WILLINGNESS TO PAY FOR INDEX BASED LIVESTOCK INSURANCE: RESULTS FROM A FIELD EXPERIMENT IN NORTHERN KENYA

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First draft: Comments greatly welcomed

October 2009

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Abstract

Index based livestock insurance (IBLI) is designed for managing livestock asset risk by compensating for location-averaged livestock mortality estimated using remotely sensed measures of vegetative cover on rangelands. This paper uses a double-bounded contingent valuation technique to elicit willingness to pay (WTP) for IBLI among pastoralists in five arid and semi-arid locations in northern Kenya, where the product is scheduled for pilot sale in 2010. A sequential insurance decision was considered. Pastoralists were first asked to make decision regarding the proportion of herd they wish to insure. Conditional on their chosen proportion, they were then asked a sequence of dichotomous WTP questions, responses of which were used to form bounds for their unobserved WTP. A modified Heckman's two-step conditional expectation correction approach is applied to estimate pastoralists' insurance demand. Wealth, risk preference, perceived basis risk and subjective expectation of loss serve as the key WTP determinants, conditional on understanding of the mechanics and value of IBLI. Households most vulnerable to falling into poverty trap were also shown to have the highest price elasticity of demand, despite their potentially highest dynamic welfare gain from the insurance. This is in contrast to the high and relatively low elasticity of demand found among the poorest, whose dynamic welfare benefits from insurance were minimal.

Keywords: Index insurance, field experiment, willingness to pay elicitation, contingent valuation, risk preference, pastoralists, Kenya

1. Introduction

Among more than three million pastoralist majorities in northern Kenya, widespread livestock mortality that often results from severe drought is considered the main threat to the key asset that their livelihoods rely on. Especially in this pastoral economy with evidence of a poverty trap characterized by a herd threshold that leads to bifurcation in herd growth prospect (Lybbert et al. 2004, McPeak 2004, Barrett et al. 2006 and Santos and Barrett 2006), the presence of catastrophic risk of livestock loss can place long-term impacts on households' welfare dynamics, especially if shocks knock their herd beneath the threshold onto the decumulating growth trajectory toward an irreversible poverty trap.

With a dearth of alternative productive livelihood strategies to pursue and scant informal risk-management options, which often fail to provide safety nets in the event of covariate shock, development of a formal asset risk management instrument for pastoralists in these areas thus could provide significant pro-poor contribution.

Index-based livestock insurance (IBLI) is developed as a means for managing covariate livestock mortality risk in arid and semi-arid locations in northern Kenya. To ensure IBLI's potential as a market viable insurance product in the targeted infrastructure deficit areas, the innovations in the design of the product, like other index insurance, aim at solving the classic incentive problems that currently impede the existence of formal insurance market in these poor communities. Like typical insurance, IBLI compensates for livestock loss. But unlike traditional insurance, it only compensates for the covariate herd losses that are objectively and transparently observable. The increasingly popular remotely sensed Normalized Differential Vegetation Index (NDVI), an indicator of vegetative cover on rangelands, is used to predict covariate herd mortality in a particular location. An objectively measured predicted herd mortality index constructed from such strong predictive relationship is then used to trigger IBLI's indemnity payments for the insured in such coverage area.

This product design thus has great potential as the transaction costs of monitoring and verification are reduced, and it avoids the twin asymmetric information problems once the underlying index can not be influenced by insurer or insuree. The risk management effectiveness of IBLI, however, depend on severity of "basis risk", which refers to the imperfect correlation between an insured's potential livestock loss experience and the behavior of the underlying index on which the index insurance payout is based. As the product is scheduled for pilot sale in Marsabit district of northern Kenya in 2010, investigations of IBLI's risk management effectiveness and its effective demand in these targeted communities thus naturally become the next critical research agenda.

On the basis of a successfully designed IBLI contract for Marsabit district of northern Kenya in Chantarat et al. (2009a), Chantarat et al. (2009b) uses panel data and a dynamic pastoral economic model to perform a household-level simulation analysis of the effectiveness of IBLI contracts in managing asset risk in 4 locations in Marsabit. This study shows that performance of IBLI varies greatly across households and locations with different natures of exposures and basis-risk characteristics. More strikingly, the impact of insurance on household's welfare dynamics is shown to be significantly influenced by household's herd size relative to the critical herd threshold – which was found to be around 15-20 TLU[1] per household. The poorest (with herd sizes less than the critical threshold), who already slowly collapse toward destitution over time are shown to benefit the least from the product. IBLI is shown to be most valuable for those with larger herd sizes than the threshold but are still vulnerable to falling beneath it, when it helps stem collapses into poverty following a bad shock. But their valuation may still not meet the market viable rate.[2] So these simulated results imply that pastoralists with large herds are expected to be the key drivers for the commercially viable product.

To complement the existing simulation results, this paper elicits willingness to pay (WTP) and demand for IBLI contracts among pastoralists using contingent valuation experiment conducted in summer of 2008 in 5 overlapping arid and semi-arid locations in Marsabit district. Our key objectives are to explore (i) determinants of IBLI demand, (ii) patterns of estimated demand and (iii) how IBLI demand varies across subpopulations in the presence of a threshold-based poverty trap. These insights would provide implications for commercializing and using IBLI as part of poverty alleviation program in the region.

The empirical work in this paper involves three interrelated field activities: (i) the baseline survey and preference elicitation, (ii) the experimental insurance game designed to educate sampled households about the newly introduced insurance contract and (iii) the WTP elicitation using contingent valuation. Our insurance demand elicitation deviates from the (small) existing literatures in many ways. First, we model a more realistic sequential insurance decision in which respondent first makes coverage decision (e.g., by choosing proportion of herd they wish to insure) and then WTP decision conditional on the chosen coverage. Second, we apply double bounded CV method that allows us to confine household's unobserved WTP into small well-defined intervals using

[1] TLU stands for tropical livestock unit. This term is commonly used to represent an aggregate unit of animals, where 1 TLU is equivalent to 1 cattle, 10 goat or sheep and 0.7 camels.

[2] For the poorest, the premium payment tends to further speed up their herd de-cumulation during good seasons. By the same token, the vulnerable households, who may benefit the most from IBLI during bad years, also weigh in the cost of increasing probability of herd collapsing when paying in premium without receiving indemnity in the good years.

a series of dichotomous WTP questions. A modified Heckman's two step estimation is then applied in our empirical estimations.

Our empirical results offer modest verifications to the neoclassical theoretical prediction regarding demand for insurance. Wealth, risk preference, perceived basis risk and subjective expectation of loss were found to serve as the key WTP determinants, conditional on understanding of the mechanics and perceived value of IBLI. The modest estimated WTPs were used to construct an aggregate demand for IBLI, which were shown to be highly price elastic. Variations in IBLI demand are also well observed. The poorest subpopulations were found to choose significantly larger IBLI coverage and exhibit relatively lower price elasticity of demand, while households most vulnerable to falling into poverty trap were shown to have the highest price elasticity of demand. Our empirical results thus offer an insightful contrast to that of Chantarat et al. (2009b) in the current analysis of IBLI contract.

In the next section, we offer a brief review of literatures on demand for agricultural insurance and the current applications of contingent valuation especially those related to agricultural insurance, which then allow us to describe key deviations of our approach. Section 3 describes our analytical framework, which allows us to develop some theoretical predicting regarding to the determinants of demand for IBLI. Section 4 then describes our survey and experiment. Econometric framework is then described in Section 5. And the empirical results are provided in Section 6. Section 7 constructs aggregate IBLI demand and explores how it varies across subpopulations. Section 8 concludes with some implications.

2. Demand for agricultural insurance and contingent valuation

To date, there are modest numbers of literatures that study agricultural insurance demand. And despite the fact that applications of index insurance in agricultural has been widely explored over the last decade, the number of literatures that focus particularly on the demand for index-based products are still small. Two comparable approaches have been used in these existing literatures.

The first approach uses revealed preference concept in estimating latent demand for hypothetical insurance based dynamic modeling of household's optimal agricultural decisions. Gautam et al. (1994) uses two-year panel data to examine the efficiency of drought management strategies used by peasant households in five villages in southern India, and found some evidence of market viable latent demand for drought insurance in the region. The same approach was utilized in Burkina Faso by Sakurai and Reardon (1997), who found that farmer's perceived probabilities of droughts and the size of cultivated area have positive impacts on insurance demand, while off-farm income and availability of public and private assistance have negative impacts on insurance demand.

The second approach involves application of field survey and experiment in eliciting household's insurance demand. The common approach, which is also widely used to estimate the value of goods and services that are not traded in the marketplace, is the contingent valuation (CV) method, in which survey questions elicit respondents' willingness to pay (Mitchell and Carson 1989, Carson and Hanemann 2005, Alberini and Kahn 2006).

Arrow et al. (1993) study the applications of CV and provides insightful recommendations to maximize the reliability of CV estimates, among those relevant to our study are: (1) use of representative sample, (2) phasing CV questions in the form of hypothetical referenda in which respondents are told how much they would have to pay for each product or scenario choice before asking them to cast a simple yes or no answer, (3) reminding respondents of their actual budget constraint when considering their willingness to pay, (4) providing some sort of a "would not choose" option in addition to the "yes" and "no" option on the referendum, (5) breaking down willingness to pay by a variety of respondent's characteristics and (6) pretesting of the CV questionnaires. Our CV experiment adhered to each of these recommendations.

A small literature applies CV methods to study WTP for agricultural insurance. Patrick (1988) and Vandeveer and Loehman (1994) use a single dichotomous (yes/no) choice question to study producers' demand for a multiple peril crop insurance, rainfall insurance and other modifications of crop insurance. McCarthy (2003) and Sarris et al.

(2006) use similar single CV question to study pattern of demand for rainfall insurance in Morocco and Tanzania, respectively.

Our approach deviates from others in three interesting ways. First, we model household's demand for IBLI as a sequential decision. Households were first asked pastoralists to choose a proportion of their herd (among 0%, 25%, 50%, 75% and 100%) that they wish to insure. And so conditional on their chosen proportion, they were then asked a series of dichotomous WTP questions. This is contrastable with the standard joint decision approach widely used in the literature, in which respondent are asked to consider insurance contracts with pre-specified combinations of coverage and price (e.g., full coverage contract in which pastoralists are required to insure all their herd). As in reality, we cannot observe households' total herd sizes prior to their insurance decision – but rather the herd sizes households are willing to insure – and various literatures related to agricultural insurance provide evidence that the insured acreages vary across producers and far from full coverage (Barnett et al. 2004, Miranda and Venedov 2001, among others), the standard, pre-specified coverage insurance question may not well replicate the actual insurance decision.

Second, we use double-bounded CV method, in which pastoralists were asked a sequence of dichotomous insurance questions that progressively narrows down the range of their unobserved WTP. Specifically, pastoralists were first asked to consider a specific insurance and if they are willing to pay at a specific price.[3] A follow-up question with higher (lower) price are then asked if they response "yes" ("no") to the first question, and the process continues until we can classify their willingness to pay into 8 different intervals classified using 7 prices (actuarial fair, $\pm 10\%$, $\pm 30\%$ and $\pm 50\%$ of the fair price).

Our method has been shown to generate more efficient estimates than those based on a single question (Hanemann et al. 1991) or based on an open-ended follow-up

[3] The starting prices of (actuarial fair, 10% and 30% of fair price) were randomized across households to take into account the potential first-impression bias.

question (Watson and Ryan 2007, Haab and McConnell 2002).[4] And since our approach is an extension of the standard ones, it allows us to also estimate the WTP estimates elicited using the standard methods for comparison and robustness check. And for our last deviation, we add “not sure” to the “yes” and “no” answers of each CV question to allow uncertain answers to be submitted without introducing bias in estimates of WTP.

In the context of the index insurance product already available in the market, Gine et al. (2008) and Cole et al. (2009) study the patterns of adoption of rainfall insurance product designed to compensate low-income Indian farmers in case of deficit rainfall. Using series of randomized field experiment, they found that among the relatively low level of adoption, price, trust and credit constraints were the three critical demand determinants. They also found that uninformed risk-averse households are unwilling to experiment with this insurance product, given their limited experience with it. Our empirical results will offer great contrast to these studies as well.

3. Analytical framework

Consider a pastoral economy where there are two sources of wealth for household i in location l at any period t: stochastic livestock $(H_{ilt} \geq 0)$ and deterministic non-livestock wealth $(W_{ilt} \geq 0)$, which includes income from non-livestock activities, crop stocking and other assets that household can liquidate for consumption and investment. The liquidity constraint is imposed through non-negative wealth (Deaton 1991). Since livestock are central to economic activities in this economy, we use livestock unit (TLU) as the standard monetary unit in this model. Livestock production, the main source of income, is determined by $f(H_{ilt}, X_{ilt})$, where X_{ilt} represents household-specific characteristics.

The stochastic herd accumulation dynamics in this setting can be written as

$$(1)\quad H_{ilt+1} = \left(1 + b(ndvi_{lt}, \varepsilon_{ilt}, X_{ilt}) - m(ndvi_{lt}, \varepsilon_{ilt}, X_{ilt})\right)H_{ilt} + i_{ilt} + \pi_{lt}(\hat{m}(ndvi_{lt}), m^*)h_{ilt}H_{ilt}.$$

[4] A single question CV method requires researcher to choose a distribution of offer price and so inefficient set of prices may impact mean WTP. Research also found that people commonly gave “protest answers” to open-ended questions.

where net herd growth rate is governed by stochastic biological rates of reproduction, b_{ilt}, and mortality, m_{ilt}, which are subjected to two distinctive sources of risk: a covariate component driven by rangeland conditions captured by the area-average vegetation index $(ndvi_{lt})$, and a component (ε_{ilt}) uncorrelated with the former and idiosyncratic across heterogeneous households. Household's the net livestock investment rate (herd recruitment less offtake rates) is represented by i_{ilt}.

The index based livestock insurance (IBLI) contract is designed to protect livestock asset losses due to covariate rangeland condition by providing uniform compensation across households in the same geological coverage based on observations of $ndvi_{lt}$. Specifically, an annual IBLI contract in location *l* makes total indemnity payout (as a rate proportionate to household's choice of insured livestock) at the end of coverage year *t* if the predicted livestock mortality index for the location denoted by $\hat{m}(ndvi_{lt})$ reaches the pre-determined strike level m^* (at 10% in this study) according to[5]

(2) $$\pi_{lt}\left(\hat{m}(ndvi_{lt}), m^*\right) = Max\left(\hat{m}(ndvi_{lt}) - m^*, 0\right).$$

The annual premium rate ρ (typically equals to $a(E\pi_{lt})$ with a represent premium loading) is quoted as percentage of household's total value of insured livestock, $h_{ilt}H_{ilt}$ with h_{ilt} representing proportion (%) of herd household chooses to insure. This annual premium then needs to be paid in by the insuree at the beginning of the coverage year.

Household *i*'s budget constraint in each period *t* can therefore be given by

(3) $$c_{ilt} + i_{ilt} \leq f(H_{ilt}, X_{ilt}) + \left(W_{ilt} - W_{ilt+1}\right) - \rho h_{ilt} H_{ilt} \quad ,$$

[5] The agricultural calendar in northern Kenya can be disaggregated into two seasons: short rains/ short dry, long rains/ long dry – each consists of a rain and dry season pair. The actual annual contract is designed to have two possible indemnity payment dates at the end of each season in a year. Since the time index here represents year, the payment at the end of the period represents the sum of the two seasonal payments. For details on IBLI design, see Chantarat et al (2009a).

where c_{ilt} represents consumption and $W_{ilt} - W_{ilt+1}$ reflects other liquid wealth (e.g., from other non-livestock income, transfer, etc.) left from carrying over to the next period.

So at the beginning of each year *t* when state of the world is unknown, household *i* first chooses the optimal livestock investment and insurance to maximize the standard intertemporal discounted utility. The state of the world is realized at the end of the year and so IBLI makes indemnity payment to compensate for livestock loss, which then adds to the livestock accumulation dynamics in (1).

Household *i*'s optimization problem can be characterized using Bellman's equation as

$$(4) \qquad V_t(H_{ilt}) = \underset{i_{ilt}, h_{ilt}}{Max}\; u\big(f(H_{ilt}, X_{ilt}) + (W_{ilt} - W_{ilt+1}) - \rho h_{ilt} H_{ilt} - i_{ilt}\big)$$

$$+ \delta_i E_t\Big(V_{t+1}(H_{ilt+1}) \,|\, \Omega_{ilt}\big(ndvi_{lt}, \varepsilon_{ilt}, \pi_{lt}(\hat{m}(ndvi_{lt}), m^*)\big)\Big)$$

where $u(c_{ilt})$ is defined with respect to household-specific CRRA, R_i. Here δ_i is discount rate and $E_t(\cdot)$ is taken over household's subjective expectation based on a set of belief $\Omega_{ilt}\big(ndvi_{lt}, \varepsilon_{ilt}, \pi_{lt}(\hat{m}(ndvi_{lt}), m^*)\big)$ with respect to nature of individual livestock losses and potential of IBLI in managing the losses with respect to vegetation index (i.e., basis risk), which may or may not reflect the real state of the world.

In this setting where household is considering a hypothetical IBLI, we consider a sequential insurance decision, in which household first chooses the optimal proportion of herd to insure, h_i^*, without prior knowledge of the actual IBLI premium. Conditional on their optimal insurance decision and beliefs – which also govern their expectation of the IBLI premium – the household's equilibrium conditions to (4) imply an optimal insurance decision written in a reduced form as

$$(5) \qquad h_i^* = h\Big(R_i, \delta_i, \Omega_{ilt}\big(ndvi_{lt}, \varepsilon_{ilt}, \pi_{lt}(\hat{m}(ndvi_{lt}), m^*)\big), H_{ilt}, W_{ilt}, X_{ilt}\Big).$$

Evaluating the insurance decision at the self-insurance equilibrium (without IBLI), an equilibrium premium rate – which makes household indifferent between purchasing or not purchasing IBLI and so representing household's maximum willingness to pay for IBLI conditional on their chosen insuring proportion, h_i^* – can also be written in a reduced form as

$$\rho_i^*\left(h_i^*\right) = \rho\left(R_i, \delta_i, \Omega_{ilt}\left(ndvi_{lt}, \varepsilon_{ilt}, \pi_{lt}(\hat{m}(ndvi_{lt}), m^*)\right), H_{ilt}, h_i^*, W_{ilt}, X_{ilt}\right). \quad (6)$$

Preferences, subjective beliefs, wealth and other household-specific characteristics thus serve as the key determinants of household's insurance decision in our setting. And theoretical predictions can be made regarding insurance demand determinants according to a standard neoclassical model.

First, with respect to household's preference, WTP will be increasing in risk aversion and decreasing in household's discount rate in a setting without asymmetric information (e.g., households fully understand the insurance contract). Second, with respect to their subjective expectation and beliefs, WTP will be increasing in household's perceived livestock mortality risk and in household's expected insurance payout taking into account the perceived basis risk associated with IBLI product (e.g., the correlations between individual mortality losses and the predicted mortality index that governs IBLI indemnity payout).

Third, by the standard wealth effect, household's income and assets represent the extent of financial resource to afford IBLI, which have positive impact on insurance decision. As the welfare impact of a formal risk management instrument like IBLI depends largely on the effectiveness of the existing risk-coping mechanisms (Townsend 1994, Morduch 1995), household's wealth could also reflect availability of existing self-insurance capacity and so could have negative impact on insurance decision. Theoretically, wealth thus could have ambiguous impact on insurance decision.

By similar token, degree of credit constraint also plays key but ambiguous role in household's WTP for insurance. On one hand, credit constrained households may value reduction in asset risk provided by IBLI more highly because they have lesser ability to smooth consumption ex post by other means. On the other hand, the shadow value of their needy liquid asset may be too high to make IBLI attractive.

Many of these predictions have been empirically verified especially in the insurance markets in developed countries. However, factors that deviate the economic setting away from full information – e.g., household's awareness, ability to understand the product and trust that condition their perceived cost and benefit of IBLI – are shown theoretically and empirically to influence demand for insurance and other financial instruments (Guiso et al. 2007, Gine et al. 2008 and Cole et al. 2009). These factors are expected to serve as important demand determinants for a new product like IBLI among the targeted pastoralist clients in northern Kenya with very limited knowledge and experience of insurance.

4. The survey

Five arid and semi-arid pastoral locations in Marsabit district – consisting of Dirib Gombo, Kargi, Karare, Logologo and North Horr (shown in Figure 1) – were chosen for this study. They represent variability in climate, geographical resources, pastoralism, ethnic majorities and market access. The sample was stratified by wealth class: low, medium and high, based on owned herd size classified by community standards.[6] For the sample size of 42 households in each location, approximately 14 households were randomly drawn from these location-wealth strata.[7] Three survey activities were conducted in the field starting in June 2008: (i) baseline household survey, (ii) educational insurance game and (iii) willingness to pay experiment using CV.

Baseline survey

Table 1 presents weighted summary statistics from the survey on household characteristics, risk perceptions, 11-year historical herd loss recalls since 1997 and simple

[6] Wealth classification standards vary by location. The boundaries in TLU for (L,M,H) wealth class for the five locations are Dirib(<3,3-8,>8), Kargi(<15, 15-25,>25), Karare(<15,15-30,>30), Logologo(<10,10-25,>25) and North Horr(<15,15-35,>35).

[7] All reported statistics and estimations in this study are thus corrected for their appropriate sampling weights.

experimental elicited preferences. Details of our constructed variables are described in Appendix 1.

Pastoral households in our studied locations are generally poor with reported mean per capital income less than $0.5 a day.[8] Livestock is considered the main source of livelihood for households in these pastoral communities with an average of 63% share of livestock income from total income. Livestock also serve as their main asset with mean herd size of 15 TLU per household consisting on average of six individuals. Livestock and other asset holdings in these communities, however, vary greatly across our sampled households. 36% of sampled households were identified as credit constrained, e.g., indicating demand for credit without capacity to access from any formal/informal sources.

Pastoralism in these arid and semi-arid areas is nomadic in nature, where herders commonly adapt to spatiotemporal variability in forage and water availability through herd migration. This can be shown by the 68% share of herd reported to migrate at least once over the year. Very low years of education are generally observed among the household heads. Their experience with financial transactions also seems very limited with 7% of sample reported having bank accounts. 15% of the sampled households, however, reported their active involvement in the local social network groups – mostly related to livestock production, marketing and other livelihood activities.

Our risk ranking exercise shows that the covariate livestock loss due to inadequate rain and forage was the most concerned risk, of which households had difficulty coping given their resources. The existing risk management strategies in these communities, which clearly fail to provide adequate protection against such loss, were ranked from utilization of assets and savings (e.g., selling off livestock), obtainment of credit, reduction of consumption and outside assistance, e.g., food aid. Apart from migration, decreasing herd size (e.g., through loaning and sales) was the main precautionary action undertook in expectation of catastrophic herd loss. Appendix 2 reports these statistics.

To obtain insight of household's profile of risk of livestock loss, 11-year herd loss recalls were conducted, in which household heads were asked to approximate beginning

[8] This is based on October 2009 exchange rates (75.05KSh/US$).

herd sizes and annual losses since 1997.[9] The 11-year recalls imply an average of 18% probabilities (one in about five years) of the occurrence of catastrophic herd loss, e.g., beyond 200% of individual-specific mean. Correlations of individual and area averaged herd losses beyond 10% based on these recalls – a weak representation of basis risk associated with IBLI – are relatively high at an average of 0.53, but vary greatly across households. Pastoralists expected an average of 34% livestock loss over the year 2009, which represents the coverage period for the hypothetical IBLI they were asked to consider.

As preference represents a key determinant for household's insurance demand, we elicit risk, time and ambiguity preference using simple experiments with real monetary incentives. Our risk preference elicitation game follows the method used in Binswanger (1980, 1981), Eckel and Grossman (2002) and Barr (2003). Households were first given 100 Ksh – an equivalent of one day wage in the areas – for their 2-hour survey participation. They were then asked if they would like to use it to play one of the five lotteries, which vary by risk and expected return. Six categorizations of risk aversion (similar to Binswanger 1980) associated with six geographic mean CRRA were derived based on households' choices (see Appendix 3 for the setting of this experiment).

We elicit household's discount rates from the minimum compensation household would be willing to accept in exchange for their one-month postponement of 10,000 KSh cash receipt. The result implies extremely high mean discount rate of 52% per month.[10] Household's ambiguity preference was then estimated by observing their choice between the two games they would play for real prize: one with known winning probability and the other with "ambiguous" outcome probability. 52% of the sample was found to be ambiguity averse. Appendix 1 describes these experiments in more detail.

[9] Calendar of important events in each location was used to aid the recalls.

[10] Hypothetic setting is used in this experiment. The high discount rates might also capture high degree of liquidity constraints among the sampled households in these communities. They might also potentially result from cultural issues provoked by the framing of this experiment. For example, delaying payment in northern Kenya tend to have high indication of default. Thus, people would rather choose to receive sure money now than nothing a month from now. The evidence of considerable high discount rates are also found theoretically and empirical in Lybbert and McPeak (2009), Gine et al. (2008).

Educational insurance game

After the baseline survey, households were then invited to join one of IBLI sessions conducted twice repeatedly in each location. Each session started with a brief introduction of IBLI and then followed by intensive educational insurance game constructed to replicate real pastoral livelihood in the areas. The game with options to buy IBLI contracts were played repeatedly with real monetary incentive aiming to develop pastoralists' understanding of how IBLI works and the potential impact of IBLI on herd dynamics. At the end of the game, we then conducted group discussion about related questions and opinions on IBLI products, the response of which seem to indicate these sampled households' interest and eagerness to learn more about IBLI (see Lybbert et al. 2009 and McPeak et al. 2009 for details on this experimental game).

Willingness to pay experiment using CV

Already informed about IBLI, the sampled households were then followed by enumerators for CV experiment. An annual IBLI contract with 10% strike and two possible indemnity payouts at the end of each of the two seasons in the 2009 coverage year was introduced.[11] Households were also told that the predicted mortality index will be constructed and announced at the end of each season by the International Livestock Research Institute (ILRI) – independent of the insurance company. The bottom of Table 1 presents statistics of the predicted NDVI-based mortality index that triggers indemnity payout from this contract. The average actuarial fair premium rate is estimated to be 6.8% of the total insured herd value.

After the actual contract introduction, household were first asked to choose the insurance coverage, e.g., the proportion of herd they would like to insure among 0%, 25%, 50%, 75% and 100% (without knowing price information). Five starting offer prices (fair price, 10% and 30% above and below fair price) were then randomly assigned to each household in each wealth group to eliminate the bias resulted from impression of the first offer price. Conditional on the chosen coverage proportion, enumerators –

[11] 30% strike contract was also considered in the WTP experiment. As the 10% strike contract is likely to be the actual contract to be piloted in 2010, we focus on this specification. Other results are not reported but can be provided upon request. The statistics regarding IBLI are reproduced from Chantarat et al. (2009a).

equipped with a calculator – then walked the respondents through (i) the calculations of total premium based on the total KSh value of their chosen insured herd (estimated at a pre-specified per TLU value at 10,000 KSh)[12] and (ii) the calculation of contract's total KSh indemnity payment conditional on various predicted mortality index and the respondents' total insured herd value. The respondents were then asked if they would be willing to buy the proposed IBLI contract for their chosen insurance coverage.

The household could answer "yes", "no" or "not sure" to the willingness-to-pay question. Enumerators were told to carefully distinguish the response of "maybe yes" from "definitely yes" through the use of "not sure" for the former one. If the respondent answered "yes" ("no") to the first offer price, enumerators were instructed to repeat the WTP question (and calculation routine) with the next higher (lower) price emphasizing in each of the renew questions that the contract and price was the only combination available in the area at that particular time. The series of WTP questions continue until the respondent's answer changed to "no" ("yes") within the range of seven available prices. If the respondent answered "not sure" to the first offer price, enumerators were instructed to repeat the question with the next higher price and continue the process until the respondent's answer changed to "no", as well as, to repeat the question with the next lower price and continue the process until the respondent's answer changed to "yes".

By this routine, the respondents' unobserved WTP can be narrowed down into one of the eight intervals $\{(0,0.5P), [0.5P,0.7P), [0.7P,0.9P), [0.9P, P), [P,1.1P), [1.1P,1.3P), [1.3P,1.5P), [1.5P, +\infty)\}$, where P represents fair annual premium rate at 6.8% per insured herd value. The upper (lower) bound of WTP thus reflects the minimum (maximum) offer price that households response "no" ("yes") to the willingness-to-pay question. Figure 2 describes the structure of CV questions. In the presence of "not sure" response (found in only 5% of sample), we replace the upper bound with the minimum offer price that households response "not sure" to narrow down the WTP from some potential uncertainty.[13]

[12] The goat/sheep equivalent of the total premium was also calculated for the respondents in case their insurance calculation and decision involve selling off some of their herd for premium payment.

[13] The resulting estimated WTP can thus be compared with that of the case without considering "not sure". The WTP estimates from the standard single question (double bounded with only one follow up question) method can also be calculated by only taking information observed at the first (first two) willingness-to-pay

5. Econometric framework

Household's insurance demand in our experiment is thus modeled as a sequential decision as they first choose among ordinal coverage choices (h_i) and then make willingness to pay decision (WTP_i) conditional on the chosen coverage. And since the covariates that determine household's coverage decision will likely determine their WTP, and it is reasonable to assume that there might be some unobserved characteristics that influence both decisions, this interdependent insurance decisions can be specified as a model with an endogenous ordinal variable. This deviates slightly from a model with endogenous binary variable considered extensively in Maddala (1983), Heckman (1979), among others.

Specifically, household's sequential insurance decision can be modeled as

$$(7) \qquad h_i^* = X'_{i1}\beta_1 + \varepsilon_{i1} \qquad , \; h_i = h(j) \quad \text{if} \quad \alpha_{j-1} < h_i^* \le \alpha_j \quad \text{for} \;\; j = 1,2,3,J$$

$$WTP_i^* = \beta_h h_i + X'_{i2}\beta_2 + \varepsilon_{i2} \qquad , \; WTP_i \in [\, p_{iL}, p_{iU} \,] \,.$$

The unobserved choice of insured livestock proportion h_i^* is first modeled as ordered probit with respect to the observed household's choice of insured livestock proportion chosen among J ordinal choices,[14] $h_i(j),..,h_i(J)$. Here α_j represents unknown threshold parameters with $\alpha_0 = -\infty$ and $\alpha_4 = +\infty$.

Household's chosen coverage also conditions their willingness to pay for insurance. We do not observe WTP_i^* but household's response to the series of CV questions allow us to classify their WTP into one of the eight price interval $[\, p_{iL}, p_{iU} \,]$, on which a bounded likelihood model can be specified. X_{i1}, X_{i2} are vectors of covariates. The two error terms in the model follows bivariate normal distribution such that $\varepsilon_1, \varepsilon_2 \sim BVN(0,0,1,\sigma_2^2,\rho_{12})$.

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question (s). We also estimated these results for the purpose of comparison. Results are not reported here but can be provided upon request.

[14] In this case, the coverage choices reduced to h_i (1) = 0.25, h_i (2) =0.50, h_i (3) = 0.75 and h_i (4) = 1. No household in our sample chose 0% coverage and so this choice is automatically dropped.

The overall full information likelihood of household's interdependent insurance decision is thus associated with the probability of joint events, which can be derived from conditional probability: $\Pr(h_i = h(j))\Pr(WTP_i \in [p_{iL}, p_{iU}]/h_i = h(j))$ for $j = 1,2,3,4$. And so, in order to maintain the model's general specification, the full information maximum likelihood specification is first presented as

(8)

$$\ell(\alpha', \beta', \sigma_2) = \sum_{i=1}^{N} \left\{ \sum_{j=1}^{4} \left[\mathrm{I}(h_i = h(j)) \cdot \left(\log[\Phi(\alpha_j - X'_{i1}\beta_1) - \Phi(\alpha_{j-1} - X'_{i1}\beta_1)] + \log[\Phi_{U/j} - \Phi_{L/j}] \right) \right] \right\}$$

where $\Phi_{K/j} = \Phi\left(\dfrac{p_{iK} - \beta_h h(j) - X'_{i2}\beta_2 + \sigma_2 \rho_{12}(\alpha_j - X'_{i1}\beta_1)}{\sigma_2 \sqrt{1 - \rho_{12}^2}} \right)$ for $K = U, L$ and $\mathrm{I}(h_i = h(j)) = 1$ if $h_i = h(j)$ and = 0 otherwise. $\Phi(\cdot)$ is the standard normal cumulative distribution function.

We estimate this model based on limited information maximum likelihood using Heckman's conditional expectation correction. The use of Heckman's two-step approach (Heckit) with first-step ordered probit model and second-step bounded likelihood model has not been considered in the literature, to the top of our knowledge. Green (2002) discusses the model with first-step ordered probit but second-step linear regression. The maximum likelihood estimators (α', β_1) from the first step ordered probit estimation are used to estimate conditional expectation correction term, inverse Mills ratio (IMR) λ_i, associated with the observed $h_i = h(j)$. The estimated IMR is then inserted into the second-step double bounded WTP model in place of h_i. And so (β_h, β_2) are then estimated using maximum likelihood. We apply Heckman's correction for standard errors in our estimations. Appendix 4 summarizes our approach in applying Heckit and correction for covariance matrix in our model.

A test of the interdependency of the coverage and WTP decisions (e.g., correlation between the errors in (7)) – which provide implication about the suitability of model specification – compares the Heckman's two-step results with the estimated results without conditional expectation correction. This is thus identical to the Wald test of the significance of the Heckman correction term (IMR). Therefore, under the null hypothesis of no correlation, $\hat{\beta}_h$ would be zero (Heckman 1979 and Dubin and McFadden 1981).

6. Empirical results

Table 2 reports the empirical results for a 10% strike IBLI contract considered in this paper.[15] Results of the first step ordered probit estimation is shown in the left panel. As no one in the sample chooses 0% coverage, there are only four ordinal coverage choices (25%, 50%, 75% and 100%). For identification purposes, we include extra variables on preference, household and herd characteristics – significantly influencing coverage decision in this first step – apart from the standard covariates used in both steps. Ambiguity averse household chooses significantly lower coverage. Land holding and the extent to which household has at least one member living or working away from the community significantly decrease household's chosen coverage. These availabilities of alternative diversifying livelihood or income as self coping strategies thus reduces demand for formal insurance.

Our empirical results for the coverage decision provide modest verification of the theoretical prediction earlier stated. Risk aversion and time preference has no significant influence on household's coverage decision, while in general the effect from their risk experience, subjective expectation and perception well confirm the prediction. IBLI coverage decision increases significantly with expectation of loss in the coverage year and – though less significantly – with the perceived extreme risk of livestock loss observed in the 11-year recalls. Bad experience during the last rain season is also show to significantly increase coverage proportion.

Economic income has significant positive impact on household's coverage decision resulting from the overwhelming wealth effect. In contrast, the significantly negative influence of herd size seems to indicate the dominating effect from the buffer stock argument. Other thing equal, marginal utility impact from catastrophic shock is

[15] We pay particular attention to the 10% contract here as this appears to be the commercial underwriter's preferred specification for pilot sale. Results for the 30% strike contract also included in our experiment are qualitatively similar and so are omitted here but are available upon request.

expected to be less severe for those with larger herd, whose livestock could also serve as buffer assets. The availability of buffer stock assets thus potentially reduces demand for insurance. The buffer stock argument also offers plausible explanation for our next result that credit constrained households tend to insure significantly larger proportion of herd. Since the credit constrained household has less means to cope with catastrophic, they would IBLI substantially. Therefore, apart from the wealth impact from income, the overall results in this first step ordered probit model seem to suggest that household's coverage decision depends substantially on availability of risk coping and management strategies. Lastly, household head's education level (e.g., whether or not he/she obtain some level of secondary, or post-secondary education), which could provide some indication of cognitive ability to understand the mechanics and value of IBLI, is shown to have positive – but not significant – impact on coverage decision, despite its potential role in creating information asymmetry in the overall analysis.

Results from the second-step double-bounded likelihood model estimation conditional on chosen coverage are shown in the next panel of Table 2. The statistically significance of the estimated coefficient of IMR thus confirms the appropriateness of our 2-step specifications. This also indicates that the household's WTP will decrease significantly with their chosen coverage. Strikingly, we continue to observe negative – but not significant – impact of CRRA on household's WTP for insurance, which seems contradict to the theoretical prediction holding other factors constant. This result, however, was also observed in various related literature (e.g., the studies of rainfall insurance uptake among farmers in India by Gine et al. 2008 and Cole et al. 2009) who argue that the observed evidence could result from deviation away from full-information setting and so could reflect the uninformed household's unwillingness to experiment on the newly introduced product. Interacting CRRA with other variables indicating household's familiarity with insurance product, they show that the net impact of CRRA turns positive. Using household head's education as an indicator of their understanding of IBLI and so interacting it with CRRA, we also can confirm the net positive impact of CRRA – especially among those obtained up to secondary education.

Other empirical results in the second step WTP estimation are comparable with the IBLI coverage decision. Household's WTP increases significantly with expectation of loss and with income and productive asset. Wealth effect seems to strongly determine household's WTP decision despite the contrasting result pooled from the buffer stock argument for the significant negative influence from herd size. Actively involvement in social network groups – mostly relating to livestock production, marketing and other livelihood strategies, – weakly representing household's familiarity and openness to experiment with financial transactions and instruments, provide significant positive impact on WTP for IBLI.

The net impact of education on WTP for IBLI is still significantly negative in the first specification of the second-step WTP estimation. Because education may condition information asymmetry in household's evaluation of IBLI, the last panel on the right of Table 2 shows the empirical results when we interact education with household's perceived basis risk, which is decreasing in the correlation between individual and area-averaged livestock losses beyond 10% observed from the 11-year recalls. Household's perceived correlation of livestock losses conditional on understanding of IBLI contract – weakly indicated by education – is shown to have significant positive impact on WTP. The net impact of education on WTP in this new specification is shown to be positive.

In sum, income, availability of coping strategies and household's expectation of loss are found to be the key drivers for insurance coverage decision. Conditional on chosen coverage, wealth, risk preference, perceived basis risk and subjective expectation of loss thus serve as the key WTP determinants among sampled households, well informed about mechanics and value of IBLI contract. Our last specification of the second-step estimation is then used to estimate WTP and demand for IBLI.

7. Estimated Demand for IBLI

Table 3 reports weighted summary statistics of chosen IBLI coverage and the estimated WTP for 10% IBLI contract we considered in this paper. The overall mean chosen coverage stands at slightly lower than 70%. The mean and median WTP only mark up the actuarial fair rate – at 6.8% per annum – by an average of 15%, not enough to generate effective demand for the commercially viable contract at a marked up rate of 30-50%, on average. The variations of chosen coverage and estimated WTP across herd size terciles are also observed. Though with largest variations, chosen IBLI coverage appears the highest – at 95% significant level – among the poorest tercile, on average. Variations in both coverage and WTP decrease as we move from the poorer to the richer terciles.

To further explore how coverage and WTP decision vary with herd size, Figure 3 estimates non-parametrically the chosen coverage and WTP conditional on observed herd sizes. While there is no statistically significant relationship between the estimated WTP and herd size, significant inverse relationship between chosen IBLI coverage and herd size can be observed among households with less than 40 TLU herd sizes. In sharp contrast to the simulated findings in Chantarat et al. (2009b), the poorest sub-population seem to express comparable WTP for IBLI as well as to choose the significantly highest IBLI coverage among others in these communities. This result arises despite the fact that welfare gain from IBLI among this sub-population is shown to be minimal in these settings characterized by threshold-based poverty trap. With the bifurcated herd threshold identified at around 15-20 TLU, poor households with herd sizes far below can benefit from IBLI through reductions of herd variations and/or of probabilities of collapsing into destitution, while paying very high prices as periodically premium payment would further speed their herd decumulation process. These simulated results from Chantarat et al. (2009b), however, ignore the possibilities that IBLI might crowd in finance, investment and credit access, which might in turn increase the welfare benefit among these poorest sub-population.

Contrasting results are also found among the households identified as vulnerable, e.g., with herd sizes around and slightly larger than the bifurcated herd threshold that would still make them vulnerable from collapsing into de-cumulating growth path due to catastrophic herd loss. Our results from field experiment shows that they are among the sub-populations with the lowest chosen IBLI coverage, despite the simulated results that dynamic welfare gain from IBLI of this vulnerable group might be the highest under the presence of bifurcated herd threshold, especially if IBLI protects them from collapse into non-productive herd growth.

Using household's sequential decisions on coverage and WTP, we then proceed to construct aggregate demand for IBLI for the five studied locations in Marsabit as following. We first rank all estimated WTP for the household in descending order. Households' quantity demanded at their estimated WTP can be calculated by multiplying their chosen coverage herd (chosen coverage (%) multiplied by herd size) by the sampling weight corresponding to the households in the sampling location. Aggregate demand curve for IBLI can then be constructed, where total quantity demanded a specific WTP is calculated by adding the total quantity desired of the immediately larger WTP to that of the specific WTP.[16] The constructed aggregate demand is shown to be very elastic with price elasticity of demand of -2.54. Using the some what closed to the market commercial premium rate of at least 30% mark up from the fair rate, effective IBLI demand is shown to exist among only 16% of the populations in these 5 studied locations.

To explore how IBLI demand vary by herd size in the presence of bifurcated herd threshold, we also construct IBLI demand by wealth group classified with respect to the critical herd threshold of at least 15 TLU. Specifically, the lowest herd group consists of households with herd sizes less than the lower bounds of the critical threshold (e.g., between 0-15 TLU) occupying 48% (13%) of population (herd population). The vulnerable herd group consisting of those, who are prone to crossing over the critical threshold, are confined within one standard deviation above the 15 TLU threshold (e.g., between 15-30 TLU) occupying 23% (35%) of population (herd population). Lastly, the large herd group occupies the majority of the herd population and thus consists of those with at least 30 TLU herd size, well above the critical threshold – and so on expectation immune from crossing onto non-productive growth due to shocks.

Figure 4 presents the constructed aggregate and herd group-specific IBLI demand. Price elasticity of demand and summary of effective demand at commercial mark up rates are shown in Table 4. Aggregate demand for the vulnerable group is shown to be the most elastic with the smallest share of population exhibiting effective demand at the commercial mark up rate of 30%-40%. This is in contrast to the demand from the low herd group, which is shown to be the least elastic with the largest share of population exhibiting effective demand at such commercial viable rates.

[16] Aggregate demand curve for IBLI is thus representative for the 5 survey locations. With appropriate scaling and sampling assumptions, aggregate demand for Marsabit district can also be constructed.

8. Conclusions and implications

Index based livestock insurance (IBLI) is successfully designed in Chantarat et al. (2009a) for managing livestock asset risk by compensating for location-averaged livestock mortality estimated using remotely sensed measures of vegetative cover on rangelands. This paper uses field experiment to elicit willingness to pay for IBLI among sampled pastoralists in Marsabit district, where the product is scheduled for pilot sale in 2010. Our key objectives are to explore (i) determinants of IBLI demand, (ii) patterns of estimated demand and (iii) how IBLI demand varies across subpopulations. These empirical results offer a great contrast to that of Chantarat et al. (2009b), which simulates effectiveness of IBLI using dynamic model and household panel data in the overlapping locations.

Central to the analysis in these interrelated research works is the existence of threshold-based poverty traps in the targeted pastoral locations characterized by at least a bifurcated herd threshold that leads to herd growth (decumulation toward destitution) for the herd size above (below) it. Theoretical and empirical evidence behind this imply important role of risk in the population's welfare dynamics, the important role of IBLI especially in preserving herd growth dynamics and so the variation of IBLI valuation induced by such non-linearity.

Our empirical results offer modest verifications to the neoclassical theoretical prediction regarding demand for insurance. Patterns of insurance coverage decision and the conditional WTP decisions vary slightly in the two-step estimation, specification of which is shown to be appropriate. We found that availability of coping strategies and household's expectation of loss are the key drivers of insurance coverage decision. Conditional on the chosen coverage, wealth, risk preference, perceived basis risk and subjective expectation of loss thus serve as the key WTP determinants among sampled households, well informed about mechanics and value of IBLI contract. The estimated WTPs in these communities has, on average, 15% mark up from the actuarial fair rate – clearly lower than the commercial viable rates., at which about 16% of the population still exhibit effective demand. The constructed aggregate IBLI demand is highly elastic with price elasticity of demand at -2.54.

Variations in IBLI demand are well observed. The poorest subpopulation tend to choose significantly larger IBLI coverage and exhibit the least price elastic demand, despite the simulated results that indicate that their dynamic welfare benefits from IBLI were minimal in the presence of threshold-based poverty trap. Households most vulnerable to falling into poverty trap were also shown to have the highest price elasticity of demand, despite their potentially highest dynamic welfare gain from the insurance.

Our findings of high price elasticity of demand provide direct implication to the commercialization of IBLI. Specifically, this could imply substantial returns to small reductions in commercial pricing. The extremely high price elasticity of demand among the sub-populations vulnerable to falling into poverty due to shocks further imply great potential for using targeted subsidizing IBLI as part of social protection program in the region. Barrett et al. 2008 terms this as productive safety net in the sense that it can protect the targeted vulnerable non-poor from unnecessarily slipping into a poverty trap that they may find hard to escape and that may require greater humanitarian resource. Targeted subsidizing IBLI can prove appropriate as a cost effective and sustainable poverty reduction program in the areas. Our empirical research implemented in parallel to the pilot sale of IBLI in early 2010 will explore greater insight for the optimal subsidization scheme using incentive pricing experiments.

Our experiment results that indicate great and relatively inelastic demand of IBLI among the poorest, who potentially aim to use IBLI to complement their meager means of coping with live-threatening losses, further provide great indication of pro-poor, humanitarian values of IBLI. The extent to which these potentially credit constrained subpopulations could actually afford and benefit from the real commercial contract, however, becomes empirical questions.[17] What are the key determinants of the actual insurance uptake? What are the induced behavior and market impacts of IBLI that might facilitate further improvement in welfare dynamics? Agenda of research is underway to explore these key issues in parallel to the 2010 pilot sale.

[17] This is in contrast to the empirical results from Gine et al. 2008 and Cole et al. 2009, who identify that credit constraint is one of the main impediment in the uptake of rainfall insurance among Indian farmers, and so that the pro-poor impacts of insurance is still very limited.

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Table 1: Summary of (weighted) Statistics

Variables	Mean	Median	S.D.	Minimum	Maximum
Household and herd characteristics					
Household size	6	6	2	2	11
Head is male (=1 if yes, =0 if no)	0.76	1.00	0.43	0.00	1.00
Head's age (years)	47	48	13	24	90
Head education (1-12 yrs) (=1 if yes, =0 if no)	0.13	0.00	0.33	0.00	1.00
Head education (>12 yrs) (=1 if yes, =0 if no)	0.03	0.00	0.18	0.00	1.00
Dependent ratio (%)	46%	50%	22%	0%	86%
Member living away (=1 if yes, =0 if no)	0.13	0.00	0.33	0.00	1.00
Share of immature (non-adult) livestock (%)	28%	30%	19%	0%	71%
Share of mobiled herd (%)	68%	87%	38%	0%	100%
Per capita annual income and livelihood					
Per capita economic income (1,000 KSh)	12.7	6.1	30.3	0.2	323.0
Share of income from: livestock	63%	84%	38%	0%	100%
Salaried employment	7%	0%	23%	0%	99%
Trade and business	8%	0%	21%	0%	96%
Petty trading and casual labor	7%	0%	18%	0%	74%
Assets and credit constraint					
Total livestock (TLU)	15.5	12.5	16.8	0.1	130.6
Total landholdings (hectare)	0.5	0.0	1.1	0.0	15.0
Total productive asset (1,000 KSh)	188.8	0.0	1,703.0	0.0	19,100.0
Total non-productive asset (1,000 KSh)	2.6	0.2	6.8	0.0	90.0
Credit constrained (=1 if yes, =0 if no)	0.36	0.00	0.48	0.00	1.00
Familiarity with financial transactions					
Has bank account (=1 if yes, =0 if no)	0.07	0.00	0.25	0.00	1.00
Actively involved in group(s) (=1 if yes, =0 if no)	0.15	0.00	0.36	0.00	1.00
Preferences					
Risk aversion (CRRA)	0.63	0.70	0.40	0.00	1.00
Discount rate	0.52	0.50	0.31	0.05	1.00
Ambiguity aversion (=1 if yes, =0 if no)	0.52	1.00	0.50	0.00	1.00
Livestock loss experience and perception					
If experienced very bad long rain in 2008(=1 if yes, =0 if no)	0.22	0.00	0.41	0.00	1.00
% of years with livestock loss > 200% own mean	18%	18%	16%	0%	82%
Correlation btw. individual and area losses beyond 10%	0.53	0.62	0.34	-0.36	0.95
Expected livestock loss in 2009 (%)	34%	30%	20%	0%	100%
Summary statistics of IBLI contract					
Predicted seasonal NDVI based mortality index* : M(ndvi)	9.1%	4.7%	9.4%	0.0%	46.0%
PR(M(ndvi)>10%)	34.5%				
Actuarial fair annual premium at 10% strike	6.8%				
Unweighted number of observations	207				

Note: We drop 1 household that could not attend the insurance game and CV experiments and 2 households with no livestock.

* The predicted seasonal index is used to trigger IBLI indemnity payment at the end of each of the two seasons in the coverage year.

Table 2: Two-step Estimation of IBLI Demand

First stage: Weighted ordered probit model with dependent variable = chosen proportion of insured herd
Second stage: Weighted interval regression model with dependent variable = upper and lower bounds of WTP
Location dummies and constant are included (results omited)

Specifications	**1st: Coverage***		**2nd: WTP (1)**		**2nd: WTP (2)**	
Starting bid			0.31**	(0.13)	0.32**	(0.13)
IMR			-0.25*	(0.15)	-0.24*	(0.15)
Preference						
CRRA	-0.29	(0.29)	-0.60	(0.40)	-0.62	(0.40)
CRRA × Head education (1-12 yrs)	-1.17	(0.92)	1.53*	(0.81)	2.20***	(0.74)
CRRA × Head education (>12 yrs)	-0.24	(1.54)	1.19	(1.88)	1.06	(1.82)
Discount rate	0.22	(0.38)	-0.69	(0.60)	-0.71	(0.60)
Ambiguity aversion (=1 if yes, =0 if no)	-0.48**	(0.20)				
Livestock loss experience and perception						
Experienced very bad long rain 2008 (=1 if yes, =0 if no)	-0.84*	(0.54)	0.47	(0.55)	0.46	(0.55)
Probability of m_it>200% mean_i	1.26	(0.90)	0.68	(1.14)	0.53	(1.21)
Correlations (m_it,m_t)	0.22	(0.41)	0.20	(0.55)	-0.13	(0.60)
Correlations (m_it,m_t) × Head education (1-12 yrs)					2.43**	(1.17)
Correlations (m_it,m_t) × Head education (>12 yrs)					0.71	(1.53)
Expected livestock loss in 2009	1.87**	(0.84)	1.89**	(0.83)	1.82**	(0.82)
Wealth and credit constraint						
Ln (income per capita)	0.53***	(0.16)	0.42**	(0.18)	0.45***	(0.17)
Ln (total livestock)	-0.34**	(0.15)	-0.91***	(0.17)	-0.92***	(0.16)
Ln (productive assets)	0.04	(0.03)	0.12***	(0.04)	0.13***	(0.04)
Ln (nonproductive assets)	0.00	(0.04)	-0.11***	(0.04)	-0.11***	(0.04)
Credit constrained (=1 if yes, =0 if no)	0.65**	(0.30)	0.56	(0.54)	0.57	(0.53)
Landholding	-0.41***	(0.15)				
Familiarity with financial transactions						
Have bank account (=1 if yes, =0 if no)	-0.63	(0.43)	0.52	(0.90)	0.68	(0.85)
Belong to active network (=1 if yes, =0 if no)	-0.02	(0.26)	1.23***	(0.41)	1.27***	(0.41)
Household and herd characteristics						
Household size	0.07	(0.07)	0.20***	(0.07)	0.20***	(0.07)
Head is male (=1 if yes, =0 if no)	-0.52*	(0.33)	0.50	(0.40)	0.55	(0.39)
Head age	-0.01	(0.01)	-0.02	(0.01)	-0.02	(0.01)
Head education (1-12 yrs) (=1 if yes, =0 if no)	0.87	(0.84)	-1.91***	(0.72)	-3.60***	(0.93)
Head education (>12 yrs) (=1 if yes, =0 if no)	0.16	(1.05)	-0.41	(1.64)	-0.81	(1.59)
Dependent ratio	-0.69	(0.57)				
Member living away (=1 if yes, =0 if no)	-0.62*	(0.36)				
Proportion of immature animals	0.67	(0.79)				
Number of observations	207		207		207	
Pseudo adjusted R2	0.29		0.44		0.44	
Proportion of correct prediction	0.57					

Note: Robust standard erros in parentheses. *significant at 10%, ** 5% and *** 1% respectively.

*Estimations of threshold parameters α1, α2, α3 are omited.

Table 3: Summary of Chosen Coverage and Estimated WTP

Variables	Mean	Median	S.D.	Minimum	Maximum
Chosen Coverage (% Herd)					
Overall	68.9%	75.0%	30.2%	0.0%	100.0%
1st Tercile	81.2%	100.0%	33.3%	0.0%	100.0%
2nd Tercile	64.4%	50.0%	27.7%	25.0%	100.0%
3rd Tercile	60.0%	50.0%	24.5%	25.0%	100.0%
Estimated WTP (% of insured herd value)					
Overall	7.8%	7.7%	1.4%	2.8%	12.0%
1st Tercile	7.6%	7.2%	1.6%	3.0%	12.0%
2nd Tercile	8.0%	8.0%	1.4%	2.8%	11.6%
3rd Tercile	7.6%	7.7%	1.2%	4.2%	10.1%

Note: Herd sizes cut off for 1st and 2nd terciles are 6 TLU and 18 TLU respectively

Table 4: Price Elasticity of IBLI Demand

Herd Group	% Population	% Herd Population	Elasticity of Demand	Proportion with effective demand at Fair	1.3×Fair	1.4×Fair
Less than 15 TLU*	0.48	0.13	-2.08	0.61	0.23	0.12
Between 15-30 TLU	0.23	0.35	-3.32	0.65	0.10	0.04
Greater than 30 TLU	0.28	0.53	-2.70	0.69	0.10	0.07
Aggregate	1.00	1.00	-2.54	0.64	0.16	0.09

* 15 TLU is equivalent to the bifurcated herd threshold found in these communities, 30 TLU is equivalent to 1 S.D. above the threshold.

Figure 1: Study Locations in Northern Kenya

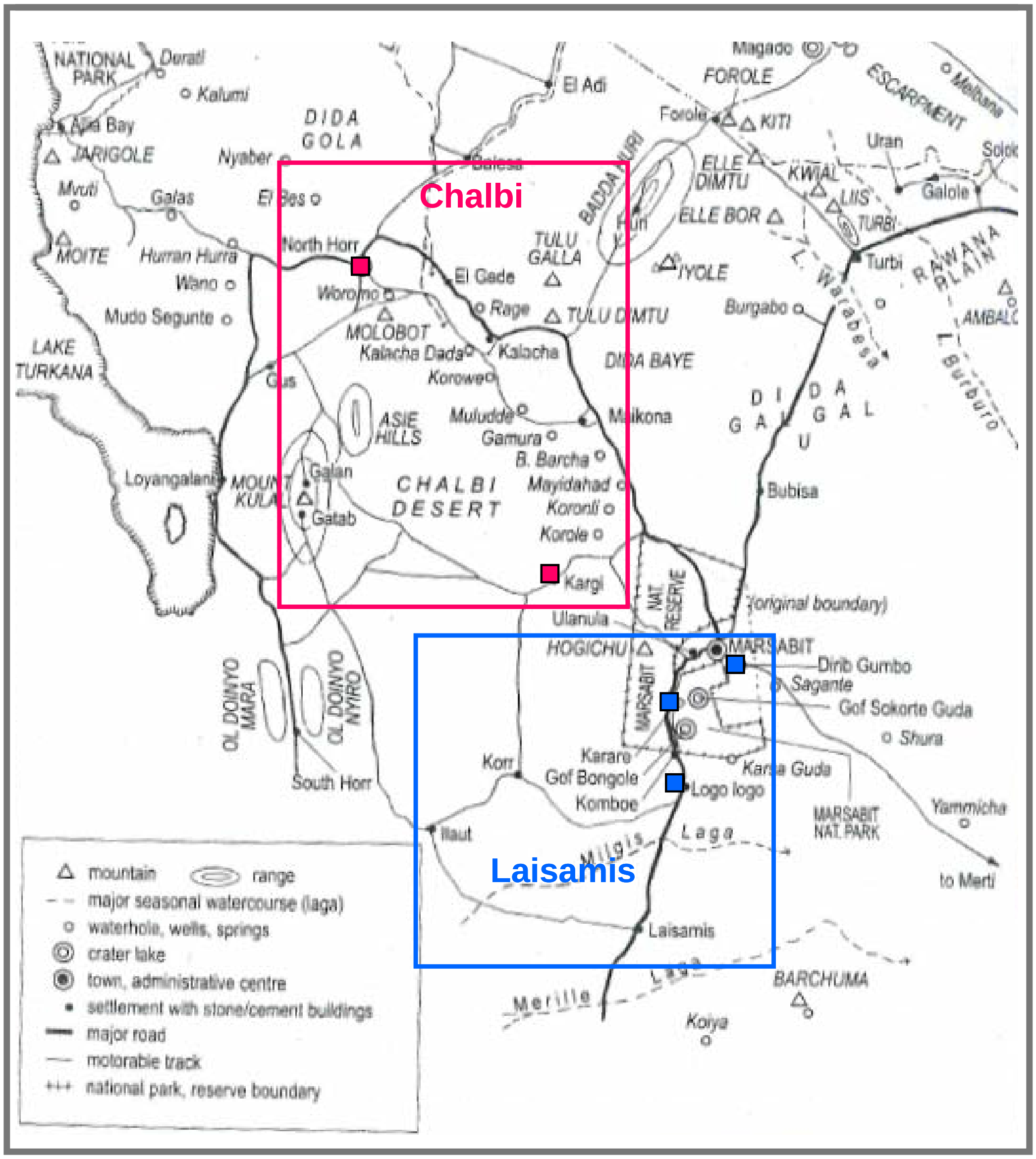


Figure 2: Structure of Double-bounded CV Method

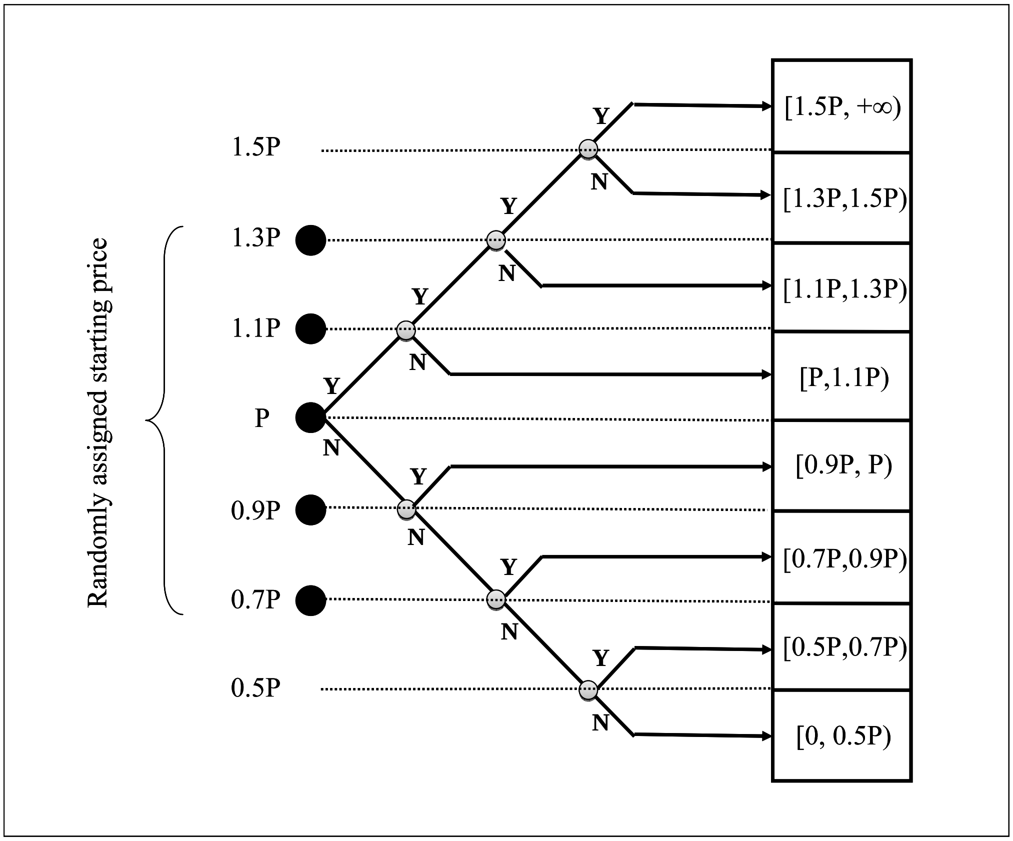


Figure 3: WTP for 10% Strike Contract and Insured Proportion by Herd Size

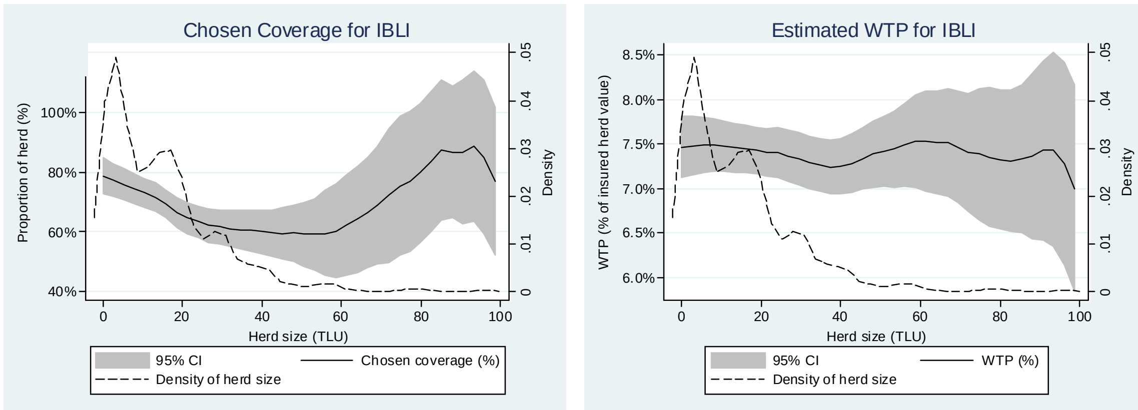
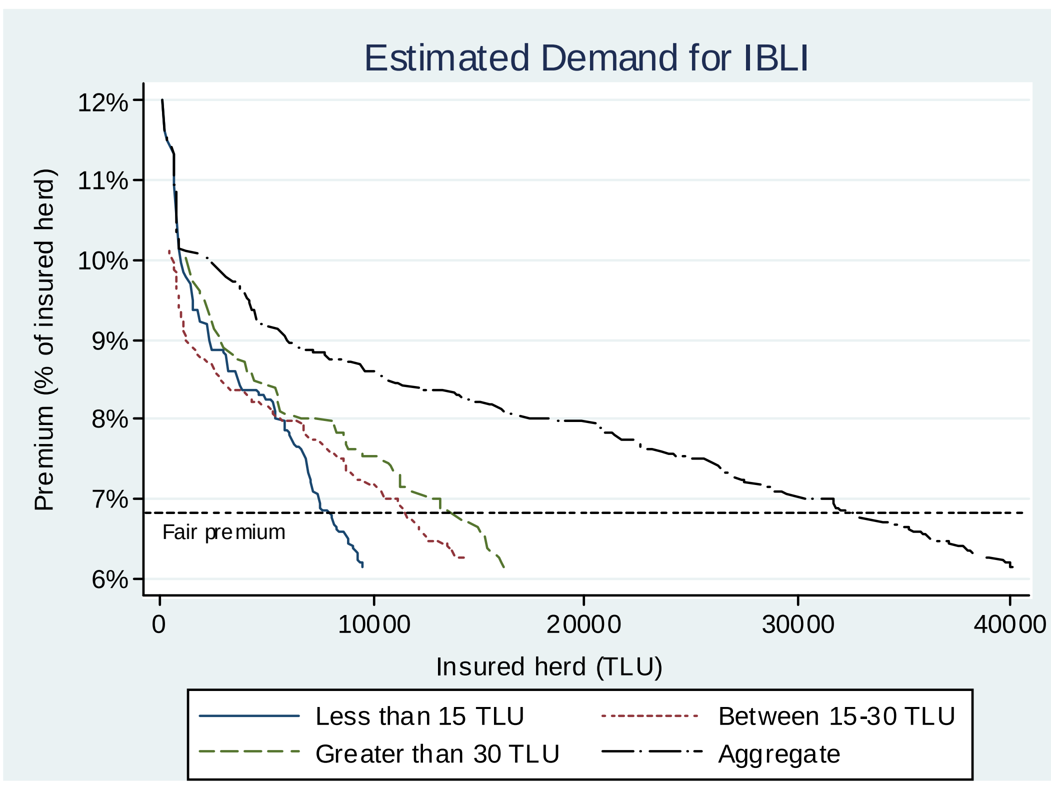


Figure 4: Demand for 10% Strike Contract by Herd Group



Appendix 1: Description of Variables

Variable name	Value	Description
CRRA	(0,0.1,0.3, 0.4,0.7,1)	Respondents were first given 100 Ksh for participating in the survey. They can use this 100 Ksh to play one of the five 50/50 lotteries, which a fair coin was then tossed to determine their real prize. Q: In this game, your chance of winning depends on a coin flip. If the coin land on head (tail), you will win the amount below the head (tail) picture. You can choose to keep 100 KSh for sure or choose to play one of the 5 games, which one would you choose? (0) 100 KSh for sure (1) 130 KSh if head/ 80 KSh if tail (2) 160 KSh if head/ 60 KSh if tail (3) 190 KSh if head/ 40 KSh if tail (4) 220 KSh if head/ 20 KSh if tail (5) 240 KSh if head/ 0 KSh if tail We estimate the range of coefficients of relative risk aversion implied by each possible choice of gambles under the assumption of CRRA utility: $E(U(P)) = \sum_k \pi_k U(P_k) = \sum_k \pi_k \left(\frac{P_k^{1-R}}{1-R} \right)$, $U'(P) > 0, \quad 0 \le \pi \le 1$ and k=1,2. π represents probability of each possible payoff P and R is the CRRA. In each choice, the upper (lower) bound of R can be calculated as the value of R that generates same utility level for the payoffs associated with the preferred gamble and the less (more) risky adjacent. Following Binswanger (1980), CRRA are calculated by assigning mean measures to each of the ranges using the geometric mean of the two end points. In the case of gamble 5, a value of zero is given to the CRRA measure to represent a class of risk neutral or risk seeker. The value of one is then assigned to the case of gamble 1 to represent the extremely risk averse class. Six risk aversion classifications (extreme, severe, intermediate, moderate, low/neutral and neutral/risk seeker), slightly similar to Binswanger (1980), are further assigned to each of the case (see Table below).
Discount rate	(0,…,1)	Implied monthly discount rate calculated from the minimum amount individual is willing to accept one month later. Q. Imagine that you have just won a prize of 10,000 KShs today. You can get 10,000 KShs now for sure. However, if you are willing to wait for one month, you can get more. (Keep asking and stop when respondent accepts the offer amount one month later) (1) 10,000 now/10,500 later? (2) 10,000 now/11,000 later? (3) 10,000 now/12,000 later? (4) 10,000 now/13,000 later? (5) 10,000 now/14,000 later? (6) 10,000 now/15,000 later? (7) 10,000 now/16,000 later? (8) 10,000 now/17,000 later? (9) how much does the prize need to be in order for you to wait for one month to receive it?
Ambiguity aversion	(0,1)	Equal to 1 if individual is ambiguity averse, i.e. respondent selects pack 1 with known probability of winning in the game: You need to choose a knife from one of the two packs to play the game. If the knife you choose is the right color, you will win 100 KSh. Which packs of knifes would you like to play? Pack 1 is a clear pack and so you can see that it contains 2 knifes with black paint and 3 knifes without black paint. You will win if you pick a knife (without looking) with black paint. Pack2 is a solid pack. It contains 5 knifes, some with and without black paint. I don't know for sure how many of each there are. You will win if you pick the knife that you specify.

Head education (1-12 yrs)	(0,1)	Equal to 1 if household head has between 1-12 years of schooling. These represent the number of years spent up to secondary education.
Head education (>12 yrs)	(0,1)	Equal to 1 if household head has any post-secondary education (e.g., diploma, university, etc.)
Dependent ratio	(0,…,∞)	This is calculated by dividing the number of individuals under 15 years or over 64 years of age by the total household size.
Member living away	(0,1)	Equal to 1 if household head reported having at least one household member currently living or working away from the community.
% immature herd	(0,1)	This is calculated by one minus percentage of adult animals (at least 3 years old for cattle and camel, at least 6 months old for goat and sheep)
% of mobile herd	(0,1)	This is the proportion of herd that has moved at least once over the past year in search for forage and water
Ln(Income per capita)	(0,…,∞)	Ln(1+income) where economic income calculated from the sum of market value of milk and meat production, crop production, livestock trading, petting trading, other trades and business, wage and salary earnings.
Share of income from livestock	(0,1)	This is the proportion of income that comes from livestock trading and sales of livestock and livestock products
Ln(total livestock)	(0,…,∞)	Ln(1+total livestock) which only includes livestock that household owns. The total amounts are converted into an aggregate "Tropical Livestock Unit" (1 TLU = 1 cattle = 0.7 camel = 10 goat/sheep)
Ln(total productive asset)	(0,…,∞)	Ln(1+productive asset), which includes non-local breed animals, shop and business, house of plot in town, vehicle, cell phone, etc., all valued in KSh.
Ln(total non-productive asset)	(0,…,∞)	Ln(1+non-productive asset), which includes household consumable goods, such as jewelry, clothing, furniture, all valued in KSh.
Credit constrained	(0,1)	Equals to 1 if individual responses that they haven't applied for (formal/informal) loan/credit since last year and citing reasons related to lack of credit. This equals to zero if they cite no need for credit. It also equals to one if they have applied for any (formal/informal) credit but have never gotten one since last year.
Actively involved in group (s)	(0,1)	Equal to 1 if household cites livelihood-related group/association(s) (e.g., various women groups, milk production and marketing groups, financial service association (FSA), etc.) that they actively involve in and that they can call up any member of this group for assistance.
Experience very bad long rain 2008	(0,1)	Equal 1 if response "Much below normal" to the question: Please tell me your opinion and experience about the amount of long rain 2008 (Much below normal/Somewhat below normal/Normal/Somewhat above normal/Much above normal)
% years with loss>200% own mean	(0,…,1)	Proportion of years in 11 years of historical annual herd loss recalls (1997-2007) with losses exceeding 200% of individual-specific mean annual livestock loss. The recall exercise asked about total and losses for each species each year.
Correlations (m_it,m_t) beyond 10% loss	(-1,…,1)	Correlations between individual annual rates of herd losses beyond 10% (i.e.,Max(0,mit-0.1)) and area averaged rates beyond 10% (i.e., Max(0,m_t-0.1)) calculated from 11 years of loss recalls (1997-2007).
Expected % loss in 2009	(0,0.1,0.2, 0.3,…,1)	Response to Q: What proportions of your herd do you think you will lose in the next 12 months from now? (None, 1/10, 2/10, 3/10,…, All, No idea)

Appendix 2: Risk Perception and Existing Coping Strategies

Please rank the three problems that you are most concerned of and have difficulty to cope given your household's resources, skills and networks.

Problem	1st concern	2st most concern	3st most concern	weighted sum
Livestock loss due to drought/excessive rain	169	17	15	44%
Livestock loss due to disease outbreak	23	77	27	20%
Livestock loss due to conflict/raiding	2	16	35	6%
Milk production loss due to drought/excessive rain	5	50	57	14%
Crop fail due to drought/excessive rain	1	3	4	1%
Low market access and low selling price of livestock	4	28	38	8%
High food price	1	5	10	2%
Loss of business/trade	3	1	1	1%
Illness and death	0	5	8	1%
Insecurity and violence	1	7	14	2%
Others	0	0	0	0%

In times when your household faced with major livestock losses, please rank the three most important strategies that your household used to cope with those losses?

Coping strategies	1st concern	2st most concern	3st most concern	weighted sum
Reducing household consumption	62	23	15	20%
Utilization of asset and saving	91	48	22	31%
Obtaining credit from various sources	44	83	46	27%
Seeking alternative livelihood	6	45	12	10%
Outside assistance from others, governments, NGO, etc.	6	10	114	12%

Please provide the two most important actions you take to prepare your household upon your expectation of catastrophic herd loss.

Rik management strategies	1st concern	2st most concern	weighted sum
Save more money	99	30	36%
Increase grain stocking	23	23	11%
Expand herd size	8	12	4%
Decrease herd size (through loaning and sales)	71	92	37%
Purchase more supplemental feeds/vetenary inputs	1	32	5%
Allocate some household members/investments to other ag	6	18	5%
Others	1	2	1%

Appendix 3: Summary of Setting of Risk Preference Elicitation

Gamble Choice	High Payoff	Low Payoff	Expected Payoff	S.D. Payoff	CRRA ranges	Geometric mean CRRA	Risk aversion class
1	100	100	100	0	r>0.99*	1.0	Extreme
2	130	80	105	25	0.55<r<0.99*	0.7	Severe
3	160	60	110	50	0.32<r<0.55	0.4	Intermediate
4	190	40	115	75	0.21<r<0.32	0.3	Moderate
5	220	20	120	100	0<r<0.21	0.1	Low/Neutral
6	240	0	120	120	r<0	0.0	Neutral/risk seeking

Note: *Without assumption of $r \leq 1$, the actual value of r is 1.67.

Appendix 4: Heckman's Two Step Estimation and Correction for covariance Matrix

The first step ordered probit model is defined as

$$(A1) \quad h_i^* = X'_{i1}\beta_1 + \varepsilon_{i1} \quad , \quad h_i = \begin{cases} h(1) = 0.25 & if \ -\infty < h_i^* \le \alpha_1 \\ h(2) = 0.50 & if \ \alpha_1 < h_i^* \le \alpha_2 \\ h(3) = 0.75 & if \ \alpha_2 < h_i^* \le \alpha_3 \\ h(4) = 1.00 & if \ \alpha_3 < h_i^* \le +\infty \end{cases} ,$$

where α_j represents unknown threshold with assumed $\alpha_0 = -\infty$ and $\alpha_4 = +\infty$.

Consider a simple second-step WTP model:

$$(A2) \quad WTP_i^* = X'_{i2}\beta_2 + u_{i2} \qquad , WTP_i \in [\, p_{iL}, p_{iU}\,] \quad \text{and} \quad \varepsilon_1, u_2 \sim BVN(0,0,1,\sigma_u^2, \rho_{1u})$$

And so, using Heckman's approach to estimation, one can write for $j = 1,2,3,4$:

$$\begin{aligned}(A3) \quad E\left(WTP_i^* / h_i = h(j)\right) &= E\left(WTP_i^* / \alpha_{j-1} - X'_{i1}\beta_1 < \varepsilon_{i1} \le \alpha_j - X'_{i1}\beta_1\right) \\ &= X'_{i2}\beta_2 + E\left(u_{i2} / \alpha_{j-1} - X'_{i1}\beta_1 < \varepsilon_{i1} \le \alpha_j - X'_{i1}\beta_1\right) \\ &= X'_{i2}\beta_2 + \rho_{1u}\sigma_u \left(\frac{\phi(\alpha_{j-1} - X'_{i1}\beta_1) - \phi(\alpha_j - X'_{i1}\beta_1)}{\Phi(\alpha_j - X'_{i1}\beta_1) - \Phi(\alpha_{j-1} - X'_{i1}\beta_1)} \right) \\ &= X'_{i2}\beta_2 + \rho_{1u}\sigma_u \lambda_i \end{aligned}$$

With $\Pr(h_i = h(j)) = \Phi(\alpha_j - X'_{i1}\beta_1) - \Phi(\alpha_{j-1} - X'_{i1}\beta_1)$, the IMRs for household i with a chosen insured proportion $h_i = h(j)$ can be represented by

$$(A4) \quad \lambda_i = \sum_{j=1}^{4} \mathrm{I}(h_i = h(j)) \left(\frac{\phi(\alpha_{j-1} - X'_{i1}\beta_1) - \phi(\alpha_j - X'_{i1}\beta_1)}{\Phi(\alpha_j - X'_{i1}\beta_1) - \Phi(\alpha_{j-1} - X'_{i1}\beta_1)} \right) \quad ,$$

where $\phi(\cdot)$ represents a normal probability distribution function and an indicator function $\mathrm{I}(h_i = h(j)) = 1$ if $h_i = h(j)$ and = 0 otherwise.

Using these, we can fully describe the two-step estimation we use, which closely follows that of Heckman's two-step estimator described in Greene (2002). The first step is to estimate the ordered probit model using maximum likelihood. The estimated (α', β_1) is then used to estimate λ_i. The maximum likelihood estimator (β_2, β_λ) can then be estimated from the second-step WTP model with (X_{i2}, λ_i) as regressors. The corrected asymptotic covariance matrix for this two step estimator can be derived as

$$\text{(A5)} \quad \text{Asy.Var}(\beta_2, \beta_\lambda) = \hat{\sigma}_u^2 (X'X)^{-1} \left(X'(\mathrm{I} - \hat{\rho}_{1u}^2 \Delta) X + \hat{\rho}_{1u}^2 (X'\Delta X_1) \Sigma (X_1' \Delta X) \right) (X'X)^{-1}$$

where $X = (X_{i2}, \lambda_i)$; $X_1 = X_{i1}$

$$\hat{\sigma}_u^2 = \frac{\hat{u}'\hat{u}}{n} - \hat{\beta}_\lambda^2 \bar{\hat{\delta}}$$

$$\hat{\delta}_i = \frac{(\hat{\alpha}_{j-1} - X_{i1}\hat{\beta}_1)\phi(\hat{\alpha}_{j-1} - X_{i1}\hat{\beta}_1) - (\hat{\alpha}_j - X_{i1}\hat{\beta}_1)\phi(\hat{\alpha}_j - X_{i1}\hat{\beta}_1)}{\Phi(\hat{\alpha}_j - X_{i1}\hat{\beta}_1) - \Phi(\hat{\alpha}_{j-1} - X_{i1}\hat{\beta}_1)} - \lambda_i^2$$

$$\bar{\hat{\delta}} = p\lim \frac{1}{n} \sum_{i-1}^{n} \hat{\delta}_i$$

$$\hat{\rho}_{1u}^2 = \hat{\beta}_\lambda^2 / \hat{\sigma}_u^2$$

$\Delta = diag[\hat{\delta}]$ and Σ is asymptotic variance matrix of the first step regression.

Making this adjustment for corrected asymptotic variance matrix thus yields efficient estimates for the second-step estimators.