

# The impacts of thresholds on risk behavior: What's wrong with index insurance? <sup>1</sup>

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## Abstract

Almost universally, implementers of index insurance for low income households have chosen to embed insurance with other interventions designed to improve productivity, with the insurance used almost entirely to make the other interventions possible. A common example is to use the insurance to allow farmers to have access to loans by reducing the probability of weather related defaults. A bundled loan/insurance implementation with overwhelming take-up rates had low insurance take-up rates when researchers unbundled the package, covering the loan default risk, so that the loans could be available without requiring insurance. If low income farmers are highly risk averse, why do they place so little value on risk reducing insurance once their access to productive inputs is secured? In general, why do index insurance implementers targeting the lowest income households nearly universally utilize insurance as a tool to increase productivity instead of using it to reduce variance? We provide a potential explanation driven by optimal risk behavior in the face of income thresholds, illustrating how models of risk aversion may not adequately represent the behavior of those with very low incomes. We show how variance reduction may not be the most important outcome for a low income farmer who lives near the poverty threshold. We show that if a farmer's goal is to avoid falling into a poverty trap, then the lower his income is, the less risk averse he becomes in the mean-variance utility maximization framework regarding the design of index insurance contracts. We begin this paper by introducing a mean-variance utility maximization framework, using a known joint distribution for the index and yield, and then we show how one's risk aversion changes when the mean-variance utility function is switched to a poverty trap avoidance utility function. We argue that one reason farmers don't always seek to minimize variance is that they may be very near a poverty trap threshold, and are therefore less willing to give up additional expected income in exchange for decreased income variance. In this case, it may be best for implementers to utilize insurance to unlock increases in productivity as opposed to variance reduction per se.

**JEL codes:** D80,O12,O16,Q14

# 1 Introduction

Index insurance is a relatively new tool being explored for implementation in developing countries. Since it remains to be established if index insurance is scalable or effective in helping to address development problems, it is important that critiques and evaluations of index insurance interventions appropriately identify and address the basic features of the index insurance and low income households.

An index insurance contract is one that provides its holder with a payout based on the measurement of an index that is correlated with the holder's income. For example, a farmer, whose annual income varies according to his crop's yield, may wish to buy an index insurance contract that pays its holder some amount of money in the event of low rainfall - which is typically associated with lower than average crop yields. A well-designed contract of this type can significantly reduce the variance of the farmer's annual income, which, in turn, can induce a desirable change in the distribution of his long-term wealth and his chance of avoiding a poverty trap (Barnett, Barrett, and Skees, 2008).

One of the most common types of index insurance currently in use is weather-based index insurance for farmers (Hellmuth et al 2009). These contracts are sometimes referred to in the literature as weather derivatives, area-yield insurance contracts, catastrophe bonds or catastrophe options, or index-based risk transfer products (Miranda, 1991; Skees, Black, and Barnett, 1997; Barnett, Barrett, and Skees, 2008).

Almost universally, implementers of index insurance for low income households recommend that index insurance be embedded with other interventions to improve productivity. The insurance is used almost entirely to make the other interventions possible instead of being risk reducing per se (Hellmuth et al, 2009). A common example is to use the insurance to allow farmers to have access to loans by reducing the probability of weather related defaults. Because of the threat of large scale defaults due to droughts, microfinance institutions are unable to manage the risk of massive simultaneous defaults, leaving farmers without access to credit. By providing index insurance to the lender or the farmer, the risk of drought-driven defaults is lowered, enabling access to credit for productive inputs. In the projects with relatively high income farmers for which banks can easily enforce repayment, insurance is purchased directly by the banks, and loans are forgiven during drought years. For very low income farmers, limited liability problems make repayment enforcement problematic (Banerjee and Newman, 1994). For these projects, loans are insured through contracts sold directly to the farmer, and the farmer is required to repay in full in all years, using the insurance as payment when necessary.

An example of such a program exists for groundnuts in Malawi. The goal of the insurance package was to increase productivity as opposed to reduce the variance of income. The index insurance was bundled as part of a package to provide farmers with high yielding groundnuts, using drought insurance contracts purchased directly by smallholder farmers to enable access to loans (Hellmuth et al 2007). Instead of designing the insurance as a tool to reduce

variance in income, the contracts were designed solely to target the drought related loan repayment risks that alternate risk management strategies could not effectively address (Os-good et al, 2007). Implementation partners included the National Association of Smallholder Farmers (NASFAM), the Malawi Rural Finance Corporation (MRFC), Opportunity International Banking Malawi (OIBM), the Insurance Association of Malawi (IAM), the Malawi Meteorological Agency, and the World Bank Commodity Risk Management Group (CRMG). Technical assistance for contract design was provided by the International Research Institute for Climate and Society at Columbia University (IRI).

The key challenge to this program was that the overwhelming farmer take-up rate outpaced the growth capacity of the groundnut supply chain, leading to a shift to other crops with stronger supply chains in the third year of the project (Hellmuth et al, 2009).

Testing the assumptions behind the bundled design of the pilot, in the second year of the project's implementation, Gine and Yang (2009) offered two versions of the contract in a randomized experiment. It is important to note that this study was an analysis of the insurance bundling issue, not an evaluation of the impacts of the insurance driven development project. The first product was the combined insurance/loan bundle offered outside the experiment. In the other version, the researchers offered the loan without requiring the farmer to purchase insurance. Because drought risk prevented farmers from not having access to the loan without the insurance, the researchers used project funds to guarantee the lenders that loans would be repaid. They found that take-up rates of the package that required insurance were substantially lower than those of the package that did not require insurance.

These perhaps surprising findings were that the farmers were more interested in the purely production-improving package than the one that included insurance-based risk reduction. The authors attribute the lack of interest in the insurance to the implicit insurance due to the limited liability of the low income farmers. These findings support the assumptions of the implementation project, that index insurance for low income farmers should be used not as risk reduction per se, but instead to enable productivity increasing activities.

From this experience it appears that these farmers, whose livelihoods are severely threatened by weather variability, place relatively little value on reduction of variance as compared to increases in productivity. If low income farmers are highly risk averse, why do they place so little value on risk reducing insurance once their access to productive inputs is secured? In general, what could justify the assumption of index insurance implementers targeting the lowest income households that insurance should be used as a tool to increase productivity instead of using it to reduce variance? In the project reports of implementers, poverty traps are mentioned, however a model explaining how poverty traps lead to a preference for productivity over variance reduction is missing.

We explore the optimal design of an insurance contract for farmers who are living in great poverty, and find another reason for farmers to be less risk averse than they would be in a mean-variance utility framework. This reason is that less risk aversion results in a greater probability of avoiding a poverty trap. In fact, the closer a farmer is to a poverty trap

threshold, the less willing he is to give up some of his expected income in exchange for a reduction in income variance.

In the rest of the paper we discuss contract design as it relates to two goals: (1) reducing the variance of a farmer’s annual income, and (2) helping a farmer avoid a poverty trap. In Section ??, we describe the set-up of the problem; here we introduce a simple form for the payout function and we assume a known joint probability distribution to describe the relationship between the index and the yield. In Section ?? we design optimal contracts in a mean-variance utility maximization framework. In Section ?? we set up a framework for a poverty trap and we design contracts that are optimal in the sense that they minimize a farmer’s probability of falling into a poverty trap, as we define it. Section ?? contains a closing discussion.

## 2 The set-up of the problem

We begin with a simple assumption about the true joint distribution of the yield,  $Y$ , and the index,  $I$ . Assume that this joint distribution is bivariate normal, where  $Y \sim N(\mu_Y, \sigma_Y^2)$  and  $I \sim N(\mu_I, \sigma_I^2)$ , and their correlation is  $\rho > 0$ . This model for the yield-index relationship presents two potential problems. First, traditionally, yields are thought to be non-negative; lognormal, gamma, and non-negative non-parametric distributions have been used extensively in the literature to model yields. In the context of index insurance, however, we treat one’s yield as a proxy for his profit, in the sense that a farmer’s profit is his yield (or revenue), less the cost of his inputs. By this definition, it is perfectly reasonable for yields (profits) to be positive or negative. Second, even if a normal distribution is centered far from zero, so that virtually none of its mass is below zero (suppose it’s mean is 10 standard deviations away from zero, for example), it may still not provide a good fit to yield data, if the distribution of yields is bimodal or non-symmetric, for example. This is a legitimate concern, but there is a relatively easy solution to this potential problem. There is a vast literature of statistical methodology for testing whether a given distribution is a good fit to observed data; the contract design methods presented in this paper for normally distributed yields can be extended to other settings in which the joint distribution of the yield and index is different.

Furthermore, there is some literature that supports using a normal distribution for yields. Skees et al. (2001), for example, report that the revenues, or yields, from crops in Morocco are normally distributed, and Vedenov and Barnett (2004) fit a variety of linear regression models for the yield-index relationship, all of which implicitly assume that the yield is normal.

## 2.1 The payout function

Next, let us assume the payout function is linear, such that, if  $P$  denotes the payout, then

$$P = aI + b. \quad (1)$$

With this payout function, the distribution of the payout is also normal:

$$P \sim N(a\mu_I + b, a^2\sigma_I^2).$$

With no further restrictions, such a payout can technically range anywhere from  $-\infty$  to  $\infty$ , but it is effectively bounded because the index,  $I$ , is almost never more than 3 or 4 standard deviations away from its mean. Next, we set the cost,  $c$ , of this index insurance contract to

$$c = E(P) + \text{loading} \times (\text{Value at Risk} - E(P)). \quad (2)$$

The first term of the cost function,  $E(P)$ , is the actuarially fair price, and the second term is an additional cost borne by the farmer to offset the opportunity cost of the insurance company, which is required to hold enough cash in reserve to cover the maximum payout. The loading is a percentage that roughly corresponds to the interest rate that the insurance company could earn on its investment if it weren't holding such a large amount of cash in reserve. From here on, we denote the loading  $l$ , and the Value at Risk "VaR." The VaR is set by the insurance company, and is typically either set to the maximum payout, or a very high quantile of the payout distribution. Going forward, we set the VaR to the 99th percentile of the payout distribution, so that

$$c = E(P) + l(Q_P(0.99) - E(P)), \quad (3)$$

where  $Q_X(z)$  denotes the  $z^{\text{th}}$  quantile of the distribution of the random variable  $X$ .

## 2.2 The distribution of net income

Now, we can define the net income,  $N$ , as the income of a farmer with index insurance:

$$N = Y + P - c, \quad (4)$$

where the payout  $P$  and cost  $c$  are given in Equations ?? and ??, respectively. We call it income because we assume that the payout and the yield are measured in equivalent units, whether the denomination is currency or kg/acre. We can now solve for  $E(N)$  and  $\text{Var}(N)$  in terms of the parameters of the payout function,  $a$  and  $b$ :

$$E(N) = E(Y) + E(P) - c \quad (5)$$

$$= \mu_Y - 2.33l\sqrt{a^2\sigma_I^2}. \quad (6)$$

$$\text{Var}(N) = \text{Var}(Y) + \text{Var}(P) + 2\text{Cov}(Y, P) \quad (7)$$

$$= \sigma_Y^2 + a^2\sigma_I^2 + 2a\rho\sigma_Y\sigma_I, \quad (8)$$

where the second term of  $E(N)$  arises because the 99th percentile of a normal distribution lies 2.33 standard deviations above the mean. Interestingly, neither the mean nor the variance of  $N$  depends on  $b$ , the  $y$ -intercept of the payout function.

### 2.3 An illustrative example

To illustrate the set-up of the problem, let us assume some realistic parameter values for the joint distribution of the yield and index. Consider groundnut yields in Lilongwe, Malawi, during the 15-year span from 1988 - 2002. They are approximately i.i.d. normally distributed with a mean of 1000 Kg/Hct and a standard deviation of 200 Kg/Hct. A potential index for these yields is the Water Requirement Satisfaction Index, or WRSI, which is a rainfall-based index for a given location and crop that is computed using daily rainfall during the growing season. WRSI is essentially a weighted sum of daily rainfall, where the weights are designed to be sensitive to the different growing phases of the groundnut plant, so as to predict as accurately as possible the crop's yield. The WRSI measurements for these 15 years are approximately i.i.d. normally distributed with a mean of 0.8 and a standard deviation of 0.06 (WRSI has no units), and the correlation between the yield and the index is about 0.5. This index, however, can be rescaled to have the same mean and standard deviation as the yield, so that it is essentially a predicted yield based on daily rainfall at a given location.

In summary, for illustrative purposes, let us assume that the yield and index have the following known joint distribution:  $Y \sim N(\mu_Y = 1000, \sigma_Y^2 = 200^2)$ ,  $I \sim N(\mu_I = 1000, \sigma_I^2 = 200^2)$ , and their correlation is  $\rho = 0.5$ . Figure ?? illustrates this relationship.

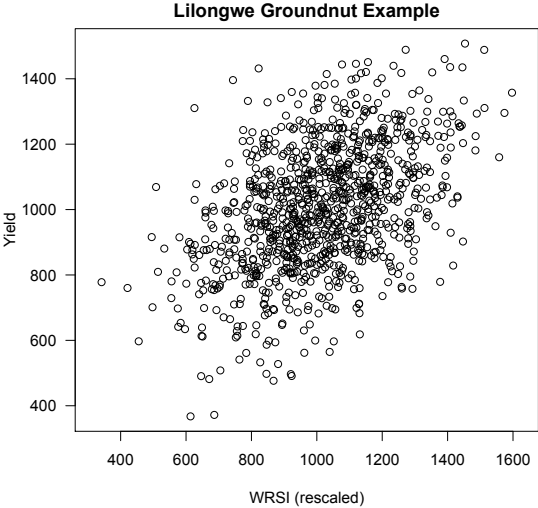


Figure 1: The hypothetical relationship between groundnut yields and the rescaled WRSI index in Lilongwe, Malawi.

Next, let us use the payout function where  $a = -0.4$  and  $b = 720$ , so that  $P = -0.4I + 720$ . With this function, the payout will be zero when the index is 1800, which is four standard deviations above its mean, and the payout is effectively capped at 640 (dollars), which would happen when the index is 200, or 4 standard deviations below its mean. In this case,  $E(P) = 320$  dollars, the VaR is 506 dollars (as we have defined it), and the cost of insurance,

$c = 331.2$  dollars. With this contract, the net income of a farmer is normally distributed with a mean of  $\mu_N = 988.8$  dollars, and a standard deviation of  $\sigma_N = 174.3$  dollars. This represents a significant reduction in the standard deviation of the farmer’s income, and it comes at the cost of a slight reduction in his expected income. In the next section we will describe this mean-variance tradeoff in more detail.

### 3 A mean-variance tradeoff

For different values of the slope of the payout function,  $a$ , we can compute  $E(N)$  and  $\text{Var}(N)$  and plot pairs of values,  $(\text{Sd}(N), E(N))$ , as are illustrated in the curves in Figure ??(b). The

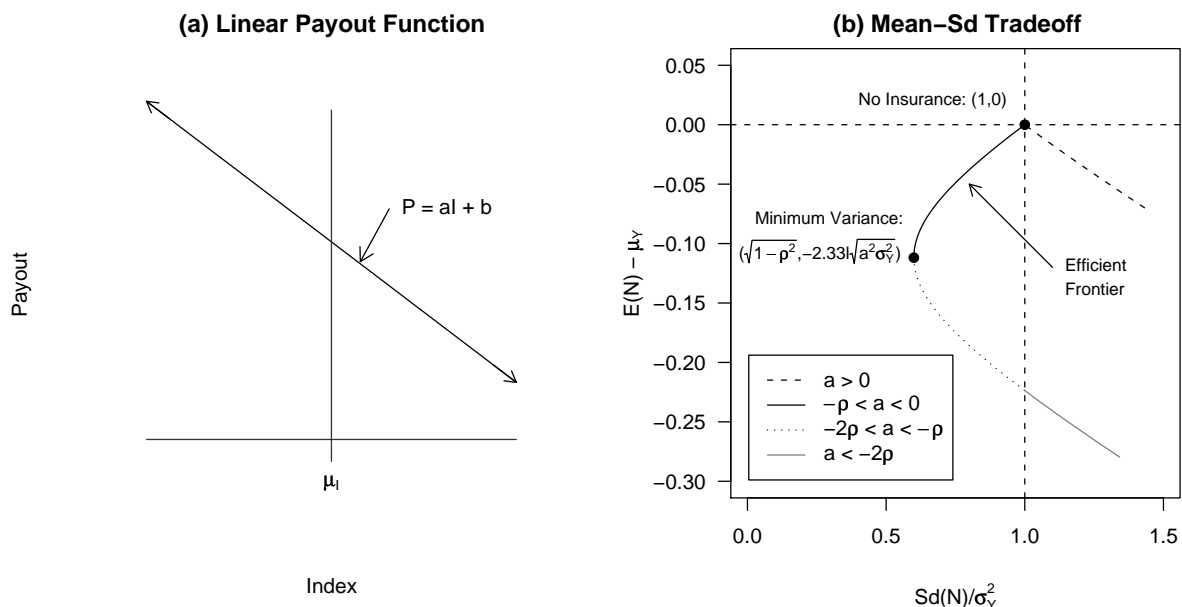


Figure 2: (a) The form of a linear payout function, where  $a < 0$ . (b)  $\text{Var}(N)$  for different values of  $a$ . The “Efficient Frontier” is the portion of the curve where the contracts are optimal with respect to a mean-variance utility function. Plot (b) is drawn using  $\rho = 0.8$ .

general result from Equations ?? and ?? is that index insurance can reduce the variance of one’s net income, at the cost of reducing its expected value. The exact value of  $(\text{Sd}(N), E(N))$ , however, depends on the choice of  $a$ , and varies widely. From Figure ??(b), it is clear that a poorly designed index insurance contract, in which  $a > 0$  or  $a < -2\rho$ , increases the variance of a farmer’s net income (provided that  $\rho > 0$ ). The section of the curve in Figure ??(b) labeled the “Efficient Frontier” is the set of contracts, in which  $-\rho < a < 0$ , that provide a tradeoff between the mean and variance of net income that could maximize the utility of an individual whose utility function is of the form

$$U(N) = E(N) - k \times \text{Var}(N), \tag{9}$$



where  $k > 0$  is often called a “risk-aversion parameter”. The fourth segment of the curve labeled in Figure ??, where  $-2\rho < a < -\rho$ , consists of contracts in which the variance of net income is reduced, but the expected net income is reduced by more than what is necessary: these contracts are sub-optimal.

We want to focus on the efficient frontier. To do this, we can solve for the optimal slope for maximizing mean-variance utility,  $a_{MV}^*$ , as a function of the risk aversion parameter  $k$  in Equation ?. The risk aversion parameter is rarely a tangible number that is known *a priori*, but if it is, then the contract with slope

$$a_{MV}^*(k) = \min\left(-\rho\frac{\sigma_Y}{\sigma_I} + \frac{2.33l}{2k\sigma_I}, 0\right)$$

will maximize the farmer’s mean-variance utility.

Much of the current literature assumes the price of insurance is the actuarially fair price (Miranda, 1991; Smith et al., 1994), and thus the goal is to minimize the variance of net income. This is equivalent to setting  $k = \infty$  in Equation ?. If we take the derivative of the right side of Equation ? with respect to  $a$  and set it to zero, we find that:

$$a_{MV}^*(k = \infty) = -\rho\frac{\sigma_Y}{\sigma_I}. \tag{10}$$

The value of  $\text{Var}(N)$  for this contract is

$$\text{Var}(N | a = a_{MV}^*(k = \infty)) = \sigma_Y^2(1 - \rho^2). \tag{11}$$

This result shows that by using index insurance, the variance of a farmer’s net yield can be reduced by a factor of  $(\rho^2 \times 100)\%$  from its original, pre-index-insurance value of  $\sigma_Y^2$ .

This is the same result found by Miranda (1991), where the optimal slope,  $\phi^*$  is set to  $\beta_i = -\rho\frac{\sigma_Y}{\sigma_I}$ , when the critical yield level  $y_c = \infty$ .

In the example from Section ?, the variance-minimizing contract would have a slope of  $a = -\rho = -0.5$ , and would result in the farmer’s net income being normally distributed with a mean of 986 dollars and a standard deviation of about 173 dollars (compared to the pre-insurance mean and standard deviation of 1000 and 200 dollars, respectively).

The fact that the  $\text{Var}(N)$  does not depend on the  $y$ -intercept of the payout function,  $b$ , means that we can choose any value of  $b$  that we like. If one wishes to virtually guarantee that there will be no negative payouts, then we can just set  $b$  to a high value, so that the  $x$ -intercept of the payout function is larger than any probable value of the index, such as  $\mu_I + 4\sigma_I$  (as we did in the hypothetical contract in Section ?). The value of  $b$  that gives this  $x$ -intercept is

$$b = a(\mu_I + 4\sigma_I).$$

Likewise, although the maximum payout is technically  $\infty$ , it will effectively be no larger than  $-8a\sigma_I$ , since there is virtually no chance that the index will be less than 4 standard

deviations below its mean. If such an agreement is practical, it may be best to set  $b = -a\mu_I$ , so that the mean payout is zero. This way half of the time the farmer will owe money to the insurance company at the end of the season, and the other half of the time, the insurance company will owe the farmer. Overall, less money will be transferred than if the farmer is forced to pay a large amount in the beginning of the season, and then the insurance company is forced to pay back a correspondingly large payout to the farmer at the end of the season, as would happen if  $b$  is set to a large number so that negative payouts never occur.

An important feature of contract design is that the efficient frontier is different for different values of  $\rho$ . Figure ?? illustrates the efficient frontiers for a set of values of  $\rho$ , ranging from 0.3 to 0.9. As the index becomes “stronger”, or more highly correlated with the yield, the farmer’s mean-variance utility increases.

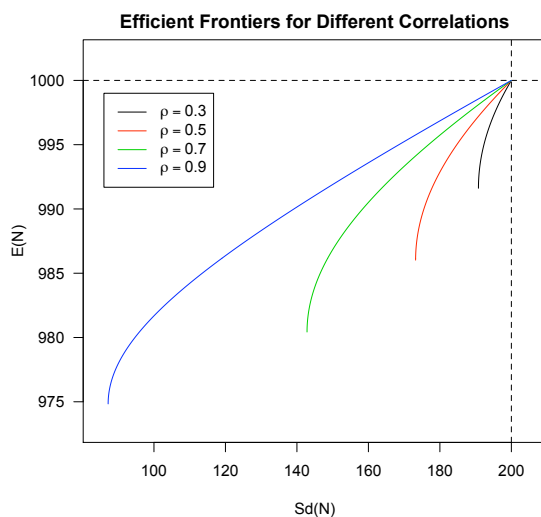


Figure 3: The mean-variance tradeoff, represented here by the colored curves (efficient frontiers) depends on the correlation between the index and the yield.

## 4 Avoiding a poverty trap

The mean-variance tradeoff is not the only framework in which to evaluate an index insurance contract. Another goal of index insurance is to build long-term wealth by avoiding a poverty trap. A poverty trap is a theoretical threshold of wealth below which a farmer’s ability to produce income is severely impaired. In theory, it is a “trap” because an individual cannot escape it without outside assistance or aid.

We can set up a simple model of a poverty trap, and optimize an index insurance contract to maximize a farmer’s probability of avoiding the poverty trap. Suppose the poverty trap

threshold is  $w_{\text{trap}}$  dollars of household wealth, and a farmer's current wealth is  $w_0 = w_{\text{trap}} + d$ , where  $d > 0$ , so that the farmer is currently not in a poverty trap.

Suppose we want to design an index insurance contract to minimize the probability of a farmer falling into a poverty trap after 1 year. Let  $W_t$  denote the farmer's wealth after year  $t$ , and let  $N_t$  denote the farmer's net income in year  $t$ . Then,

$$P(W_1 < w_{\text{trap}}) = P(w_0 + N_1 < w_{\text{trap}}) \tag{12}$$

$$= \Phi\left(\frac{w_{\text{trap}} - (w_0 + \mu_N)}{\sigma_N}\right) \tag{13}$$

$$= \Phi\left(\frac{-(d + \mu_N)}{\sigma_N}\right). \tag{14}$$

We make the further assumption that  $\mu_Y > 0$ , so that without insurance, the farmer's expected yield is positive. The scenario is illustrated in Figure ??.

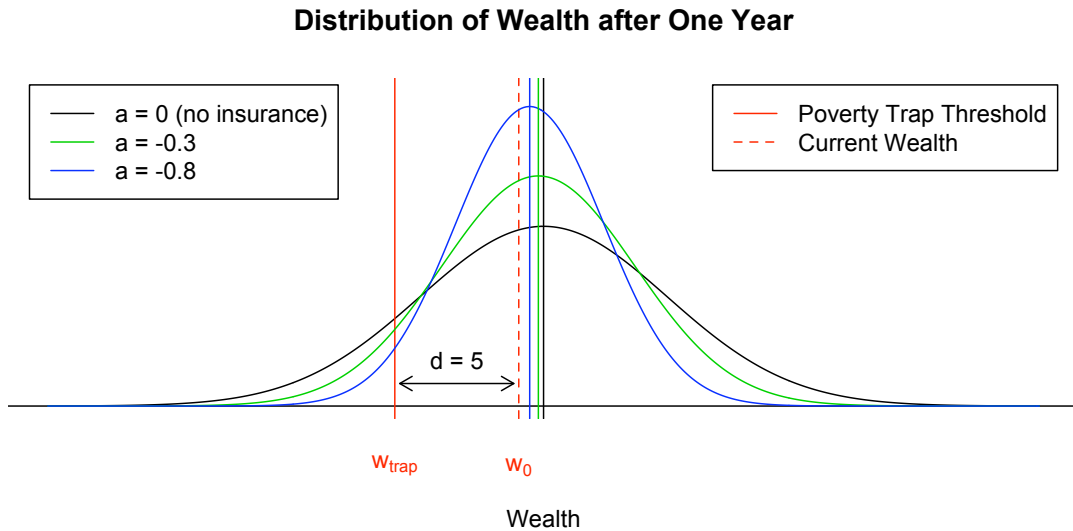


Figure 4: The probability of avoiding a poverty trap after one year. Three contracts are shown, with different payout function slopes. The set-up for the graph is  $\mu_Y = \mu_I = 1$ ,  $\sigma_Y^2 = \sigma_I^2 = 5^2$ ,  $\rho = 0.8$ ,  $w_{\text{trap}} = 0$ , and  $w_0 = 5$ . The blue contract ( $a = -0.8$ ) is the minimum-variance contract, and of the three contracts pictured here, it is the one that minimizes the probability of falling into a poverty trap at the end of the year. It is not optimal among all possible contracts, however, with regard to minimizing the probability of a poverty trap, as we show in Section ??.

To minimize the probability of falling into a poverty trap after one year, we minimize  $-(d + \mu_N)/\sigma_N$ , which only depends on the mean and variance of net income. Since the mean and variance only depend on the slope of the payout function,  $a$ , we simply take the derivative

of  $-(d + \mu_N)/\sigma_N$  with respect to  $a$  and find that the optimal slope for avoiding a poverty trap,  $a_{PT}^*$ , is

$$a_{PT}^* = \begin{cases} -\rho \frac{\sigma_Y}{\sigma_I} \left( \frac{2.33l - \rho z}{2.33l\rho^2 - \rho z} \right) & \text{if } z > \frac{2.33l}{\rho}, \\ 0 & \text{otherwise,} \end{cases} \quad (15)$$

where  $z = \frac{(d + \mu_Y)}{\sigma_Y}$ . We define  $z$  this way because it is the number of standard deviations between the poverty trap threshold and the farmer's initial wealth, measured in terms of the mean and standard deviation of his pre-insurance income distribution. In other words, it is a  $z$ -score.

This leads to the following results:

- If  $\sigma_I = \sigma_Y$ , which is a transformation we recommend for the normal distribution model here, then the optimal slope  $a_{PT}^*$  only depends on two quantities: the  $z$ -score of the poverty trap threshold, and the correlation between the yield and the index,  $\rho$ . Figure ?? shows the value of  $a_{PT}^*$  for different values of  $z$  and  $\rho$ .

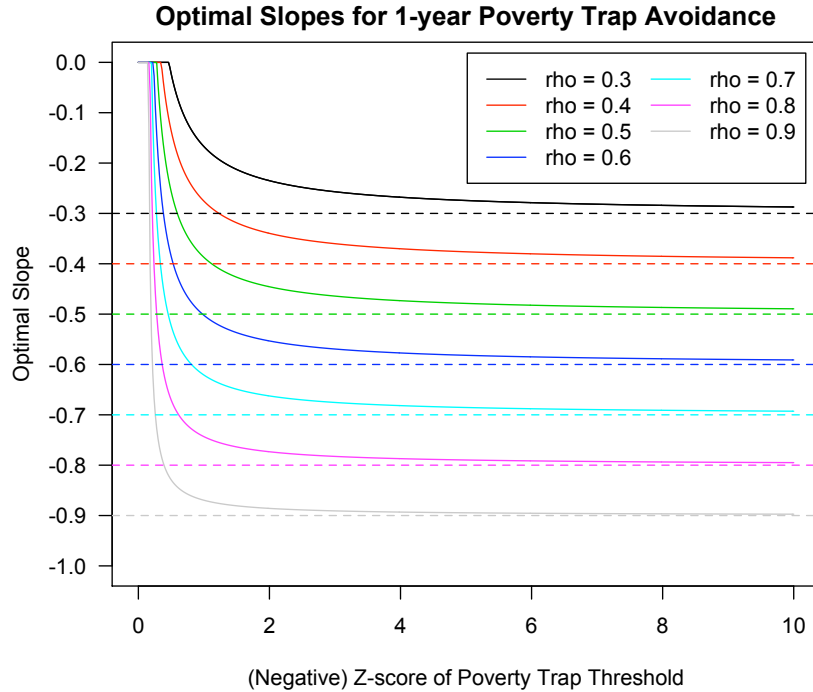


Figure 5: The optimal slope of a contract designed to maximize the chance for a farmer to avoid a poverty trap is different from the slope of the variance-minimizing contract, especially for small values of the correlation between the index and yield,  $\rho$ , and the farmer's initial wealth,  $z$ .

- If  $\sigma_I = \sigma_Y$ , then

$$\lim_{z \rightarrow \infty} a_{PT}^* = -\rho,$$

which is the variance-minimizing contract. That is, the farther a farmer's initial wealth is from the poverty trap threshold, the closer his optimal poverty-trap avoidance contract becomes to the variance-minimizing contract.

- If  $z < \frac{2.33l}{\rho}$ , then  $a_{PT}^* = 0$ , i.e. no insurance is the optimal way to avoid a poverty trap. For a loading,  $l$ , of 6%, and for correlations  $\rho \in (0.3, 0.9)$ , this threshold is between 0.47 and 0.16, respectively. In other words, for most cases, unless a farmer's expected wealth after one year,  $d + \mu_N$ , will be within one half of a standard deviation,  $\sigma_Y$ , of the poverty trap threshold, then *some* amount of index insurance ( $a > 0$ ) will help. There are rare cases, though, where a farmer is very close to the poverty trap threshold to begin with, in which *any* insurance contract will increase his chance of falling into a poverty trap after one year.
- On the other hand, if a farmer's expected wealth after one year is less than 2 standard deviations from the poverty trap threshold ( $z < 2$ ), then for most correlations, his optimal poverty-trap-avoiding contract will not be the variance-minimizing contract, and for low correlations and low values of  $z$ , the optimal poverty-trap-avoiding contract may be substantially different from the variance-minimizing contract, where the optimal poverty-trap-avoiding slope  $a^*$  is much closer to zero than the variance-minimizing value of  $a$ .

In fact, for a given correlation  $\rho$ , there is a one-to-one relationship between the  $z$ -score of a farmer's initial wealth in the poverty trap framework and his risk aversion parameter,  $k$ , in the mean-variance utility framework. That is, the optimal contract for avoiding a poverty trap for a given initial wealth,  $z$ , is also the optimal contract for maximizing mean-variance utility for a given risk aversion parameter,  $k$ . The exact relationship is linear:

$$k_{PT} = \frac{1}{2\sigma_Y(1 - \rho^2)}z + \frac{2.33l\rho}{2\sigma_Y(\rho^2 - 1)},$$

where  $k_{PT}$  denotes the mean-variance utility risk aversion parameter for a farmer whose priority it is to avoid a poverty trap, given his initial wealth  $z$ .

Figure ?? illustrates the mean-variance efficient frontier with points denoting values of  $a$ ,  $k$ , and  $z$  along the curve.

The overall conclusion to draw from the comparison of contracts using these two different utility functions (mean-variance and poverty trap) is that if a farmer's priority is to avoid a poverty trap, and his initial wealth is near the poverty trap threshold, then he is much less risk-averse than he otherwise might be.

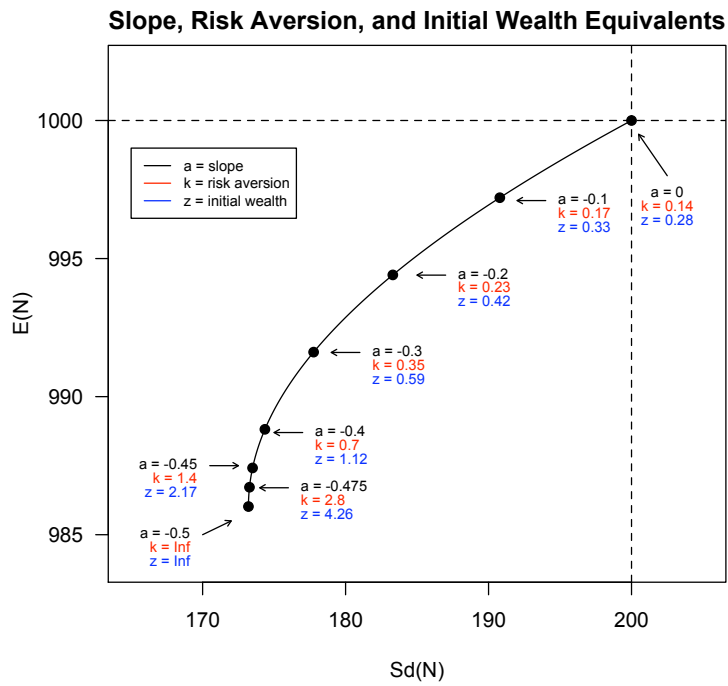


Figure 6: The optimal slope for avoiding a poverty trap given one's initial wealth,  $z$ , is also an optimal contract in terms of mean-variance utility for a given risk aversion parameter,  $k$ . As initial wealth decreases, so does one's risk aversion,  $k$ .

## 5 Discussion

We have investigated the optimal index insurance contract for a farmer whose current wealth puts him at risk of falling into a poverty trap, and we have found that as his wealth approaches a theoretical poverty trap threshold, his risk aversion, as described by the parameter  $k$  in the mean-variance utility function, decreases. This conclusion provides a potential reason for the lack of index insurance take-up in experiments such as that conducted by Gine and Yang (2009), who showed lower take-up of insurance in the presence of loans for inputs. These findings suggest that farmers at or near the poverty trap threshold are not variance-minimizers, but rather are looking for a way to maximize productivity in a way that doesn't require them to sacrifice a lot of their expected income. Similar to the case of binding constraints, models that rely on risk aversion to explain behavior may be inappropriate for agents located near a poverty trap (or any) threshold. Future research could attempt to model productivity as a function of inputs while simultaneously incorporating a poverty trap threshold, to formally link these two related pieces of evidence that variance reduction isn't always the highest priority.

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