Topping Informal Risk Pooling with Indexed Insurance: A VaR Application.

M'Kiaira Kimathi Miriti
University of Kentucky
Department of Agricultural Economics
312 Charles E. Barnhart Bldg.
Lexington KY 40546-0276
(859) 257 7272 ext 248
Kimathi@uky.edu

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Abstract

Value at Risk (VaR) is applied to investigate the potential of incentives for member selection in an index insuring mutual group of farmers. Member selection could have far reaching implications of introducing indexed insurance in smallholder economies. Results indicate that there are no incentives for member selection.

Introduction

Literature over recent years has presented indexed insurance as a promising alternative for financing gargantuan catastrophe risks such as earthquakes and hurricanes (Froot, 1997; Doherty, 1997; Lamm, 1997; Skees, 1998). This literature serves as an eye opener among researchers and practitioners of economic development, among whom the problem of correlated risk is a dominant concern (Mosley, 2000; Brown and Nagarajan 2000; Patel, 2002). Indexed insurance contracts for many common risks that afflict many agrarian economies can be designed in much the same way that indexed insurance contracts are designed to cover earthquakes and hurricanes. Yet disproportionate transaction costs owing to a miniscule scale of operation could inhibit individual index insurance in developing economies. Because these risks are shared, however, indexed contracts covering them can also be shared.

Objectives

The primary objective is to investigate the sensitivity of a collectively owned index reinsured portfolio to individual systemic risk profiles of its composite exposure units. Value at Risk (VaR) is applied to compare risk in collective portfolios that are derived through a strategic and successive selection of members according to own systemic risk exposure. The likelihood, and nature, of member selection when a mutual group forms to use area index insurance contracts is then inferred.

Mutual Insurance

Non market mutual insurance is widespread in many low income economies where market insurance is exceptionally insufficient (Arnott and Stiglitz, 1991). It typically occurs in the form of numerous resource exchanges among family and relatives, friends and neighbors. Mutual insurance begins when an individual needing to be insured against an accidental loss makes a resource transfer to another, a family member, friend or neighbor. The recipient becomes an insurer, with an obligation of making insurance payments to the donor if the latter experiences a loss. The donation, which is practically the insurance premium, is forgotten if the donor does not experience a loss (Victorio 2002).

Various forms of rural institutions such as credit schemes are founded on the principle of mutual insurance. These institutions arise when individuals who

need insurance cluster together, knit by the common objective of gaining insurance from each other. Variants of mutual insurance institutions, broadly termed microfinance and microinsurance, may arise purely from local organization of individuals who are moved to action by their individualized, but widespread, need for forms of financial services, or may be initiated by external concerns such as donors and non governmental organizations which recognize the potential for improved local risk management when commonly exposed units pool together. These institutions operate in many environments, enabling many communities to manage adversities that are beyond the individual capacities of solitary individuals or households. Village banks and village clubs make it possible for households and individuals in many developing economies to fairly smooth consumption even though financial institutions are weak.

Mutual insurance is an effective means for absorbing idiosyncratic risk. Participants incur the costs associated with the smaller average variability of the loss suffered by the group instead of that of the individual variability. However correlated risk must be retained unless ceding opportunities exist. Indeed, the average risk in a mutual insurance group is larger than the typical participant's risk if all risk is systemic.

Doherty (2000) offers an extensive discussion of the risk properties of the distribution of the average loss of a pooled portfolio. In particular, these properties derive from the individual properties and the commonalities of distributions of individual exposure units of the pooled portfolio. If the variance of exposure unit i of the pooled portfolio of n units is σ_i^2, then the variance of portfolio average loss is:

$$\sigma^2\left(\frac{L_t}{n}\right) = \sigma^2(l_t) = \frac{1}{n^2}\left(\sum_i^n \sigma_i^2 + \sum_i^n \sum_{j \neq i}^n \sigma_{i,j}\right)$$

Equation 1

The presence of common risk in the pooled portfolio is denoted by the presence in Equation 1 of a positive term resulting from the summed covariance term. When this term is zero, then the risk is totally individual, and can conceptually be reduced to zero simply by pooling many portfolios, i.e. enlarging n. Equation 1 can be simplified as:

$$\sigma^2\left(\frac{L_t}{n}\right) = \sigma^2(l_t) = \frac{1}{n^2}\left(\sum_i \sigma_i^2 + \sum_i \sum_{j \neq i} \gamma_{i,j}\sigma_i\sigma_j\right)$$

Equation 2

where

$\gamma_{i,j} = \dfrac{\sigma_{i,j}}{\sigma_i \sigma_j}$, the correlation coefficient between the portfolios of the ith and j^{th} households. Equation 2 can be simplified even further if all n portfolios are

identical such that $\gamma_{i,j}$ is the correlation coefficient between any pair of household portfolios:

$$\sigma^2(l_t) = \frac{1}{n^2}\left(n\sigma^2{}_i + n(n-1)\gamma_{i,j}\sigma_i\sigma_j\right) = \frac{\sigma^2{}_i}{n} + \frac{(n-1)}{n}\gamma_{i,j}\sigma_i\sigma_j$$

Equation 3

As n becomes large the quotient $\frac{(n-1)}{n}$ tends to unit, meaning that at the limit the last term will equal $\gamma_{i,j}\sigma_i\sigma_j$. This term is the burden of the mutual pool when opportunities for transference are absent. This term will be larger the larger are the $\gamma_{i,j}$ terms, or the more significant are the covariant terms. The burden is non existent if all risk is idiosyncratic, i.e. if $\Sigma\sigma_{i,j} = 0$, or when all are $\gamma_{i,j}$ terms are independently zero.

In theory the mutual insurance can distribute the effect of a systemic loss in one period over many periods. For example the mutual pool can use a loan to smooth loss intertemporally. In practice however the intensity of loss in a given period could be too large for the mutual insurance to smooth it out over any reasonable period. Besides, nothing stands in the way of another major systemic loss occurring in the portfolio before a past one is fully smoothed. What the mutual pool needs is another instrument to transfer this part of risk to an external entity, preferably one with the potential to absorb potentially large losses, and one that avails surety *ex ante*. Indexed insurance is a strategic medium for this purpose.

Indexed insurance

Factor indexed derivatives hold a promise to deliver insurance-type risk coverage for correlated risk. Indexed insurance is benchmarked on the factors of the hazard so that indemnity payments can be activated by the occurrence of disaster. A simple indexed insurance contract against drought may pay indemnities when the rainfall measured over a specific period at a selected station falls short of a pre specified threshold. Similarly a commodity yield indexed insurance contract may pay indemnities when area yields fall short of a pre specified threshold. Individuals and other entities would pay premiums well before the insurance period, and would be compensated according to *ex ante* defined functions if the trigger event occurs.

In low income economies, where enterprises are typically small, financial transactions tend to be overwhelmingly high. The simplest reason for a difference in the costs of financial services to small and large holdings is the existence of a uniform fixed cost of each financial transaction (Saito and Villanueva, 1981, Binswanger and Sillers, 1983). When insuring against correlated risk in these economies, it may be efficient to insure the various mutual insurance institutions, rather than their individual participants. A single indexed insurance contract can cater for the needs of multitudes of individuals within a locality since all participants are commonly exposed. Moreover, since

mutual insurance entities are typically effective in enabling the management of idiosyncratic risks among their members but are weakened by systemic risks, a means to strengthen them in the face of systemic risk may be what their dependents need most. When it participates in indexed insurance contracts a mutual insurance entity can provide its members with security against systemic risk because these contracts present the opportunity to filter off this elusive risk component from the pooled portfolio. This is ideally the concept of reinsurance.

The operation of shared coverage with indexed insurance can take various forms. Individuals can decide to contribute into a premium pool, and then to share indemnities according to their relative premium inputs. In this arrangement the mutual pool is a passive vehicle through which premiums and indemnity payments are transferred between insurers and the insured. A more interesting approach is one in which individuals generally decide to insure the mutual portfolio in recognition of the fact that the survival of the mutual group is more valuable than ensuring full private coverage for the private cost.

The proposal for mutual insurance groups to transfer risk with indexed insurance may be complicated by the fact that not all participants are identically exposed to a systemic risk. Individuals who are most exposed to the risk have the greatest incentives to mobilize the group to use indexed insurance. What is not clear is whether those who are least or intermediately exposed will be acceptable to the group. It is already established that only the portfolios exposed at above a certain level may reduce risk with indexed insurance when the insurance is applied to individual portfolios (Miranda, 1991).

If the average risk in an index insured collective portfolio can be demonstrated to increase when a particular category of holdings is introduced, then it is arguable that this category of holdings is undesirable to the index insured mutual group. The effect of various categories of holdings on the mutual portfolio risk is evaluated with an application of VaR.

If all mutual insurance groups are likely to adopt indexed insurance to cede traditionally uninsurable catastrophe risk then any category of holdings with perverse effects on index insured group portfolios will likely be excluded from all mutual insurance. This outcome would constitute a detrimental social exclusion of a select group of households.

Data and Methods

VaR is a statistical measure of possible portfolio losses. Losses greater than the VaR are suffered only with a specified small probability (Linsmeier and Pearson, 1996). A mutual insurance will have different VaR values depending on the common nature of risk in its exposure unities. Only the systemic risk is studied because it is the one relevant to indexed insurance. The definition of VaR in the

study is also in a way to avoid mixing up effects of risk with those of non risk variables, particularly the portfolio alpha.

The study uses time series farm-level corn yield data from several US counties. From this data the systemic risk profile (exposure beta) is estimated for every farm, as the slope in an OLS model relating farm yield to area yield (Miranda, 1991).

$$y_{it} = \mu_i + \beta_i (y_t - \mu) + \varepsilon_{it}$$

Equation 4

where

$$\beta_i = \frac{\mathrm{cov}(y_i, y_t)}{\sigma^2_{y_t}}$$

$E(\varepsilon_{it}) = 0$ $\quad$ $Var(\varepsilon_{it}) = \sigma^2_{\varepsilon}$ $\quad$ $Cov(y_t, \varepsilon_{it}) = 0$

$E(y_{it}) = \mu_i$ $\quad$ $Var(y_{it}) = \sigma^2_{yit}$

$E(y_t) = \mu$ $\quad$ $Var(y_t) = \sigma^2_{yt}$.

The data is also used to calibrate an area yield insurance index.

$$\eta_t = \max[(y_c - y_t), 0]$$

Equation 5

where η_t is period t indemnity outlay from the indexed contract and y_c is a relevant critical yield in the context of participants' definition of loss.
A hypothetical mutual insurance group is then defined, initially comprising a single member. Basis for characterizing the systemic risk profile of premier members of a mutual insurance group, where group formation is motivated by the objective to collectively reinsure with an index contract, is inferred from Miranda (1991). A Monte Carlo simulation is then applied to estimate VaR, and to relate this estimate to the exclusion and inclusion of other farm holdings in the mutual portfolio. The unit of analysis in the group portfolio is denominated to the acre so that risk statistics can be comparable across groups of different sizes.

It is assumed that a unit of insurance is purchased for each participating acre. Thus for each acre the mutual group pays premium p, and receives indemnity η_t in each period t. The overall group portfolio can thus be expressed as:

$$Y_t^{net} = \sum_i y_{it} - kP + k.\eta_t = \sum_i \left(\mu_i + \varepsilon_{it}\right) + \sum_i \beta_i (y_t - \mu) + k(\eta_t - P)$$

Equation 6

where k is the acreage of the typical mutual insurance participant.

Expressed at the acre level the portfolio is:

$$y_t^{net} = \frac{1}{k}\sum \mu_i + \frac{1}{k}\sum_i \beta_i (y_t - \mu) + (\eta_t - P)$$

Equation 7

When the mutual group encompasses all production units in the area the expression simplifies further to[1]:

$$y_t^{net} = y_t + \eta_t - P$$

Equation 8

The study involves the last two terms in the right hand side of Equation 6. These are the parts that involve indexed insurance. The first two terms in the bracket comprise the non-risk yield variation across farms, and the individual specific risk which is typically assumed to be stochastic normal distributed. How mutual insurance groups deal with these factors is not in the scope of this study. The scope of the study is to investigate how the typical member's risk is affected by inclusion or exclusion of select portfolios according to risk profiles.

The function applied in estimating VaR is not the yield, rather the net reduction in yield, namely net yield loss. This is derived from Equation 7 as:

$$loss_t^{Acre} = P - \eta_t - \frac{1}{k}\sum_i \beta_i (y_t - \mu)$$

Equation 9

As suggested by Linsmeier and Pearson (1996) the estimation of VaR involves 1) generating yearly area yield as pseudo-random values assuming it to follow some stochastic process, e.g. a random walk, and then recovering farm yields according to the OLS farm models estimated from historic data (Equation 4), and 2) treating these yields as the actual farm observations. VaR is defined as the maximum loss in net yield (expressed as a proportion of historic area average) such that the probability of a greater loss is only 5% (or other pre-specified small probability). Actual estimation of VaR involves ranking the index insured portfolios from the least to the largest after exposing them to respective risk processes, and picking out the one with a 5% quantile of the distribution as the VaR (Manfredo and Leuthold, 1998). Farms that increase VaR in the group

[1] See Miranda (1991) on the $E(\beta_i)$.

portfolio are identified as likely unacceptable members of the potential mutual insurance.

An area yield series of 1000 years was generated as a random walk. Individual farm yields were then obtained for these 1000 years according to the discussion above[2]. Different mutual groups were then defined from the farms in the dataset by defining diverse member selection criteria on the basis of individual systemic risk profiles. Then VaR was calculated for each group, and compared across group formation criteria.

Results

Beta estimates

The table below presents the distribution all beta values of the 25,596 farms used in the study. These values are categorized into 20 classes, each containing 5% of the values. The classes are also arranged in the order of size of beta values reported, starting from the class with the smallest beta value exposures.

Beta range			
Lower limit	Upper limit	Frequency	Cumulative frequency
-1.1396106	0.5178949	1279	1279
0.5179041	0.6497053	1280	2559
0.6497402	0.7279086	1280	3839
0.7279106	0.7858244	1280	5119
0.7858301	0.8323536	1280	6399
0.8324355	0.8711896	1279	7678
0.8712313	0.9081364	1280	8958
0.9082352	0.9416865	1280	10238
0.9417022	0.9747097	1280	11518
0.9747140	1.0067516	1280	12798
1.0067645	1.0373273	1279	14077
1.0373374	1.0704913	1280	15357
1.0705010	1.1052008	1280	16637
1.1052337	1.1406595	1280	17917
1.1406814	1.1800056	1280	19197
1.1800064	1.2248460	1279	20476
1.2248609	1.2804783	1280	21756
1.2804923	1.3512082	1280	23036
1.3512999	1.4685100	1280	24316
1.4692209	2.8673167	1280	25596

[2] this step was actually not done – it need not be done because the loss, which is of interest, can be obtained with less computational demands.

Charts for VaR

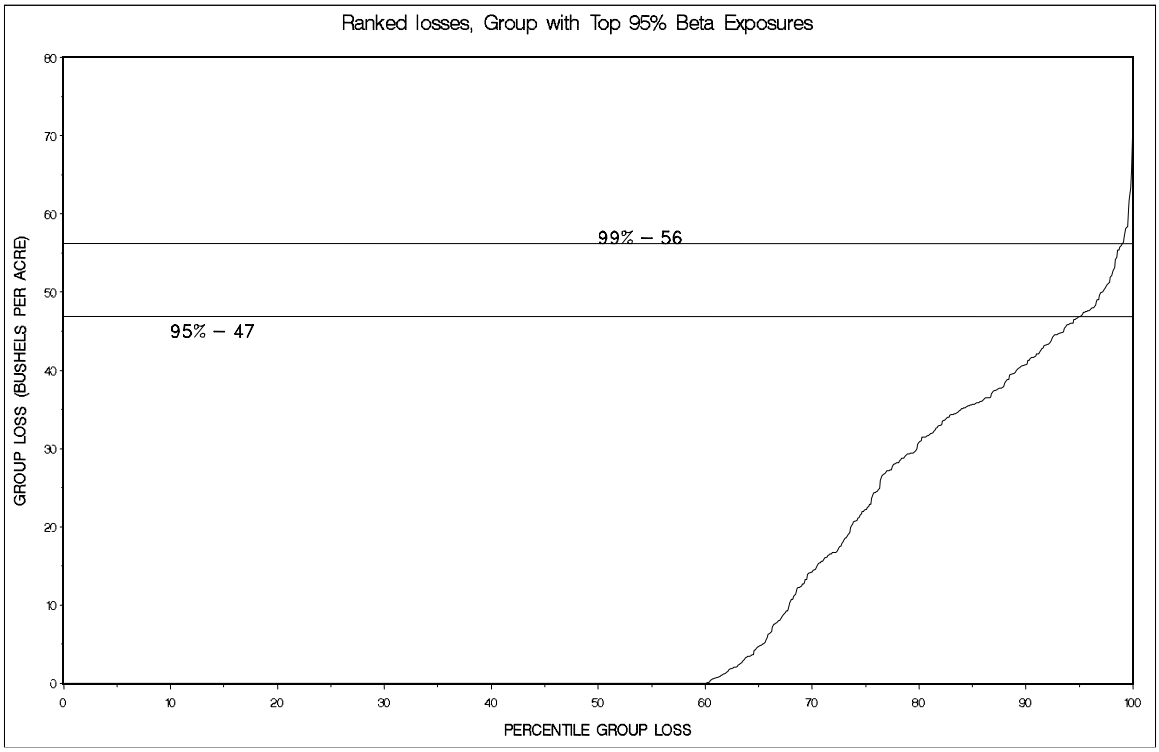

Table of statistics used to generate the VaR chart above

Statistic	LABEL	Group loss
N	number of nonmissing values, GroupLoss	1000
MEAN	the mean, GroupLoss	11.23312713
STD	the standard deviation, GroupLoss	17.25667604
MAX	the largest value, GroupLoss	71.7716155
P99	the 99th percentile, GroupLoss	56.2475562
P95	the 95th percentile, GroupLoss	46.85813669
P90	the 90th percentile, GroupLoss	40.76004903
Q3	the upper quartile, GroupLoss	22.22380729
MEDIAN	the median, GroupLoss	0
Q1	the lower quartile, GroupLoss	0
MIN	the smallest value, GroupLoss	0

At the 95% level the VaR for the group formed by the largest 95% beta values is 46.86 bushels per acre. At the 99% level the value is 56.25 bushels per acre. Such values will be tabulated here for various group formulations (i.e. group composed of the largest 90%, 85%, 70%, etc, as well as a group composed of all 25,596 exposures. Preliminary results indicate that the smallest VaR at both the 95% and 99% levels is the general membership group.

Discussion

The supply of financial services to small investors is typically dwarfed by disproportionate transaction costs owing to economies of scale (Saito and Villanueva, 1981, Binswanger and Sillers, 1983). On this account indexed contracts for systemic insurance may fail to reach needy small holder economies. Yet systemic risk in many developing economies would be more conveniently addressed at the institutional level, e.g. in the microfinance portfolio, where truly systemic risk is aggregated. Thus economies of scale may not be so relevant after all, but the effect of individual exposures to the institutional portfolio risk could be of paramount importance.

References

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