Risk Sharing and Incentives with Crop Insurance and External Equity Financing

Sangtaek Seo, David J. Leatham, and Paul D. Mitchell

Agricultural Finance Markets in Transition
Proceedings of The Annual Meeting of NCT-194 Hosted by the Center for the Study of Rural America,
Federal Reserve Bank of Kansas City
October 6 - 7, 2003

Risk Sharing and Incentives with Crop Insurance and External Equity Financing

Sangtaek Seo, David J. Leatham, and Paul D. Mitchell*

Abstract

Farmers have increasingly been procuring external equity financing through either written or verbal business arrangements. Passage of the Agricultural Risk Protection Act in 2000 has resulted in widespread adoption of crop insurance among farmers. Crop insurance changes farmers' production decisions, so that investors providing external equity may want to adjust the equity financing contract to account for these changes. This paper uses a principal-agent model to determine optimal risk sharing and incentives under crop insurance and external equity financing. Results show that with the introduction of crop insurance, the investor's optimal equity financing contract requires that the farmer bears more risk in order to have the incentive to work hard.

Key words: risk sharing, incentives, crop insurance, equity financing, principal agent model.

*Graduate Research Assistant, Professor, and Assistant Professor, Department of Agricultural Economics, Texas A&M University

Risk Sharing and Incentives with Crop Insurance and External Equity Financing

Arrangements such as land leases, partnerships and other corporations, and vertical integration have been the traditional channels through which farmers have obtained external equity, i.e. equity capital procured from the non-farmers or other sources than retained earnings. Sharecropping is probably the most common use of external equity (Allen and Lueck). Based on the 1988 Agricultural Economics and Land Ownership Survey, Canjels reported that almost one-third of all leased acres were sharecropped in 1988. In many of these arrangements, the landlord provides the land and/or input costs for farming and shares the output with the farmer. Partnerships and other forms of corporations comprised 10% of farms in 1997 and these farms accounted for 48% of total farm product sales (USDA-NASS). The members of the partnership and corporation might share the output or dividends according to the investment share or the share of the operating costs. To use external equity, a farmer needs a contract in verbal or written form with the investor providing the external equity. For example, 90% of surveyed California wine grape farmers used contracts in 1999, with 70% using written contracts only, 11% using oral contracts only, and 9% using both contract types (Goodhue, Heien, and Lee). These contracts typically specify the investment share, input use, and/or output shares. The investor may provide additional economic incentives to derive the best effort of the farmer.

Farmers have several risk management alternatives available, such as crop insurance, futures and options, and government programs. Among these subsidized crop insurance is widely adopted by the farmer. As a result of purchasing crop insurance, a farmer may change production decisions depending on his risk attitudes and the fairness of insurance (Ahsan, Ali, and Kurian). The most studied production decisions include land allocation and variable input use, especially nutrients and pesticides (Babcock and Hennessey; Horowitz and Lichtenberg; Smith and Goodwin). To maintain focus, this paper only considers land allocation as a production decision. Also including variable input use makes the model rather complicated without little gain in terms of conceptual understanding.

Because crop insurance also benefits the external equity investor, he may require crop insurance or specify a certain level of coverage in the contract (Leatham, McCarl, and Richardson). The investor may also want to adjust the contract to induce the farmer's best effort, since crop insurance may change the farmer's production decisions and hence the risks both the farmer and the investor face. To better understand these relationships, we develop a principal-agent model of the contract between the external equity investor and the farmer when the farmer can purchase crop insurance.

Many principal-agent models of sharecropping and crop insurance have been developed, primarily focused on the design of optimal contracts to prevent adverse selection and moral hazard (e.g. Canjels and Volz; Chambers; Nelson and Loehman; Skees and Reed; Ahsan, Ali, and Kurian; Raviv; Allen and Lueck). Principal-agent models have also been used to analyze agricultural financing contracts (e.g., Wang, Leatham, and Chaisantikulawat; Santos). Wang, Leatham, and Chaisantikulawat studied risk sharing and incentives with external equity financing, but did not incorporate risk management tools such as crop insurance or risk averse investors.

This paper first determines an investor's preferences for crop insurance based on the farmer's production decisions and then determines the optimal contract between the investor and the farmer with crop insurance and external financing. Those aims can be done with several assumptions about risk attitudes and fairness of insurance. For production decisions with crop insurance, we assume a risk neutral insurer and a risk averse farmer. For the contract between the

investor and the farmer, we assume a risk averse investor and a risk averse farmer with fair and unfair insurance, and use the case of no insurance for comparison.

Farmer Production Decisions with Crop Insurance

Following Ahsan, Ali, and Kurian, we develop a model of a risk averse farmer allocating total acreage M to either a risky crop or a safe (risk-free) crop. Denoting investment in the risky crop as the acreage A, then the investment in the safe crop is $M - A$. Two states of nature exist—a good state with probability $1 - \rho$ and a bad state with probability ρ. The farmer purchases actuarially fair crop insurance that pays the indemnity $aF(A)$ when the bad state occurs, where a is the insurance coverage level and $F(\cdot)$ is the revenue production function for risky crop acreage ($F' > 0$). The farmer pays an insurance premium $a\gamma A$ regardless of the state, where γ is the per acre premium for the risky crop. For the insurance to be fair, the premium $a\gamma A$ must equal the expected indemnity $\rho aF(A)$.

Given these assumptions, farmer income in the good state is $Y_1 = F(A) + r(M - A) - a\gamma A$, where r is the rate of return for the safe asset $(M - A)$, and $Y_2 = aF(A) + r(M - A) - a\gamma A$ in the bad state. Thus random farmer income Y is:

$$(1) \qquad Y = \begin{cases} Y_1 = F(A_f) + r(M - A_f) - a_f \gamma A_f & \Pr = 1 - \rho \\ Y_2 = a_f F(A_f) + r(M - A_f) - a_f \gamma A_f & \Pr = \rho \end{cases},$$

where the subscript f denotes the optimal acreage allocation and coverage level the farmer chooses with fair insurance.

For actuarially unfair insurance, the insurer collects more than the fair premium to pay insurance administrative costs and earn a normal rate of return. This additional payment is typically a proportional adjustment c of the fair premium, so that the unfair premium is $(1 + c)\rho aF(A)$. Assuming a competitive market, the insurer's expected profit will equal zero. Given unfair insurance, the risk averse farmer chooses the coverage level a and risky crop acreage A to maximize expected utility $U(\cdot)$ subject to the insurer's zero profit condition. Thus the objective and constraint are

$$(2) \qquad \max_{a_u, A_u} \ (1 - \rho)U(Y_1) + \rho U(Y_2)$$

$$(3) \qquad a_u \gamma A_u - a_u (1 + c)\rho F(A_u) = 0,$$

where the subscript u denotes the optimal coverage level and acreage allocation with unfair insurance.

Rearranging the first order condition for the insurance coverage level a_u gives

$$(4) \qquad \frac{U'(Y_1)}{U'(Y_2)} = \frac{1 - \rho(1 + c)}{(1 - \rho)(1 + c)} = \frac{1 - \rho - \rho c}{1 - \rho - \rho c + c} < 1.$$

Since income in the good state exceeds income in the bad state ($Y_1 > Y_2$), then the optimal coverage level must be less than one ($a_u < 1$), implying that the farmer does not buy full insurance, but self-insures some of the risk.

Rearranging the first order condition for risky crop acreage A_u gives the relationship

(5) $$F'(A_u) > \frac{r}{1-\rho-a_u\rho c}.$$

Using equation (5) and results from Ahsan, Ali, and Kurian gives $F'(A_u) > \frac{r}{1-\rho-a_u\rho c}$ $> F'(A_n) > \frac{r}{1-\rho} = F'(A_f) = F'(A_0)$, where A_n, A_f, and A_0 respectively denote optimal risky crop acreage for a risk averse farmer without insurance, a risk averse farmer with fair insurance, and the risk neutral farmer. As a result, optimal risky crop acreage for a risk averse farmer with fair insurance is the same as for a risk neutral farmer, but exceeds optimal risky crop acreage for a risk averse farmer without crop insurance, which must exceed optimal risky crop acreage for a risk averse farmer with unfair insurance: $A_0 = A_f > A_n > A_u$. Let μ and σ^2 respectively denote the mean and variance of revenue from the risky crop. Assuming both are proportional to risky crop acreage, the optimal acreage ordering gives the following ordering for the revenue means and variances: $\mu_0 = \mu_f > \mu_n > \mu_u$ and $\sigma_0^2 > \sigma_n^2 > \sigma_u^2 > \sigma_f^2$, as summarized in Table 1.

Applying standard comparative static methods to equation (5) gives $\frac{\partial F'(A_u)}{\partial a_u} > 0$ and $\frac{\partial F'(A_u)}{\partial c} > 0$, which imply $\frac{\partial A_u}{\partial a_u} < 0$ and $\frac{\partial A_u}{\partial c} < 0$. Thus land allocated to the risky crop decreases with the insurance coverage level and the unfairness of crop insurance. With a convex loading factor instead of linear loading factor, this effect likely is stronger (Chambers and Quiggin).

Equity-Investor's Preferences for the Farmer's Purchase of Crop Insurance

When crop insurance is fair, a risk neutral investor prefers that the farmer purchase crop insurance because the farmer then behaves as a risk neutral farmer and maximizes expected revenue. This is consistent with the farmer's preferences, since with fair crop insurance, the farmer's expected revenue increases as a result of the acreage reallocation and downside risk is eliminated. With unfair crop insurance, a risk neutral investor prefers that the farmer not buy crop insurance, since the associated acreage reallocation causes a decrease in the farmer's expected revenue. However, for a range of premium loads, the farmer prefers to buy crop insurance since he is willing to tradeoff the decrease in downside risk with the decrease in mean revenue. When crop insurance is fair and the investor is risk averse, the investor prefers that the farmer purchase crop insurance because, after the associated acreage allocation, the insurance increases mean revenue and decreases downside risk. When crop insurance is unfair and the investor is risk averse, the investor's preferences for the farmer's purchase of crop insurance are unclear, depending on the investor's trade off between expected revenue and variance relative to the farmer's tradeoff. Table 2 summarizes the investor's preferences for crop insurance.

Principal-Agent Model of an External Equity Investor and a Farmer

We develop a principal-agent model of the contractual relationship between an external equity investor and a farmer. This model extends the work of Wang, Leatham, and

Chaisantikulawat by assuming a risk averse investor and allowing the farmer to purchase crop insurance. We also incorporate the farmer's production decision under crop insurance as presented in the previous section.

An investor and a farmer share the cost M of an investment using external equity and retained earnings. The farmer's share is δ and the investor must invest the remainder $(1 - \delta)$, where $0 < \delta < 1$. The business outcome is stochastic as a result of uncertain production or market price or both. For convenience[1], the output price is normalized to one and only agricultural output q is stochastic. The farmer's effort level (e) is a continuous choice variable for the farmer that affects the distribution of output. For notation, denote the conditional probability density function for output as $f(q \mid e)$. The output distribution when the farmer exerts effort level e_1 first order stochastically dominates the output distribution when the farmer exerts effort level $e_0 < e_1$. The crop output is observable, but not the farmer's effort, which creates a moral hazard problem.

Because effort causes disutility for the farmer, the farmer is willing to tradeoff effort and the associated shift in the output distribution. However, because of the effect of effort on the output distribution, the investor prefers the farmer to exert higher effort, since effort has no direct cost to the investor. To induce the farmer to exert the desired effort, the investor must create a contract that gives the farmer the appropriate incentive. However, the contract can only compensate the farmer based on the observable output, not on the unobservable effort. Denote this compensation as $t(q)$, where q depends on the farmer's effort level e, the crop insurance coverage level $a(\hat{q})$, and stochastic yield $\tilde{\theta}$.

From the investment, the investor and the farmer's payoff are proportional to output q minus the compensation $t(q)$ to the farmer. The investor and the farmer's profit function are

(6) $$\pi_p = (1-\delta)\left(q(e,\hat{\theta},\tilde{\theta}) - t(q)\right)$$

(7) $$\pi_a = \delta\left(q(e,\hat{\theta},\tilde{\theta}) - t(q)\right) + t(q),$$

where the subscripts p and a denote the investor (principal) and the farmer (agent).

Following standard assumptions, we assume farmer's effort cost function $c(e)$ is separable from the utility function, where $c' > 0$ and $c'' > 0$ (Laffont and Martimort). So that the farmer is willing to take the contract, the investor must ensure the farmer's expected utility with the contract equal or exceeds his reservation utility $\overline{U}$, the expected utility from his next best option. This participation or individual rationality constraint (IRC) is

(8) $$\int_q U(\pi_a) f(q \mid e) dq - c(e) \geq \overline{U}.$$

[1] We also suppress the subscript in risky crop acreage, *A,* from now on.

Since farmer effort is unobservable, the investor must also ensure that the contract gives the farmer the incentive to exert the desired effort. This incentive compatibility constraint (ICC) requires that if the farmer accepts the contract, his expected utility when exerting high effort equals or exceeds his expected utility with low effort. Mathematically, this ICC can be expressed as follows:

$$\text{(9)} \qquad \arg\max_{e} \int_{q} U(\pi_a) f(q \mid e) dq - c(e) .$$

As specified, condition (9) cannot be implemented when solving the investor's optimization problem. The First Order Approach (Laffont and Martimort) is a commonly used to replace this global condition with a local condition consisting of the first order condition for problem (9):

$$\text{(10)} \qquad \int_{q} U'(\pi_a) \frac{\partial \pi_a}{\partial e} f_e(q \mid e) dq - c'(e) = 0 .$$

Thus the investor's problem is to find the contractual compensation $t(q)$ and effort level e that maximize his expected utility $V(\cdot)$ of income π_p:

$$\text{(11)} \qquad \max_{t(q),e} \int_{q} V(\pi_p) f(q \mid e) dq ,$$

subject to the individual rationality constraint (8) and the incentive compatibility constraint (10).

To derive an explicit solution, we introduce the Linear-Exponential-Normal (LEN) model of Spremann. We also introduce crop insurance by linking to the previous model and assuming a random yield of $\tilde{\theta} = F(A) + r(M - A)$, where $\tilde{\theta}$ has as normal distribution with mean μ and variance σ^2, $\tilde{\theta} \sim N(\mu, \sigma^2)$ (Weninger and Just). Thus, the outcome with crop insurance is:

$$\text{(12)} \qquad q(e, \hat{\theta}, \tilde{\theta}) = e + \tilde{\theta} + I(\hat{\theta}, \tilde{\theta}) - p(\hat{\theta}) ,$$

where $I(\hat{\theta}, \tilde{\theta})$ is the indemnity ($\max[(\hat{\theta} - \tilde{\theta}), 0]$) and $p(\hat{\theta})$ is the insurance premium. Equation (12) shows the conditional distribution of output given effort. When crop insurance is actuarially fair, the insurance premium equals the expected indemnity, and when it is unfair, the insurance premium exceeds the expected indemnity: $p(\hat{\theta}) \geq E[I(\hat{\theta}, \tilde{\theta})]$.

A farmer compensation scheme is linear in the outcome. The investor pays a fixed payment and a varying payment that is proportional to output: $t(q) = w + bq$. Note that w can be negative, implying that the farmer must make some initial investment or expenditure, but b will be positive, otherwise the farmer will have no incentive to exert any effort. A convex quadratic function is used for the farmer's effort cost function: $c(e) = e^2$, implying increasing marginal disutility for effort.

A constant absolute risk aversion (CARA) utility function is used for both the investor and the farmer. Since yield has a normal distribution, the investor's income also has a normal distribution. In addition, since the compensation function is a linear transformation of yield, the

farmer's income also has a normal distribution. As a result, both the investor's and the farmer's expected utility can be expressed in terms of the mean and variance of their respective incomes:

(13) $$\mathrm{E}[U(\pi_p)] = \mathrm{E}[\pi_p] - 0.5\alpha_p \operatorname{var}(\pi_p)$$

(14) $$\mathrm{E}[U(\pi_a)] = \mathrm{E}[\pi_a] - 0.5\alpha_a \operatorname{var}(\pi_a)$$

where α_p and α_a are the coefficients of absolute risk aversion for the investor and farmer.

Optimal Contract for External Equity Financing with Crop Insurance

For the model as specified, farmer profit is:

(15) $$\pi_a = \delta\left[e + \tilde{\theta} + I(\hat{\theta}, \tilde{\theta}) - p(\hat{\theta}) + w + b\left(e + \tilde{\theta} + I(\hat{\theta}, \tilde{\theta}) - p(\hat{\theta})\right)\right] - e^2 .$$

Based on the specified model, the mean and variance of farmer profit is then:

(16) $$E[\pi_a] = [(1-\delta)b + \delta]\mu + \delta e + (1-\delta)(w + be) - e^2$$

(17) $$Var(\pi_a) = [\delta + (1-\delta)b]^2 \sigma^2 ,$$

where $\sigma^2 = Var(\tilde{\theta} + I(\hat{\theta}, \tilde{\theta}))$ represents the truncated variance, since crop insurance removes downside risk, so that profit variance with crop insurance is less than without crop insurance. Given the compensation parameters *w* and *b*, the farmer chooses his effort to maximize his expected utility:

(18) $$\max_e [\delta + (1-\delta)b]\mu + \delta e + (1-\delta)(w + be) - e^2 - 0.5\alpha_a [\delta + (1-\delta)b]^2 \sigma^2 .$$

Solving the first order condition for this problem gives the farmer's optimal effort e^*:

(19) $$e^* = 0.5[\delta + (1-\delta)b].$$

Substituting this effort level into individual rationality constraint (8) and solving for *w* gives:

(20) $$w^* = \frac{1}{1-\delta}\left\{\bar{U} - [\delta + (1-\delta)b]\mu - 0.25[\delta + (1-\delta)b]^2 * \left(1 - 2\alpha_a \sigma^2\right)\right\} .$$

The investor's optimal fixed compensation *w* increases in the farmer's reservation utility $\bar{U}$ and decreases in the farmer's expected profit. If the risk aversion parameter, α_a, and variance term, σ^2, are positive and small enough, the fixed compensation decreases with the introduction of crop insurance because it has an effect of decreasing risk, thus making $\left(1 - 2\alpha_a \sigma^2\right)$ increase.

The investor's profit with crop insurance is:

(21) $$\pi_p = (1-\delta)\left[(1-b)(e+\tilde{\theta}+I(\hat{\theta},\tilde{\theta})-p(\hat{\theta}))-w\right].$$

Based on the specified model, the mean and variance of the investor's profit is:

(22) $$E(\pi_p) = (1-\delta)[(1-b)(e+\mu)-w]$$

(23) $$Var(\pi_p) = (1-\delta)^2(1-b)^2\sigma^2$$

Expected profit with and without insurance are equal because the insurance is fair. The variance depends on farmer's risk attitude, the existence of crop insurance, the fairness of crop insurance, and insurance coverage level. Substituting equations (22) and (23) into the investor's objective in equation (11) and simplifying gives:

(24) $$\underset{b}{Max}\begin{pmatrix} (1-\delta)\left[(1-b)\left(0.5[\delta+(1-\delta)b]+\mu\right)\right] \\ -\left\{\bar{U}-[\delta+(1-\delta)b]\mu-0.25[\delta+(1-\delta)b]^2 * \left(1-2\alpha_a\sigma^2\right)\right\} \\ -0.5\alpha_p(1-\delta)^2(1-b)^2\sigma^2 \end{pmatrix}$$

Solving the first order condition for b gives:

(25) $$b^* = \frac{1}{1-\delta}\left[\frac{\left(1+2\alpha_p\sigma^2\right)}{\left(1+2(\alpha_a+\alpha_p)\sigma^2\right)}-\delta\right].$$

Using this result, several comparative static results can be obtained. The variable compensation rate b^* depends inversely on the farmer's share of investment: $\frac{\partial b^*}{\partial \delta} < 0$. This occurs because the greater the farmer's share of the investment, the greater farmer's incentive to exert effort. The variable compensation rate b^* decreases with the farmer's risk aversion because the farmer needs to bear less risk to motivate high effort: $\frac{\partial b^*}{\partial \alpha_a} < 0$. On the other hand, as the investor's risk aversion increases, the variable compensation rate b^* also increases, $\frac{\partial b^*}{\partial \alpha_p} > 0$, because the investor wants to share more risk with farmer. As the variance of the outcome increases, the variable compensation rate b^* decreases, $\frac{\partial b^*}{\partial \sigma^2} < 0$, because a smaller b^* gives the farmer relatively less risk. Thus overall, crop insurance leads to the increase in variable compensation because it reduces the risk. Because of this effect of crop insurance, the investor must increase the farmer's risk share from the contract to motivate high effort. In effect, crop insurance insulates the farmer from sufficiently powerful incentives to motivate high effort, so the investor compensates by increasing the variable compensation rate to increase the farmer's risk

share. Furthermore, we know that the variable compensation rate increases with an increase in the insurance coverage level because $\frac{\partial A}{\partial a} < 0$ and $\frac{\partial \sigma^2}{\partial A} > 0$.

Substituting the optimal b^* into equations (19) and (20) gives the optimal w^* and e^*:

$$(26) \qquad e^* = 0.5\left[\frac{\left(1+2\alpha_p\sigma^2\right)}{\left(1+2(\alpha_a+\alpha_p)\sigma^2\right)}\right]$$

$$(27) \qquad w^* = \frac{1}{(1-\delta)}\left[\bar{U} - \left(\frac{\left(1+2\alpha_p\sigma^2\right)}{\left(1+2(\alpha_a+\alpha_p)\sigma^2\right)}\right)\mu - 0.25\left(\frac{\left(1+2\alpha_p\sigma^2\right)}{\left(1+2(\alpha_a+\alpha_p)\sigma^2\right)}\right)^2\left(1-2\alpha_a\sigma^2\right)\right]$$

Again, several comparative static results can be obtained. The optimal level of effort increases with the investor's risk aversion and decreases with the farmer's risk aversion and the variance of outcome: $\frac{\partial e^*}{\partial \alpha_p} > 0$, $\frac{\partial e^*}{\partial \alpha_a} < 0$, and $\frac{\partial e^*}{\partial \sigma_A^2} < 0$. Because the farmer's compensation is highly dependent on output, the farmer must exert more effort relative to the case without insurance. Also the insurance coverage level increases the optimal level of effort because $\frac{\partial A}{\partial a} < 0$ and $\frac{\partial \sigma^2}{\partial A} > 0$.

The optimal level of the fixed compensation w decreases with the investor's risk aversion $\frac{\partial w^*}{\partial \alpha_p} < 0$. This means that the risk averse investor wants to share more risk with the farmer, and thus decreases the fixed compensation. The optimal level of the fixed compensation increases with the variance of outcome $\frac{\partial w^*}{\partial \sigma^2} > 0$, resulting in the increase with the insurance coverage level. It also increases with the farmer's risk aversion $\frac{\partial w^*}{\partial \alpha_a} > 0$. Thus the investor needs to increase the fixed compensation to induce the participation of the risk averse farmer in the contract. The optimal level of fixed compensation also increases with the farmer's investment share $\frac{\partial w^*}{\partial \delta} > 0$. The farmer with high investment share would be willing to exert effort, thus the investor increases fixed compensation instead of variable compensation. Similarly, the optimal level of fixed compensation increases with the farmer's reservation utility, $\frac{\partial w^*}{\partial \bar{U}} > 0$, and decreases with expected revenue, $\frac{\partial w^*}{\partial \mu} < 0$. Expected revenue is positively correlated with its variance so that the fixed compensation decreases with expected revenue to share more risk.

Crop insurance leads to increase the optimal level of effort through the increase in variable compensation, and decreases the optimal level of fixed compensation. Thus it induces more risk sharing between the investor and the farmer.

Implications

Comparing these results to those of Wang, Leatham, and Chaisantikulawat, we find that the risk neutral or risk averse investor induces more effort, pays more variable compensation, and pays less fixed compensation with crop insurance regardless of fairness of crop insurance. In other wards, crop insurance increases a farmer's optimal effort e, and for the optimal contract, crop insurance increases the slope b and decreases the intercept w. Figures 1 through 5 summarize these results graphically.

In Figure 1, the compensation schedule under crop insurance shows lower fixed payment w and higher variable payment rate b compared to the case without insurance. This new compensation scheme leads to more risk sharing between the investor and the farmer in order to induce more effort from the farmer. Also these effects become stronger with an increase in the insurance coverage level, as illustrated in figure 2. As expected, a higher coverage level reduces the downside risk further so that the farmer can afford to bear more risk. Thus a higher coverage level leads to a higher variable compensation b and effort level e, and a lower fixed compensation w than with a lower coverage level. Figure 3 shows how the fairness of crop insurance also affects the optimal compensation scheme. Fair insurance decrease more variance than unfair insurance, which gives afford for the farmer to bear more risk. So the contract with more variable compensation and effort, and less fixed compensation is needed.

As the investor's risk aversion increases, the variable compensation b and effort level also increase e and the fixed compensation w decreases because the investor would prefer to share more risk with the farmer, as shown in figure 4. On the other hand, as the risk aversion of farmer increases, opposite results are obtained as shown in figure 5, because the farmer would not accept the contract if the variable compensation is too high.

Conclusion

This paper determines the investor's preferences for crop insurance according to risk attitude and the fairness of the crop insurance. Also, for any given crop insurance, we determine the optimal contract design that induces the best effort from the farmer using a variable compensation rate and a fixed compensation rate.

A risk averse farmer with fair crop insurance behaves like a risk neutral farmer. He allocates more to the risky crop, thus resulting in higher expected revenue and a lower variance, as long as the crop insurance is actuarially fair. So both a risk neutral investor and a risk averse investor prefer a farmer with fair crop insurance. If the insurance is not fair, the risk averse farmer reduces the risky crop acreage compared to the case without insurance. Thus, even though crop insurance decreases the variance of revenue, expected revenue also decreases. Therefore, a risk neutral investor does not like unfair crop insurance, but a risk averse investor must tradeoff between decreased expected revenue and decreased variance. The risk averse investor may prefer unfair crop insurance as long as the benefit from reducing risk is greater than the cost of reducing expected revenue. Given crop insurance, the investor will adjust the compensation scheme to induce the best effort from the farmer. The results show that the investor's optimal contract will use a larger variable compensation rate than without insurance. The variable compensation rate

also increases with the coverage level. The optimal contract with fair insurance uses a larger variable compensation rate than unfair insurance. The risk averse investor prefers that the optimal contract depend more on variable compensation than the risk neutral investor. The risk averse farmer is given a larger variable compensation rate than the risk neutral farmer.

Optimal contract requires the farmer to bear more risk so that the farmer has the appropriate incentives to work hard. Thus by making the compensation scheme depend more on variable compensation with crop insurance, the investor may induce more effort from the farmer and share more risk with the farmer. Thus crop insurance may reduce the moral hazard problem caused by asymmetric information.

References

Ahsan, S. M., A. Ali, and N. J. Kurian. "Toward a Theory of Agricultural Insurance." *American Journal of Agricultural Economics* 64(1982): 520-29.

Allen, D. W., and D. Lueck. *The Nature of the Farm: Contracts, Risk, and Organization in Agriculture*. Cambridge MA: MIT Press, 2002.

Babcock, B. A. and D. Hennessy. "Input Demand under Yield and Revenue Insurance." *American Journal of Agricultural Economics* 78(1996):395-407.

Canjels, E. "Risk and Incentives in Sharecropping: Evidence from Modern U.S. Agriculture." CEPA Working Paper Series II, Working Paper No. 4. Center for Economic Policy Analysis. October 1998.

Canjels, E. and Volz U. "Share Contracts and Unobserved Ability." CEPA Working Paper 2001.03. Center for Economic Policy Analysis. New School University. November 2001.

Chambers, R. G. "Insurability and Moral Hazard in Agricultural Insurance Markets." *American Journal of Agricultural Economics* 64(1988): 604-16.

Chambers, R. G., and J. *Quiggin, Uncertainty, Production, Choice, and Agency: The State-Contingent Approach*. Cambridge University Press, 2000.

Goodhue, R., D. Heien, and H. Lee, "Contract Use in the California wine grape economy." AIC Issue Brief. 1999. Online. Available at http://aic.ucdavis.edu/pub/briefs/brief11.pdf.

Horowitz, J. K., and E. Lichtenberg. "Insurance, Moral Hazard, and Chemical Use in Agriculture." *American Journal of Agricultural Economics* 75(1993):926-35.

Laffont, J-J., and D. Martimort. *The Theory of Incentives: The Principal-Agent Model*. Princeton, NJ: Princeton University Press, 2001.

Leatham, D. J., B. A. McCarl, and J. W. Richardson. "Implications of crop insurance for farmers and lenders." *Southern Journal of Agricultural Economics* 19(1987):113-20.

Nelson, H. and E. T. Loehman. "Further Toward a Theory of Agricultural Insurance." *American Journal of Agricultural Economics* 69(1987):525-31.

Raviv, A. "The Design of an Optimal Insurance Policy." *American Economic Review* 69(1979):84-96.

Santos, J. C. "Debt and Equity as Optimal Contracts." *Journal of Corporate Finance* 3(1997):355-66.

Skees, R. J. and M. R. Reed. "Rate making for Farm-Level Crop Insurance: Implications for Adverse Selection." *American Journal of Agricultural Economics* 68(1986):653-59.

Smith, V. H., and B. K. Goodwin. "Crop Insurance, Moral Hazard, and Agricultural Chemical Use." *American Journal of Agricultural Economics* 78(1996):428-38.

Spremann, K. "Agent and Principal." In Agency Theory, Information, and Incentives, eds. G. Bamberg and K. Spremann, pp. 3-37. Berlin: Springer-Verlag, 1987.

United States Department of Agriculture, National Agricultural Statistical Service. *1997 Census of Agriculture.* 1999.

Wang, Z., D. J. Leatham, and T. Chaisantikulawat. "External Equity in Agriculture: Risk Sharing and Incentives in a Principal-Agent Relationship." *Agricultural Financial Review* 62(2002):13-24.

Weninger, Q., and R. Just. "Are Crop Returns Normally Distributed." *American Journal of Agricultural Economics* 81(1999):287-304.

Table 1. The results of production decision.*

	Risk Neutral Farmer	Risk Averse Farmer		
	No Insurance	No Insurance	Fair Insurance	Unfair Insurance
Risky Crop Acreage (A)	1	2	1	3
Expected Revenue (μ_A)	1	2	1	3
Revenue Variance (σ_A^2)	1	2	4	3

* Numbers represent farmer rankings from highest (1) to lowest (4).

Smallest number denotes the highest risky crop acreage, expected revenue, and revenue variance in each row. The larger the number, the smaller the magnitude of them.

Table 2. The investor's preference for farmer's purchasing crop insurance.

	Fair Insurance	Unfair Insurance
Risk Neutral Investor	Prefer	Not Prefer
Risk Averse Investor	Prefer	Uncertain

Figure 1. The effect of crop insurance on optimal compensation scheme

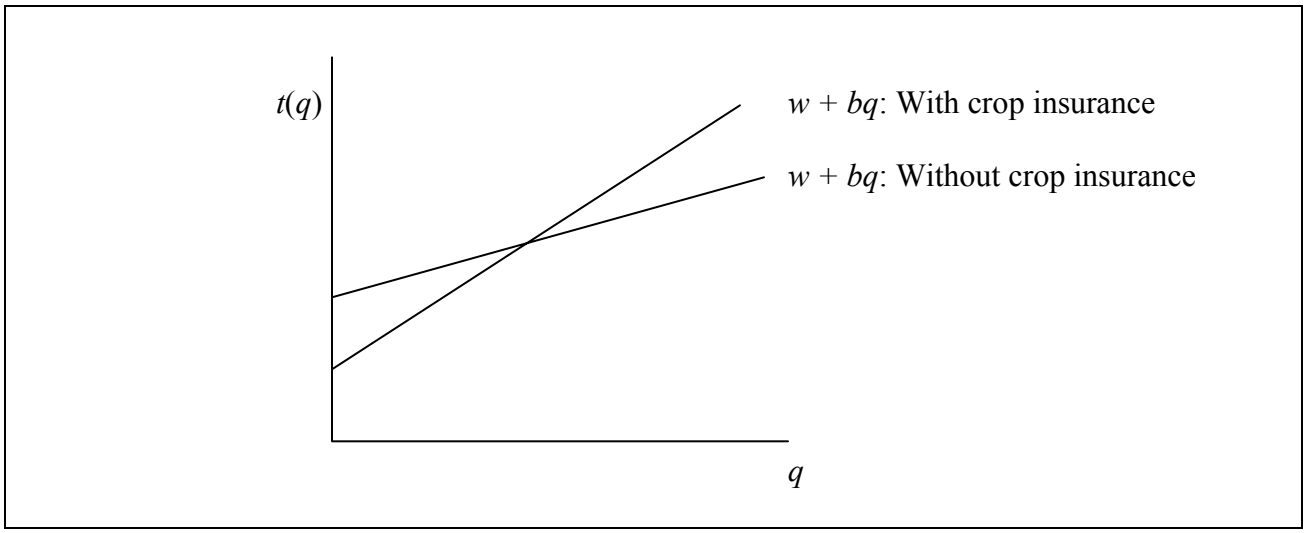

Figure 2. The effect of insurance coverage level on optimal compensation scheme

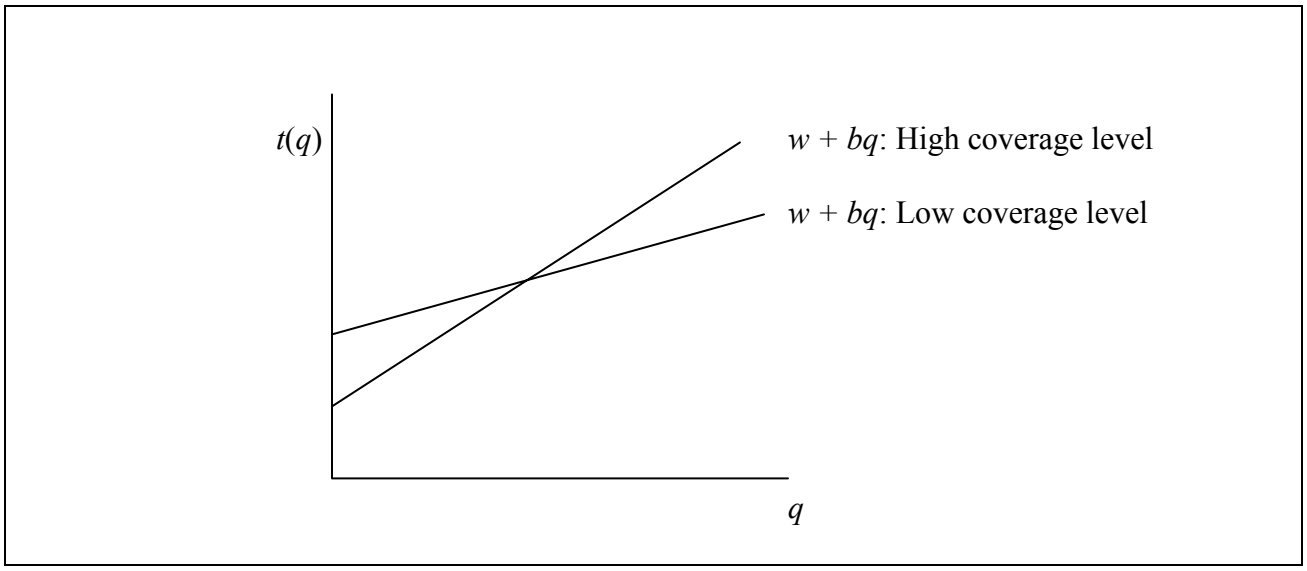

Figure 3. The effect of fairness of insurance on optimal compensation scheme

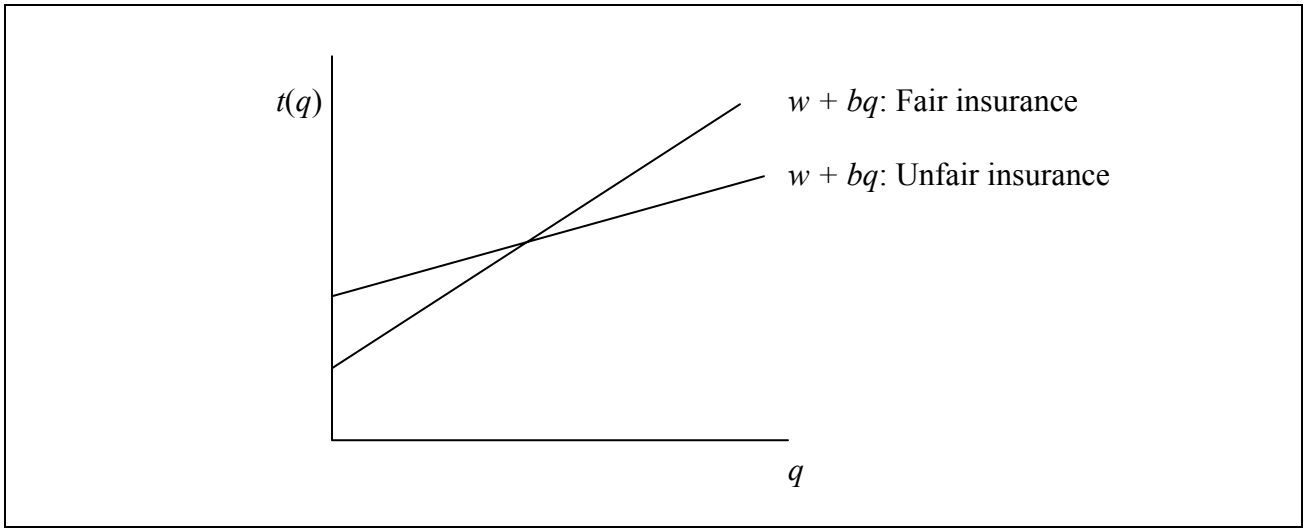

Figure 4. The effect of investor's risk aversion on optimal compensation scheme

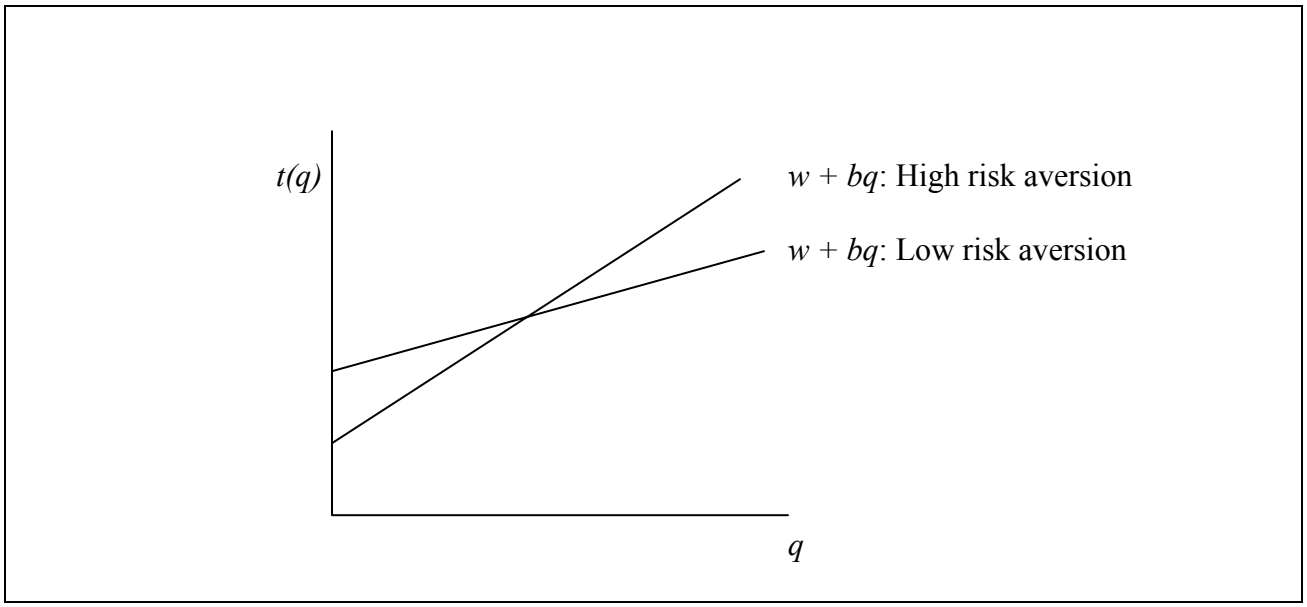

Figure 5. The effect of farmer's risk aversion on optimal compensation scheme