveyed area are positioned very close to a district town and have easy access on foot, for other households, this distance can be relevant and can imply high transaction costs. The last attribute is the deferred payment. As discussed in the review of existing studies, the liquidity problem indeed seems to be one of the most important constraints on the take-up of weather insurance. In the experiment, households could pay the premium before (at the beginning of the *Belg* season) or after the rainy season (at the end of the *Meher* season). A deferred payment implies an extra premium of 10% as an interest rate⁴.

³ This would have been nonsense and similar to just an increase in the premium of two equal alternatives.

⁴ At the time of the experiment, local microfinance institutions offered microloans with interest rates of between 10 and 15%. The time coverage of our insurance product is 9 months, and thus we opted for a 10% interest rate.

Whether the deferred payment is preferable depends on two factors. First, the period after the rainy season corresponds to the main harvest and most crop cash income is generated during this period. Despite the fact that experiments should avoid liquidity problems, liquidity can still be perceived as a constraint and households may prefer to pay the premium when most of the liquidity is available. Second, households can be impatient and can discount future payments more than the implied interest rate. This can also contribute to a preference for deferred payments.

Figure 4 presents an example choice set.

Figure 4: Example choice set.

Choice set 1	A	B	SQ
Frequency (years)	3	2	
Premium (ETB)	100	110 (including interest)	
Indemnity (ETB)	300	200	
Deferred Payment	No	Yes	
Home delivery	Yes	No	
	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Number of contracts	Premium (Indemnity)	Premium (Indemnity)	
1	100 (300)	110 (200)	
2	200 (600)	220 (400)	
	

6. EMPIRICAL APPROACH

Our empirical approach relies on the assumption that demand for weather insurance can be heterogeneous due to the presence of observable and unobservable factors. Household and product characteristics, including the underlying basis risk, can be identified as observable characteristics. Heterogeneities in product demand imply that the utility that each individual obtains when a product is standardized is remarkably dissimilar. In equation (4), heterogeneity can be expressed through individual specific parameters of the attributes that allow for taste variations. Assume that a household n can make a selection from j alternatives in each t choice situation. Equation (4) can be reformulated as follows⁵:

⁵ Equation (1) shows how utility is typically represented in discrete choice models (Hensher, Rose & Greene, 2005).

$$U_{njt} = \beta'_n x_{njt} + \varepsilon_{njt} \quad (5)$$

where x_{njt} are the attributes and ε_{njt} is a random term. The coefficient vector β_n is unobserved by the researcher and varies across households with density $f(\beta_n | \Omega)$ where Ω denotes parameters of the distribution that are to be estimated. The stochastic element $\varepsilon_{njt}\varepsilon_{njt}\varepsilon_{njt}$ is also unobserved and different assumptions on its distribution result in different choice models. As is usually common of choice analyses, we impose the condition that $\varepsilon_{njt}\varepsilon_{njt}\varepsilon_{njt}$ is an independent and identically distributed (IID) extreme value type 1 (or Gumbel) across n, j , and t (Hensher, Rose & Greene, 2005). Conditional on $\beta_n\beta_n$, the logit probability of household n choosing alternative j in the choice situation t is:

$$\pi_{njt}^{std} = \frac{e^{\beta'_n x_{njt}}}{\sum_i e^{\beta'_n x_{njt}}}, i = 1, \dots, J \quad (6)$$

The standard logit model, as expressed by equation (6), does not allow for unobserved characteristics that can induce correlations between the alternatives in a choice situation and among choices over time. The mixed multinomial logit model, i.e., the unconditional logit probability, overcomes these restrictions by allowing for variance in the unobserved household-specific parameters, and it is thus not independent of irrelevant alternatives (IIA) (Revelt & Train, 1998). The mixed logit probability is:

$$\pi_{njt}^{mix} = \int \left(\frac{e^{\beta'_n x_{njt}}}{\sum_i e^{\beta'_n x_{njt}}} \right) f(\beta_n | \Omega), i = 1, \dots, J \quad (7)$$

Equation (7) is a weighted average of the logit formula evaluated for different values of β_n . It follows that the mixed logit probability for the sequence of choices is:

$$\Pi_{njt}^{mix} = \int \prod_t \left(\frac{e^{\beta'_n x_{njt}}}{\sum_i e^{\beta'_n x_{njt}}} \right) f(\beta_n | \Omega), i = 1, \dots, J \quad (8)$$

In equation (8), we wish to estimate Ω , i.e., population parameters that describe the distribution of individual parameters (Revelt & Train, 1998). Moreover, normally distributed zero mean error components based on a household's characteristics are added to the mixed logit model to allow for different variances of the insurance alternatives and status quo option, i.e., to accommodate heteroskedasticity (Scarpa, Willis & Acutt, 2007).

7. RESULTS

In the surveyed area and in much of rural Ethiopia, traditional and index-based crop insurance products are not available. One implication for our analysis is that there is no insurance alternative to the hypothetical products offered in the experiment. The status quo is therefore a no-choice option. The status-quo equation is represented by the status-quo constant, by village constants and by the error components. The former constant controls for the gain or loss in utility the results when a household remains in the status quo condition and does not select any insurance option. Village constants allow for unknown effects of differences in social, economic and geographic characteristics between villages. We also include two zero-mean error components. The first error component is a dummy variable that takes a value of 1 if the interviewee is illiterate and a value of 0 otherwise. As stated above, illiterate individuals can be less able to appraise the value of insurance. The second error component is a dummy variable that considers interviewee gender. Females are typically not primarily involved in agricultural activity though they carry out some tasks. They may therefore be less aware of the impact of droughts on agricultural production.

It is important to note that the degree of risk aversion and other non-observable farmer characteristics can potentially drive the results. However, specific patterns of correlation across alternatives induced by the additional random components partially control for time-invariant characteristics. The mixed logit model also allows one to estimate a specific coefficient for each farmer that can be related to non-observable factors. Finally, the results of an analysis conducted on the same data by [QUOTATION OMITTED FOR REVIEW] show that many variables that also proxy for non-observable characteristics cannot explain farmers' choices.

The equations on insurance alternatives are a linear combination of the attributes excluding the contractual frequency of drought, as this is assumed to be collinear with the indemnity⁶. Moreover, we do not impose any particular restriction on the premium distribution to allow for inconsistent behaviors that were observed in Castellani, Viganò and Tamre (2014). These inconsistencies are explained below as a consequence of the presence of basis risk in the weather derivative.

Table 1 presents descriptive statistics on dependent and independent variables for each of the two models, i.e., moderate and severe. Statistics on

⁶ Preliminary estimations support this assumption. When the frequency variable is included, premium and indemnity coefficients become statistically insignificant.

the main variable of interest, the proxy for perceived basis risk, show that on average, while the moderate product seems to suffer from a limited “false positive” problem (0.14), the severe product can be affected by a remarkable “false negative” problem (-0.25). It is also important to acknowledge that 25% of the respondents are illiterate and 53% are women.

Table 1: Descriptive statistics

Variable	Moderate					Severe				
	Obs	Mean	Std. Dev.	Min	Max	Obs	Mean	Std. Dev.	Min	Max
<i>Dep. Var.</i>										
Choice	2459	0.3335	0.4715	0	1	2461	0.3332	0.4715	0	1
<i>Product attributes</i>										
Premium (P)	2459	58.6763	47.3073	0	125	2461	56.4791	46.2264	0	125
Indemnity (In)	2459	131.3339	112.5889	0	300	2461	699.9187	627.3379	0	1800
Delayed payment (Dp)	2459	0.3331	0.4714	0	1	2461	0.3328	0.4713	0	1
Home delivery (Hd)	2459	0.7088	0.4544	0	1	2461	0.6668	0.4715	0	1
<i>Basis risk proxy</i>										
Basis risk (Br)	2451	0.1352	0.3329	-1.099	1.386	2461	-0.2460	0.4917	-2.1972	1.0647
<i>Status-quo controls</i>										
Status-quo constant (Sq)	2459	0.3331	0.4714	0	1	2461	0.3336	0.4716	0	1
Illiterate (Il)	2423	0.2509	0.4336	0	1	2425	0.2507	0.4335	0	1
Gender (G)	2423	0.5316	0.4991	0	1	2425	0.5311	0.4991	0	1

Note: village constants are omitted as they provide trivial information.

In particular, we estimate three different specifications of the econometric model. For every farmer i and each alternative j (1, 2 and 3), the first econometric specification is as follows:

$$U_{ij} = \begin{cases} \beta_1^1 P_{i1} + \beta_1^2 In_{i1} + \beta_1^3 Dp_{i1} + \beta_1^4 Hd_{i1} + \varepsilon_{i1} \\ \beta_2^1 P_{i2} + \beta_2^2 In_{i2} + \beta_2^3 Dp_{i2} + \beta_2^4 Hd_{i2} + \varepsilon_{i2} \\ \alpha_{i3}^1 Sq_{i3} + \sum_{h=1}^2 \alpha_3^{1+h} \text{village const. } h + \varepsilon_{i3} + \varepsilon_{i3}^1 \times Il_{i3} + \varepsilon_{i3}^2 \times G_{i3} \end{cases} \quad (9)$$

This specification is used to check for inconsistencies as a base model for comparisons with the other specifications. The last two specifications also include interactions of the premium and indemnity variables with a proxy of

the perceived geographic basis risk. The proxy of basis risk is given by the natural log of the ratio between the perceived frequency of drought at the farmer's field and the frequency of drought implied in the insurance contract. It is therefore a measure of the difference between the two frequencies. The proxy is interacted with the premium and indemnity because the latter is proportional to the former through the contract drought frequency. We thus believe that the other variables are not affected by the presence of perceived basis risk⁷. The second specification can be expressed as:

$$U_{ij} = \begin{cases} \beta_{i1}^1 P_{i1} + \beta_{i1}^2 (P \times Br)_{i1} + \beta_{i1}^3 \ln_{i1} + \beta_{i1}^4 (\ln \times Br)_{i1} + \beta_{i1}^5 Dp_{i1} + \beta_{i1}^6 Hd_{i1} + \varepsilon_{i1} \\ \beta_{i2}^1 P_{i2} + \beta_{i2}^2 (P \times Br)_{i2} + \beta_{i2}^3 \ln_{i2} + \beta_{i2}^4 (\ln \times Br)_{i2} + \beta_{i2}^5 Dp_{i2} + \beta_{i2}^6 Hd_{i2} + \varepsilon_{i2} \\ \alpha_{i3}^1 Sq_{i3} + \sum_{h=1}^2 \alpha_3^{1+h} \text{village const. } h + \varepsilon_{i3} + \varepsilon_{i3}^1 \times Il_{i3} + \varepsilon_{i3}^2 \times G_{i3} \end{cases} \quad (10)$$

Finally, the third specification is used to predict the market demand and for this reason, it only includes variables of the second specification that are statistically significant.

Table 2 lists the estimation results of the first specification, which does not consider the basis risk proxy. First, the village constants and error components are not statistically significant. This may suggest that the model's specification is not appropriate. However, with regards to the selected error components, they become significant in the other specifications when the basis risk variable is included.

Second, statistically significant estimates of the standard deviations for the indemnity, home delivery, and status-quo variables suggest the presence of a remarkable heterogeneity in demand for both severe and moderate drought insurance. Farmers thus exhibit different preferences in terms of insurance prices, transaction costs and utility that they derive from using insurance. These findings suggest that a one-size-fits-all approach to drought insurance design may not work. On the other hand, the premium and deferred payment attributes appear to have fixed parameters. Moreover, the mean coefficient of the latter is not statistically significant, suggesting that the capacity to pay at the end of the agricultural cycle plays no role in a decision to buy the product. This may be attributable to the fact that this is an experiment, and liquidity constraints may play a minor role in comparison to real insurance schemes.

⁷ Alternative empirical estimations demonstrate that basis risk proxy interactions with delayed payment and home delivery are not statistically significant.

**Table 2: Estimation results of the first specification
(without the basis risk proxy).**

	Severe		Moderate	
	Estimate	Std Err.	Estimate	Std Err.
Premium	0.0185***	0.0047	-0.0119**	0.0056
Std dev. Premium	0.0020	0.0097	-0.0100	0.0096
Indemnity	-0.0009***	0.0003	0.0062***	0.0020
Std dev. Indemnity	0.0014***	0.0004	0.0075***	0.0021
Delayed payment	-0.2639	0.2262	-0.1105	0.1383
Std dev. Delayed payment	-0.8520	0.5388	-0.1235	0.7948
Home delivery	2.3120***	0.3941	1.8374***	0.2871
Std dev. Home delivery	3.5015***	0.5290	2.1147***	0.3782
Status-quo constant	-4.9727***	1.0152	-5.3971***	1.0800
Std dev. Status-quo constant	3.9759***	0.7567	4.3087***	0.8667
Village constant 1	1.9320*	1.1278	0.9028	1.1006
Village constant 2	-0.1149	1.1581	-0.4261	1.2108
Err. comp. (Illiterate)	2.5316	1.6505	2.3681	1.7438
Err. comp. (Gender)	1.8943*	1.1339	0.5747	1.0336
Number of obs.	2,424		2,423	
LR - χ^2	62.63***		68.18	
Pseudo-R2	0.23		0.25	

*** Significant at 1%. ** Significant at 5%. * Significant at 10%.

The home delivery coefficient is positive for 75% of the sample in the case of severe drought insurance and it is positive for 81% of the sample in the case of moderate drought insurance. These percentages are consistent over the three specifications. This suggests that transaction costs in terms of transportation and time opportunity costs are important determinants of the WTP for drought insurance. This result is also consistent with Hill, Hoddinott and Kumar (2013), who find that insurance delivery through local risk-sharing networks constitutes an important factor affecting decisions on insurance purchases. Additionally, the estimated mean and standard deviation of the status quo constant indicate that insurance is strongly preferred to a no-insurance situation, and it would increase utility levels for nearly 90% of the surveyed farmers. Estimates for the indemnity coefficient are controversial. Whereas in the case of moderate drought insurance it is

positive for 80% of the sample, it is negative for 74% of the sample in the case of severe drought insurance. Moreover, as expected, coefficients of the premium are statistically significant for both types of insurance and have the opposite sign as that of the indemnity. However, while for the “moderate” model signs are consistent with the law of demand, i.e., negative for premium and positive for indemnity, for the “severe” model, the signs are inverted. This inconsistency is similar to the one found by Castellani, Viganò and Tamre (2014). A possible theoretical explanation rests on the hypothesis that insurance for severe drought has no close substitutes and is similar to a Giffen good. For insurance to be a Giffen good, absolute risk aversion must increase or decrease fast enough (Briys, Dionne & Eeckhoudt, 1989). The price increase is then translated into a wealth decrease, i.e., a negative wealth effect. If this negative wealth effect heightens the absolute risk aversion rapidly, then the individual may purchase more insurance even as the price increases. However, we believe that this counterintuitive theoretical explanation is only possible in real insurance schemes and not in one-time field experiments. Another possible explanation is offered by Norton et al. (2014), who find that households prefer frequent payouts. In our case, severe drought is a very low frequency event and the negative frequency effect may dominate price and indemnity effects. We however argue that the perceived basis risk can primarily drive results. The distribution of the perceived frequency of severe drought is indeed skewed below the average contractual frequency (14 years). Thus, as the contractual frequency level increases, the indemnity also increases. For instance, when farmers are faced with the decision to buy a contract with a frequency of 10 years or a contract with a frequency of 18 years, they opt for the former, as the contractual frequency of drought is closer to the frequency that they perceive. We test for this hypothesis in the second specification of the empirical model where we interact both the premium and indemnity with our proxy of basis risk.

Table 3 reports the results of the second specification. According to our intuition, for the “severe” model, interactions are very statistically significant while the indemnity coefficient becomes, despite still being negative, altogether statistically insignificant. The coefficient of the premium is still positive and statistically significant, but the overall sign depends on the size of the basis risk proxy. On the other hand, for the “moderate” model, the indemnity coefficient remains statistically significant and interactions have the opposite sign as that of the “severe” model and are statistically insignificant. The last specification, which is presented in Table 4, considers only those variables that are statistically significant and are selected through a step-

**Table 3: Estimation results of the second specification
(with basis risk proxy interactions with the premium and indemnity variables).**

	Severe		Moderate	
	Estimate	Std. Err.	Estimate	Std. Err.
Premium	0.0174***	0.0066	-0.0079	0.0129
Std dev. Premium	-0.0008	0.0082	-0.0147	0.0090
Premium * Basis risk	-0.0244***	0.0089	0.0125	0.0175
Std dev. Premium * Basis risk	-0.0001	0.0078	0.0167*	0.0093
Indemnity	-0.0008	0.0006	0.0047	0.0047
Std dev. Indemnity	0.0012***	0.0003	0.0077***	0.0023
Indemnity * Basis risk	0.0016***	0.0006	-0.0100	0.0064
Std dev. Indemnity * Basis risk	0.0001	0.0004	0.0009	0.0057
Delayed payment	-0.2630	0.2345	-0.1942	0.1635
Std dev. Delayed payment	-0.9908**	0.4844	-0.3994	0.5708
Home delivery	2.3661***	0.4049	1.9862***	0.3688
Std dev. Home delivery	3.5443***	0.5324	2.2945***	0.4721
Status-quo constant	-4.9544***	1.0491	-6.1123***	1.4375
Std dev. Status-quo constant	3.7264***	0.8933	4.0478***	0.9428
Village constant 1	1.6991	1.0910	1.4781	1.2845
Village constant 2	-0.0832	1.1723	-0.2578	1.3181
Err. comp. (Illiterate)	3.5148***	1.0755	3.1447***	1.1636
Err. comp. (Gender)	2.6877***	0.9672	2.6782***	1.0060
Number of obs.	2424		2411	
LR - χ^2	64.85***		45.56***	
Pseudo-R2	0.24		0.26	

*** Significant at 1%. ** Significant at 5%. * Significant at 10%.

wise process⁸. This specification is used in the following section to estimate the predicted market demand of drought insurance. The table also presents marginal effects of each variable with respect to types of product alternatives offered through the experiment. Home delivery increases the probability of buying severe and moderate drought insurance by 15% and 10%, respective-

⁸ The third specification of the "moderate" model includes one error component that is not statistically significant. This variable is included because it stabilises the estimation of the second error component. The implications are limited.

Table 4: Estimation results of the third specification
(with basis risk proxy interactions with the premium and indemnity variables; restricted model in which only statistically significant variables are included).

	Severe			Moderate		
	Estimate	Std. Err.	Mar. Eff.	Estimate	Std. Err.	Mar. Eff.
Premium	0.0089***	0.0031	0.0007	-0.0117**	0.0054	-0.0005
Std. dev. Premium	0.0126*	0.0070	–	–	–	–
Premium * Basis risk	-0.0159**	0.0071	–	–	–	–
Std. dev. Premium * Basis risk	–	–	–	–	–	–
Indemnity	–	–	-0.0000	0.0060***	0.0019	0.0001
Std. dev. Indemnity	–	–	–	0.0083***	0.0017	–
Indemnity * Basis risk	0.0015***	0.0004	–	–	–	–
Std. dev. Indemnity * Basis risk	–	–	–	–	–	–
(Contractual frequency)	–	–	(0.0014)	–	–	–
Delayed payment	–	–	–	–	–	–
Std. dev. Delayed payment	–	–	–	–	–	–
Home delivery	2.0426***	0.3319	0.1476	1.8201***	0.2744	0.1018
Std. dev. Home delivery	2.9801***	0.4226	–	2.0748***	0.3560	–
Status-quo constant	-3.8630***	0.6131	–	-5.0687***	0.7978	–
Std. dev. Status-quo constant	3.8232***	0.6698	–	3.4821***	0.9618	–
Village constant 1	–	–	–	–	–	–
Village constant 2	–	–	–	–	–	–
Err. comp. (Illiterate)	3.7766***	1.3764	–	3.0904	1.9416	–
Err. comp. (Gender)	–	–	–	2.8168**	1.1579	–
Number of obs.	2,424			2,423		
LR – χ^2	75.43***			75.09***		
Pseudo-R2	0.23			0.25		

*** Significant at 1%. ** Significant at 5%. * Significant at 10%.

ly. For instance, an insurance company should assess the trade-off between delivering costs that it incurs when selling premiums and paying indemnities at farmers' residences and the potential 10-15% increase in demand. For moderate drought insurance, an increase in the premium by ETB 100 would on average lead to a 5% decrease in the probability of insurance purchasing, and an increase of in indemnity by ETB 100 would lead to only a 1% increase

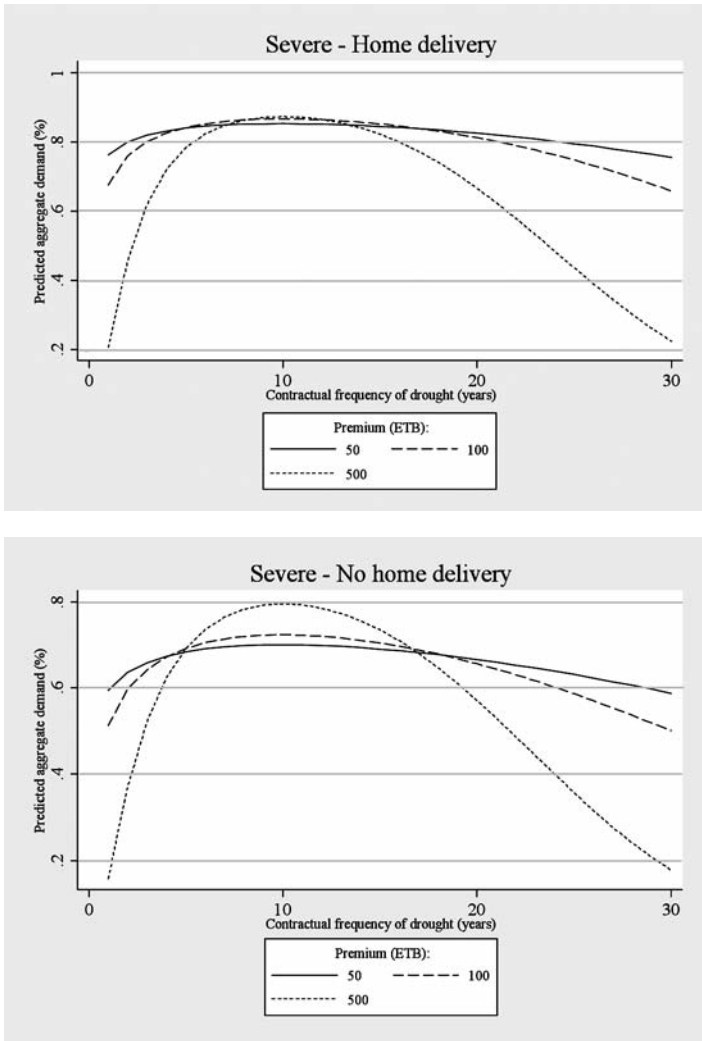
in the probability of insurance purchasing⁹. For severe drought insurance, it would lead to a 7% increase in probability if the premium were increased on average by ETB 100 and to a less than 1% increase in probability for the indemnity. We can also consider the marginal effect of a one-year increase in the contractual frequency of severe drought insurance, and this translates into a mere 1.4% increase in the probability of purchase. However, marginal effects are linear, whereas our analysis of nonlinear relationships offers further insight into underlying relationships between the variables. We present this analysis in the following section by estimating the predicted aggregate demand for different insurance products with specified attributes.

8. SIMULATED AGGREGATE DEMAND AND BASIS RISK

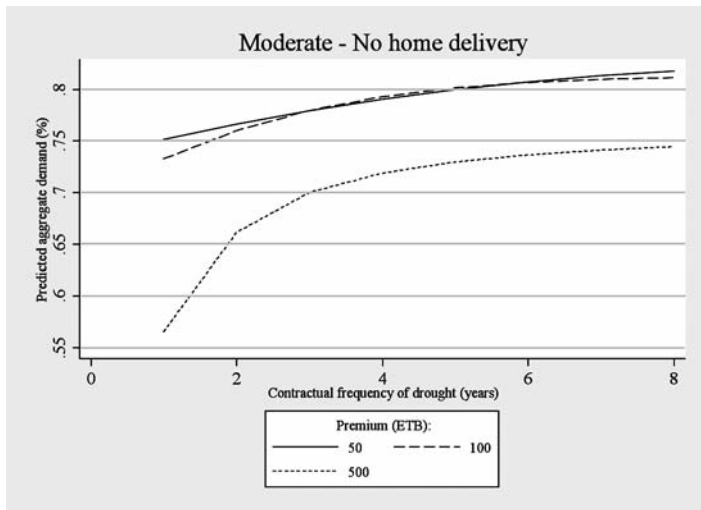
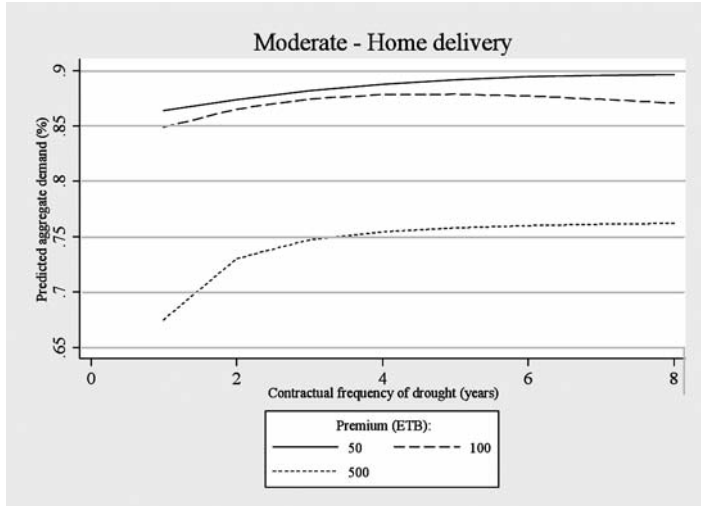
To study the relationship between basis risk and the other product attributes, we let our basis risk proxy take different values within a specific range. According to the distribution of the perceived frequency of drought, we selected a range of 1 to 30 years for the contractual frequency of severe drought insurance and a range of 1 to 8 years for moderate drought insurance. We then estimated the predicted aggregate demand for every value of contractual frequency. The aggregate demand is here defined as the difference between 1 and the average predicted probability of not purchasing insurance (i.e., the predicted outcome of the status quo equation). The main result, i.e., the same result for all simulations, is an inverted U-shaped relationship between the contractual frequency and aggregate demand for severe drought insurance. This finding is consistent in the theoretical model for highly risk-averse and compound risk-averse farmers. Thus, the presence of both potential false positives and potential false negatives reduces the probability of insurance purchases. Furthermore, the effect of basis risk strictly depends on the size of the premium. First, the greater the premium, the lower the level of aggregate demand on average. Second, the greater the premium, the greater the marginal effect of a one-year increase or decrease in contractual frequency. For example, if we raise the contractual frequency from 1 year to 10 years, the predicted aggregate demand increases by 9% if the premium is ETB 50 and it increases by 67% if the premium is ETB 500. It is also

⁹ We opted for a change in ETB 100 as suggested by the results. By examining the overall amount that each farmer is willing to buy, the range falls between ETB 50 and ETB 1,100, with a mean of ETB 150.8 for moderate drought insurance and a mean of ETB 145.6 for severe drought insurance. Moreover, these figures suggest that the range used in the market share simulations is appropriate.

Figure 5: Predicted aggregate demand (%) for severe and moderate drought insurance with and without home delivery and the variable fair premium (ETB 50, ETB 100 and ETB 500).



important to note that false positives have a more negative effect on the predicted aggregate demand level than false negatives. This is also attributable to the weather derivative that we offered. In fact, given the premium, as the contractual frequency is reduced, the indemnity shrinks accordingly. Al-



though insurance pays more frequently, a lower payout also implies reduced insurance protection against potential losses. The inverted U-shaped relationship is not verified for moderate drought insurance. In this case, aggregate demand on average increases with the premium.

Figure 6: Predicted aggregate demand (%) for severe and moderate drought insurance with home delivery, a premium loading of 15%, and the variable fair premium (ETB 50, ETB 100 and ETB 500).

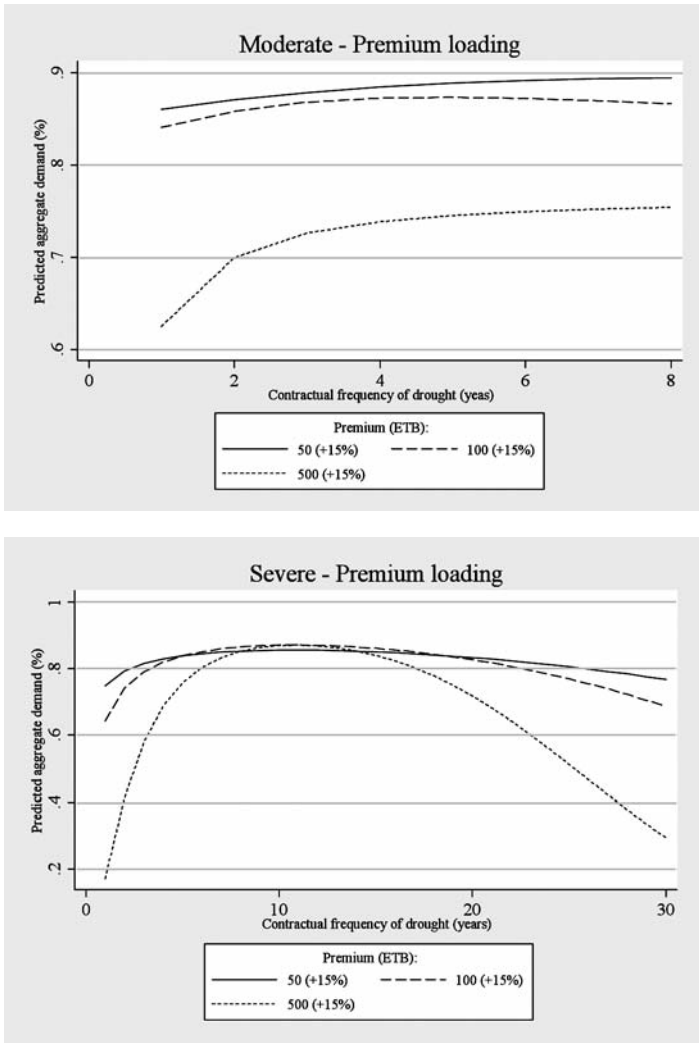
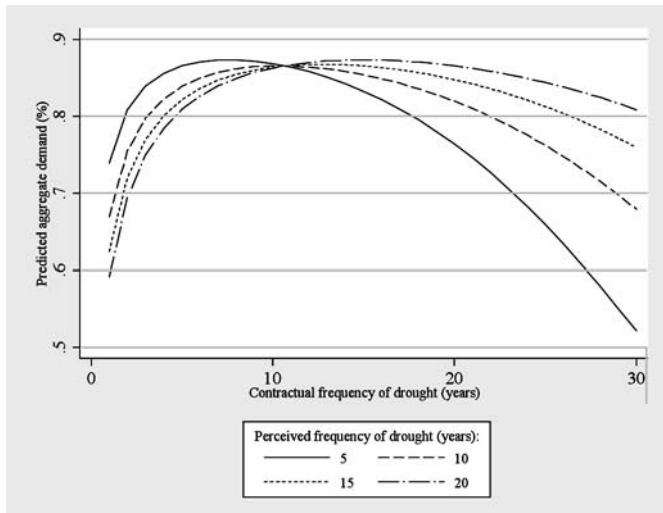


Figure 5 shows the predicted aggregate demand with and without home delivery. The results suggest that while home delivery shifts the aggregate demand curve upwards for both moderate and severe drought insurance, the opposite effect is found for different fair premium sizes. In the case of se-

vere drought insurance, home delivery reduces the influence of the fair premium on the predicted aggregate demand for values of contractual frequency that are close to the frequency associated with the maximum market share, i.e., 10 years. By contrast, for moderate drought insurance, home delivery increases the preference for small-sized premiums. This is likely attributable to average farmer transaction costs per premium. Time opportunity and transportation costs are indeed fixed with respect to the premium size, whereas the indemnity is on average much smaller than it is for severe drought insurance.

Figure 5 only considers fair premiums. If we assume a 15% insurance loading as presented in Figure 6, the predicted aggregate demand is lower for both types of drought insurance. In particular, for severe drought insurance, the contractual frequency is greater at the maximum. This means that as well as the size of the fair premium, the insurance loading exacerbates negative effects of basis risk.

Figure 7: *Predicted aggregate demand (%) for severe drought insurance with home delivery, the fair premium of ETB 100, a contractual drought frequency of 14 years and a variable perceived drought frequency (5, 10, 15 and 20 years).*



Finally, in Figure 7 we predict market shares for different values of the perceived frequency of severe drought. As the contractual frequency increases, false negatives have a greater negative impact on low values of farmer perceived frequency. With a fair premium of ETB 100 and perceived frequen-

cy of 5 years, if the contractual frequency were 20 years, the decline in the market share from maximum levels would be 10%. It is worth noting that the value of contractual frequency for the maximum market share is not equal to the perceived frequency. This suggests that the indemnity effect partially lessens the basis risk effect.

9. CONCLUSIONS

Index-based insurance is an innovative and promising risk transfer mechanism for the rural poor of developing countries. However, overall demand is still low and according to the literature, the causes of this trend vary. Some problems are related to ways that an insurance product is designed. In particular, we focus on a problem that occurs when the payout is not based on real losses suffered by the policyholder but is instead based on index realizations. The extent of this imperfect correlation (basis risk) determines the potential benefits of insurance. As a possible consequence of basis risk, the insured can suffer a significant loss without the insurance contract providing an indemnity. The opposite case, i.e., the possibility of receiving an indemnity without suffering any losses, can also depress demand if the contractual frequency of an adverse event is lower than the frequency perceived by the insured, as we show in our theoretical analysis. The problem of basis risk can be even more prominent in areas characterized by significant agro-climatic variations such as the areas surveyed of this study.

While few studies have been performed on the negative effects of basis risk, the findings of such examinations are relevant in establishing a negative relationship between basis risk and index insurance demand. In particular, we analyze the role of perceived basis risk and ways in which it affects demand for a weather derivative for drought shocks. The perceived basis risk differs from the real basis risk, as it is based on the farmers' perceptions and it can be influenced by unobservables (e.g., a farmer's level of risk aversion and preferences). To the best of our knowledge, this is the first study that explicitly addresses the perceived basis risk. This study is also the first to use a discrete choice experiment to estimate demand for drought insurance. The hypothetical product pays an indemnity that is proportional to the frequency of drought at the weather station and to the premium. To analyze the effect of perceived basis risk on drought insurance demand, we conducted a discrete choice experiment with a sample of Ethiopian farmers from three villages that differ in terms of agro-ecological characteristics. We find

that demand is heterogeneous due to a diverse preference for insurance per se, due to transaction costs and due to indemnity sizes. This suggests that standardized products can reduce demand and that insurance products with flexible attributes can better meet the needs of farmers. Drought insurance is preferred to no insurance for roughly 90% of the surveyed farmers. Transaction costs in terms of transportation and time opportunity costs are considered important for nearly 80% of the surveyed farmers, and these costs reduce insurance demand by 10-15%. Forms of heterogeneity provided by the indemnity are instead related to the type of insurance product provided: 80% positive in the case of moderate drought insurance and 74% negative in the case of severe drought insurance. The estimated signs of premium and indemnity variables of the severe drought insurance model are indeed inconsistent with the demand law. We assume that this result is partially attributable to the presence of a highly perceived basis risk. In fact, the average contractual frequency of severe drought is greater than the average perceived frequency. Our proxy of perceived basis risk is statistically significant, and the presence of perceived basis risk further increases heterogeneity in the demand for severe drought insurance. This implies that optimal drought insurance products should account for different levels of basis risk that farmers perceive. The findings of the simulated market shares for severe drought insurance reveal an inverted U-shaped relationship between the contractual frequency and market demand, i.e., both false positives and false negatives discourage demand. In addition, fair premium and insurance loading sizes further heighten the depressing effects of basis risk. This relationship is not verified for moderate drought insurance, for which the mean frequency is greater and the difference between the contractual and perceived frequency is limited.

The policy implications of this study are straightforward. The presence of perceived basis risk limits the benefits that index insurance for severe drought can offer to the poor. It appears that the lower the frequency of an event, the greater the degree of error that can be committed in estimations of the correlation between the index and perceived losses. We demonstrate that this error is strictly related to high levels of variability in the perceived frequency of rare events. However, in contrast to real basis risk, perceived basis risk can be detected only through proper market research approaches such as the one used in this study. As index insurance for drought risk is typically designed for extreme but low-frequency events, we expect that perceived basis risk may explain some of the low demand observed, as has also been found for real basis risk in other studies such as Elabed et al. (2013). We also show that demand for insurance against moderate, and thus more frequent,

drought events is also very high and is less sensitive to basis risk problems. To increase the value of index insurance for the poor, we contend that there is a need to offer insurance against events of moderate impact. Furthermore, our results support the business case for index insurance that is designed according to the financial and non-financial portfolios of risk aggregators. Skees and Barnett (2006) define risk aggregators as institutions at the meso- or macro-level that can diversify idiosyncratic risks by conducting business with several households but that are highly exposed to systemic risks. Examples of such institutions include microfinance intermediaries, local formal and informal risk-sharing groups, producers' cooperatives, suppliers, processors, and national and international aid providers (Miranda & Gonzalez-Vega, 2010; Skees & Barnett, 2006).

This study presents some limitations. First, the insurance product offered through the experiment is a weather derivative with selected attributes. The results may differ for other types of insurance products. Second, the experiment was conducted in a restricted area with specific agro-climatic characteristics. These limitations suggest that our results cannot be generalized.

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