EFFECTS OF INSURANCE ON FARMER CROP ABANDONMENT

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Abstract

Empirical evidence for the existence of moral hazard in the U.S. crop insurance program has been inconclusive. Here, we seek empirical evidence of moral hazard in the U.S. crop insurance program, departing from the established empirical literature in two significant respects. First, we attempt to uncover evidence of moral hazard by examining the effects of crop insurance on post-planting crop abandonment decisions. Second, we expand to the scope of existing empirical studies by including regions and crops that have historically experienced high loss ratios under the Federal crop insurance program. Our results provide strong evidence that insurance participation encourages producers to abandon their crops during the growing season for corn in Central Plains and Southern Plains regions and for upland cotton in Southeast, Delta States and Southern Plains regions.

Key words: crop abandonment, crop insurance, moral hazard, intra-seasonal dynamic optimization model.

Over the past three decades, a variety of crop yield and revenue insurance contracts have been introduced under the U.S. Federal Crop Insurance Program to assist agricultural producers manage their financial risks. Although crop insurance is designed to protect producers from financial risks, many researchers and policy analysts have argued that crop insurance may actually induce greater risk by providing producers with incentives to alter their production practices in such a way as to increase the likelihood of receiving an indemnity. This economic phenomenon is known as *moral hazard*.

Numerous studies have examined how crop insurance affects producer behavior (Chambers 1989; Coble et al. 1997; Chambers and Quiggin 2002). The majority of studies have focused on the effects of crop insurance on specific production practices, and have provided contradictory or inconclusive evidence of moral hazard. For example, Horowitz and Lichtenberg (1993) assessed the effects of crop insurance on fertilizer application and pesticide use among corn producers in the U.S. Midwest, concluding that crop insurance participation increased nitrogen application by 19% and pesticide use by 7%. In contrast, Smith and Goodwin (1996) concluded that insured Kansas dryland wheat producers use less chemical inputs than uninsured producers. Using a simulation model, Babcock and Hennessy (1996) concluded that Iowa corn producers who purchase insurance use less nitrogen fertilizer. Another study by Wu (1999) estimated the response of crop mix to insurance participation using survey data from individual corn producers in the Central Nebraska Basin and found that insurance participation encourages producers to switch to crops with higher expected economic returns, leading to increases in chemical use. More recent work by Goodwin, Vandeveer and Deal (2004) studied the effects of insurance participation on corn and soybean production in the Corn

Belt and wheat and barley production in the Upper Great Plains. They concluded that crop insurance participation leads to relatively modest increases in acreage and has ambiguous impacts on input use.

The failure of empirical studies to uncover unambiguous and conclusive evidence of moral hazard in the U.S. crop insurance program may be attributable to various reasons, two of which are especially relevant to the research we undertake here. First virtually all empirical studies to date have searched for evidence of moral hazard by examining the effects of crop insurance on planting-time crop allocation and fertilizer input decisions. We contend, however, that the effects of crop insurance on input decisions can easily be masked by other factors affecting production decisions, making it difficult to detect moral hazard empirically. For example, decisions regarding chemical use may be driven more by weather conditions than by crop insurance participation in regions where profound pest infestations are common (Horowitz and Lichtenberg 1993).

Second, most empirical studies to date have focused on the effects of crop insurance on major field crops in the Midwest and Upper Great Plains. The actuarial performance of the U.S. crop insurance program in these regions, however, has historically been substantially better than in other regions of the country, suggesting that the conditions necessary for significant moral hazard are likely to be stronger elsewhere. Figure 1 documents regional variation in Federal crop insurance loss ratios (indemnities received divided by premium paid by producers) during 1989-2004[1]. As seen in figure 1, the U.S. crop insurance program has operated on a nearly actuarially sound basis in the

[1] A crop insurance program is generally regarded as self-sufficient if its loss ratio equal to one (or a little less than 1 to account for administrative and other costs).

Midwest, California, and parts of Far West, but not in the Northeast, South, and Delta States regions.

In this study, we seek empirical evidence of moral hazard in the U.S. crop insurance program, departing from the established empirical literature in two significant respects. First, we attempt to uncover evidence of moral hazard by examining the effects of crop insurance on post-planting decisions that theoretically can be expected to be more sensitive to the incidence of crop insurance than input decisions. In particular, we seek to find evidence that crop insurance can significantly increase the likelihood of post-planting crop abandonment. Second, we expand the scope of our empirical analysis to include regions and crops that have historically experienced high loss ratios under the Federal crop insurance program. In particular, we attempt to uncover evidence of moral hazard in the production of corn and upland cotton in the Southeast, Delta States and Southern Plains regions of USA.

In the next section, we develop a theoretical intra-seasonal dynamic optimization model that can explicitly explain a producer's crop abandonment decisions. The model lacks analytic solution and is solved using numerical techniques (Miranda and Fackler 2002). We perform sensitivity analysis with regards to key model parameters and derive testable qualitative implications regarding the factors that are most likely to affect producer crop abandonment decisions. These factors include both participation in the crop insurance program and unfavorable changes in price and weather conditions during the growing season. In the subsequent section, a Logit model justified by the theoretical arguments is developed and estimated using a pooled cross-sectional, time-series of corn and upland cotton county-level yields during the years 1989 – 2004. In the final section, we draw conclusions from our theoretical and empirical analysis and suggest directions for future research.

A Theoretical Dynamic Model of Crop Abandonment

Most existing studies of moral hazard in crop insurance rely on static models that ignore that crop abandonment decisions typically take place during the growing season in response to changes in harvest-time price and yield expectations (Chambers 1989; Horowitz and Lichtenberg 1993; Vercammen and van Kooten 1994; Babcock and Hennessy 1996; Coble et al. 1997; Chambers and Quiggin 2002).

In this section, we construct a theoretical intra-seasonal dynamic optimization model that can explicitly explain producer crop abandonment decisions. The theoretical model begins by assuming that a producer's objective is to maximize expected net profit at harvest. The model allows a producer to re-evaluate price and yield expectations at an intermediate point in time between planting and harvest and, based on revised expectations, to decide whether to abandon the crop.

Producer's Decision Problem without Crop Insurance

Consider a crop producer whose goal is to maximize expected net profit realized at harvest time. The crop year is divided into two periods: period 1, which begins at time $t = 0$ and ends at $t = 1$, and period 2, which begins at $t = 1$ and ends at $t = 2$. At $t = 0$, the producer observes current growing and market conditions and undertakes his/her planting decision. At $t = 1$, the producer observes current growing and market conditions and decides whether to continue cultivation the crop to bring it to harvest, or to abandon his/her crop. At time $t = 2$, the producer harvests his/her crop, provided he/she did not abandon it earlier, and sells the total amount produced *y*, at the prevailing market price *p*.

The price and yield at harvest are stochastic:

$$p = p(\bar{p}, \tilde{\eta}_1, \tilde{\eta}_2)$$

$$y = y(\bar{y}, \tilde{\varepsilon}_1, \tilde{\varepsilon}_2)$$

Here, $\bar{p}$ and $\bar{y}$ denote, respectively, the price and yield expected at harvest time conditional on information available at planting time $t = 0$; $\tilde{\eta}_1$ and $\tilde{\varepsilon}_1$ denote exogenous price and yield shocks realized over period 1 and observed by the producer at time $t = 1$; and $\tilde{\eta}_2$ and $\tilde{\varepsilon}_2$ denote exogenous price and yield shocks realized over period 2 and observed by the producer at harvest time $t = 2$.

In order to simplify the analysis, we assume that it is always profitable for the producer to plant at the beginning of the crop year and focus on his/her decision *d*, undertaken at time $t = 1$, whether to abandon his/her crop or to bring it to market. At time $t = 0$, the producer incurs at a cost $c_1 > 0$ to plant his/her crop. At time $t = 1$, the producer observes the first-period price and yield shocks, $\tilde{\eta}_1$ and $\tilde{\varepsilon}_1$, allowing him/her to update the probability distribution of the final yield and harvest-time price. At this juncture, the producer decides whether to abandon his/her crop or to continue to cultivate it. If he/she decides to abandon his/her crop, $d = 0$, the producer's terminal yield will be zero and his/her terminal profits will be, with certainty

$$W_0 - c_1 \tag{1}$$

where W_0 is his/her initial wealth. If he/she decides not to abandon his/her crop, $d = 1$, the producer's terminal expected profits will be

(2) $$W_0 + p(\bar{p}, \tilde{\eta}_1, \tilde{\eta}_2) \cdot y(\bar{y}, \tilde{\varepsilon}_1, \tilde{\varepsilon}_2) - c_1 - c_2$$

where c_2 is the cost of further cultivation and harvesting incurred over period 2.

The rational producer will elect to abandon his crops at time $t = 1$ if the quantity in (1) exceeds the expectation of the quantity in (2), conditional on the information known at time $t = 1$. The decision to abandon will thus depend primarily on the market conditions that exist at the abandonment decision point $t = 1$, as revealed in the observed values of the first period price and yield shocks $\tilde{\eta}_1$ and $\tilde{\varepsilon}_1$. The set of all possible values of $\tilde{\eta}_1$ and $\tilde{\varepsilon}_1$ can be partitioned into two subsets, the values that result in an optimal decision to abandon $d(\tilde{\varepsilon}_1, \tilde{\eta}_1) = 0$ and the values that result in an optimal decision to continue cultivation $d(\tilde{\varepsilon}_1, \tilde{\eta}_1) = 1$.

Given the joint probability distribution *f* of $\tilde{\eta}_1$ and $\tilde{\varepsilon}_1$, the ex-ante probability of crop abandonment is given by:

(3) $$\textit{Pr(abandonment)} = \Pr\left(d(\tilde{\varepsilon}_1, \tilde{\eta}_1) = 0\right) = \iint_{d(\varepsilon_1, \eta_1) = 0} f(\varepsilon_1, \eta_1) d\varepsilon_1 d\eta_1$$

According to this decision model, the likelihood at planting time that a producer will subsequently abandon his/her crop depends upon the model parameters: initial wealth W_0, the costs of production at periods 1 and 2, c_1 and c_2, the yield expected at harvest conditional on information available at planting time $\bar{y}$, the price expected at harvest conditional on information available at planting time $\bar{p}$, the variances of yield random shocks $(\sigma^2_{\tilde{\varepsilon}_1}, \sigma^2_{\tilde{\varepsilon}_2})$, and the variances of price random shocks $(\sigma^2_{\tilde{\eta}_1}, \sigma^2_{\tilde{\eta}_2})$.

Producer's Decision Problem with Crop Insurance

Consider now a producer who purchases multiple peril crop yield insurance at planting. Upon purchasing the insurance, the producer elects a coverage θ that specifies the proportion of his/her program yield y^* to be insured. Under the terms of the contract, the producer pays a premium π entitling him/her to receive an indemnity if his/her realized yield falls below the insured level. Most specifically, the indemnity received by the producer equals

$$p^* \max\{0, \theta y^* - y\}$$

where y is the realized yield, p^* is the price election, which is typically set at or near to the harvest-time futures price at planting, and y^* is the producer's program yield, which is typically set at or near the simple average of the producer's yields over the preceding ten years.

The purchase of insurance alters the producer's abandonment decision problem. At time $t = 1$, the producer observes the first-period price and yield shocks, $\tilde{\eta}_1$ and $\tilde{\varepsilon}_1$, and decides whether to abandon his/her crop or to continue to cultivate it, based on his/her expectation of not only his/her final yield and market price, but also his/her net insurance benefits. More specifically, if he/she decides to abandon his/her crop, $d = 0$, the producer's terminal yield will be zero, implying that he/she will collect the full liability under the contract, $\left(p^* \cdot \theta y^*\right)$, and his/her terminal profits will be, with certainty

$$W_0 - c_1 - \pi + p^* \cdot \theta y^* \tag{4}$$

If he/she decides not to abandon his/her crop, $d = 1$, the producer's terminal expected profits will be

(5) $$W_0 + p\left(\bar{p}, \tilde{\eta}_1, \tilde{\eta}_2\right) \cdot y\left(\bar{y}, \tilde{\varepsilon}_1, \tilde{\varepsilon}_2\right) - c_1 - c_2 - \pi + p^* \max\left\{0, \theta y^* - y\left(\bar{y}, \tilde{\varepsilon}_1, \tilde{\varepsilon}_2\right)\right\}$$

The rational insured producer will elect to abandon his crops if the quantity (4) exceeds the expectation of the quantity in (5), conditional on the information known at time $t = 1$. The decision to abandon will thus depend primarily on the market conditions that exist at the abandonment decision point $t = 1$, as revealed in the observed values of the first period price and yield shocks $\tilde{\eta}_1$ and $\tilde{\varepsilon}_1$. As with the uninsured producer, the set of all possible values of $\tilde{\eta}_1$ and $\tilde{\varepsilon}_1$ can be partitioned into two subsets, the values that result in an optimal decision to abandon $d\left(\tilde{\varepsilon}_1, \tilde{\eta}_1\right) = 0$ and the values that result in an optimal decision to continue cultivation $d\left(\tilde{\varepsilon}_1, \tilde{\eta}_1\right) = 1$.

Given the joint probability distribution *f* of $\tilde{\eta}_1$ and $\tilde{\varepsilon}_1$, the ex-ante probability of crop abandonment is given by:

$$\begin{aligned} \textit{Pr(abandonment)} \quad &= \Pr\left(d\left(\tilde{\varepsilon}_1, \tilde{\eta}_1\right) = 0\right) \\ &= \iint_{d(\varepsilon_1, \eta_1) = 0} f\left(\varepsilon_1, \eta_1\right) d\varepsilon_1 d\eta_1 \end{aligned}$$

According to this decision model, the likelihood that an insured producer will abandon crop in any given year depends upon the model parameters: initial wealth W_0, the crop insurance premium, π, the coverage level θ, the program price p^*, the historical average yield y^*, the costs of production, c_1 and c_2, the yield expected at harvest conditional on information available at planting time $\bar{y}$, the price expected at harvest conditional on information available at planting time $\bar{p}$, the variances of yield random shocks $\left(\sigma^2_{\tilde{\varepsilon}_1}, \sigma^2_{\tilde{\varepsilon}_2}\right)$, and the variances of price random shocks $\left(\sigma^2_{\tilde{\eta}_1}, \sigma^2_{\tilde{\eta}_2}\right)$.

Numerical Solution

Due to the nonlinear nature of the decision problem, it is generally not possible to solve the model analytically for a closed-form solution. Thus, we employed numerical methods to compute accurate approximate solutions (Miranda and Fackler 2002). In particular, the nonlinear equations without crop insurance (6) and with crop insurance (7):

(6) $$W_0 - c_1 = E_{p,y|\tilde{\varepsilon}_1,\tilde{\eta}_1}\left(W_0 + p\left(\bar{p},\tilde{\eta}_1,\tilde{\eta}_2\right)y\left(\bar{y},\tilde{\varepsilon}_1,\tilde{\varepsilon}_2\right) - c_1 - c_2\right)$$

(7) $$W_0 - c_1 - \pi + p^* \cdot \theta y^*$$

$$= E_{p,y|\tilde{\varepsilon}_1,\tilde{\eta}_1}\begin{pmatrix} W_0 + p\left(\bar{p},\tilde{\eta}_1,\tilde{\eta}_2\right)y\left(\bar{y},\tilde{\varepsilon}_1,\tilde{\varepsilon}_2\right) - c_1 - c_2 \\ -\pi + p^* \max\left\{0, \theta y^* - y\left(\bar{y},\tilde{\varepsilon}_1,\tilde{\varepsilon}_2\right)\right\} \end{pmatrix}$$

were solved using *Newton's method* to determine the combinations of $\tilde{\eta}_1$ and $\tilde{\varepsilon}_1$ at which the producer is indifferent between abandonment and non-abandonment. This allows us to partition the set of all $\tilde{\eta}_1$ and $\tilde{\varepsilon}_1$ into two regions, the set of values for which abandonment is optimal and the set of values for which it is not.

Newton's method is designed for rootfinding problems of the form $f(x) = 0$. The algorithm begins with the analyst supplying a guess $x^{(0)}$ for the root of *f*. Given $x^{(k)}$, the subsequent iterate $x^{(k+1)}$ is computed by solving the linear rootfinding problem obtained by replacing *f* with its first order Taylor approximation about $x^{(k)}$:

$$f(x) \approx f\left(x^{(k)}\right) + f'\left(x^{(k)}\right)\left(x^{(k+1)} - x^{(k)}\right) = 0$$

This yields the iteration rule

$$x^{(k+1)} \leftarrow x^{(k)} - \left[f'\left(x^{(k)}\right)\right]^{-1} f\left(x^{(k)}\right)$$

Iterates are computed until they converge.

After (6) and (7) were solved numerically for the region of abandonment and non-abandonment, the probability of crop abandonment in (3) was further computed by integrating the joint probability density function of $\tilde{\eta}_1$ and $\tilde{\varepsilon}_1$. The integration was performed numerically using Gaussian quadrature. Gaussian quadrature is a method for approximating a definite integral with a weighted sum of function values:

$$\int_I f(x)w(x)dx \approx \sum_{i=1}^{n} w_i f(x_i)$$

where w_i is the quadrature weights and x_i is the quadrature nodes. Specifically, Gaussian quadrature nodes and weights are chosen as to satisfy moment-matching conditions. Specifically, given an order of approximation *n*, Gaussian quadrature rules choose *n* quadrature nodes x_i and *n* quadrature weights w_i such that

$$E(\tilde{x}^h) = \int_I x^h w(x)dx = \sum_{i=1}^{n} w_i x_i^h , \qquad \text{for } h = 0,1,\ldots,2n-1$$

Gaussian quadrature effectively discretizes the continuous variable $\tilde{x}$ by replacing it with a discrete random variable that possesses the same moments of order less than 2*n*. Given the mass points and probabilities of the discrete approximant, the expectation of any function of the continuous random variable $\tilde{x}$ may be approximated using the expectation of the function of the discrete approximant, which requires only the computation of a weighted sum (Miranda and Fackler 2002).

$$Ef(\tilde{x}) = \int_I f(x)w(x)dx \approx \sum_{i=1}^{n} w_i f(x_i)$$

In performing our numerical analysis, the routine **qnwnorm** from the Matlab CompEcon Toolbox (Miranda and Fackler 2002) was used to compute Gaussian nodes and weights for the jointly normal random variables $\tilde{\eta}_1$ and $\tilde{\eta}_2$, using 50 Gaussian nodes for $\tilde{\eta}_1$ and 40 nodes for $\tilde{\eta}_2$, yielding a grid of 2000 total nodes. Representing the abandonment boundary by writing $\tilde{\varepsilon}_1$ as a function *h* of $\tilde{\eta}_1$, the probability of crop abandonment can be approximated by

$$
\begin{aligned}
(8) \qquad Pr(abandonment) &= \Pr\left(d\left(\tilde{\varepsilon}_1, \tilde{\eta}_1\right) = 0\right) \\
&= \iint_{H(\varepsilon_1,\eta_1)>0} f\left(\varepsilon_1 | \eta_1\right) g\left(\eta_1\right) d\varepsilon_1 d\eta_1 \\
&= \int_{-\infty}^{\infty} \left[\int_{-\infty}^{\varepsilon_1(\eta_1)} f\left(\varepsilon_1 | \eta_1\right) d\varepsilon_1 \right] g\left(\eta_1\right) d\eta_1 \\
&= \int_{-\infty}^{\infty} F\left(h\left(\eta_1\right)\right) g\left(\eta_1\right) d\eta_1
\end{aligned}
$$

where *f* is the probability density function of ε_1 conditional on η_1, *F* is the cumulative distribution of ε_1 conditional on η_1, and *g* is the marginal probability density function of η_1.

Sensitivity Analysis

Our base-case simulation assumes the parameter values shown in table 1. By definition, the contract yield is the selected yield coverage level multiplied by the program yield specified by Risk Management Agency (RMA) and, likewise, the contract price is the selected price coverage level multiplied by the program price specified by the RMA. Here, the program price and program yield, without loss of generality, are normalized to one and the yield coverage level and price coverage level are 85% and 100%, respectively. In addition, the variances of price and yield are normalized to imply a 20% annual volatility, which is reasonable for U.S. field crops.

By solving Equation (6) and (7) numerically, we get the set of $\tilde{\eta}_1$ and $\tilde{\varepsilon}_1$ that define the boundary along which the producer is indifferent between abandoning the crop and bringing it to harvest, for both insured and uninsured producers (see figure 2). In figure 2, we see that the region of non-abandonment for the insured producers is smaller than the regions of non-abandonment for uninsured. In other words, insured producers are more likely to abandon their crop than uninsured producers. Insured producers thus require either a higher expected price or a higher expected yield, or both, at period 1 than the uninsured producers in order to bring the crop to harvest.

We call the region between the decision boundaries of the insured and the uninsured producers the *moral hazard* region. In this region, the uninsured producer will bring the crop to harvest, but the insured producer will not. Another important feature found in figure 2 is the crop abandonment decision boundary appears to be roughly a curve of constant expected revenue. This is to be expected, since the producer, in making an abandonment decision, should be indifferent at any price-yield combinations that produce that same expected revenue. As seen in figure 2, the probability of abandoning the crop decreases (increases), as the high (low) levels of yield and price at period 1 are observed at the same time.

Once the regions of abandonment and non-abandonment have been determined, the ex-ante probability of abandonment with and without crop insurance can be computed numerically. The difference between these two probabilities

(9) $$\Delta \Pr(abandonment) = \Pr(abandon \mid insured) - \Pr(abandon \mid noninsured)$$

is taken as measure of the degree of moral hazard induced by crop insurance.

Sensitivity analyses were performed to explore the relationships between this operational measure of moral hazard and key model parameters. We began by examining how the variances of the price and yield affect the magnitude of the change in the probability of crop abandonment due to the purchase of crop insurance. Figure 3 plots the probability of crop abandonment versus price variance at period 1 for both insured and uninsured producers. Unlike insured producers, producers without crop insurance are unresponsive to small price variances at period 1, though as the variance increases, the probabilities of crop abandonment for both the insured and the uninsured producers increase (see figure 3(a)). In addition, the growth rates of the probability of crop abandonment between the insured and the uninsured are not identical. Figure 3(b) shows that changes in the probability of crop abandonment exhibits concavity, which suggests that moral hazard becomes more pronounced the higher the price variance at period 1, but eventually turns downward. Accordingly, up to a certain price variance at period 1, the producers will have no incentives to bring the crop to harvest.

In contrast, the probability of crop abandonment is relatively insensitive to the price variance at period 2; this is shown in figure 4. The uninsured producer will not abandon the crop and the insured producer has a fixed probability of crop abandonment regardless of the values of price variance at period 2.

The probabilities of crop abandonment versus yield variance at periods 1 and 2 are shown in figures 5 and 6. As seen in these figures, the yield variances at periods 1 and 2 have the same impacts on the producer's crop abandonment decision. The producer who purchases crop insurance still has a greater incentive to abandon his/her crop than the producer who does not purchase crop insurance, even in the extreme case in which the variances of yield are zero. From figure 5(a), the insured producers are sensitive to the yield variance at period 1 as well as to the price variance at period 1. The probability of crop abandonment for the insured producer reaches one, while the uninsured producer still not abandon the crop and, after the yield variance exceeds 3.5, the probability of crop abandonment for the uninsured producer increases dramatically. That is, when growing conditions are not favorable, the insured producers have higher incentives to abandon their crop, which is consistent with the conclusion of Coble et al. (1997). When extremely unfavorable weather occurs, both insured and uninsured producers will abandon their crops. Therefore, the moral hazard associated with purchasing crop insurance diminishes starting at the yield variance of 3.5 (see figure 5(b) and figure 6). In figure 7, we plot the changes in the probability of crop abandonment with respect to the joint distribution of price and yield variances at period 1. Not surprisingly, the figure provides a similar story as in the previous paragraphs.

Similarly, changes in the probability of crop abandonment were assessed with respect to all other model parameters, including net harvest cost, which is paid by the producer only if the crop is not abandoned at period 1, and the price-yield correlation. Note that the cost over period 1 is a sunk cost and thus is not relevant to the abandonment decision at time 1. Intuitively, the producer's marginal payoff reduces as the net harvest cost borne over period 2 increases. As the net harvest cost increases, the probabilities of not bringing the crop to harvest for the insured and the uninsured both rise. Ultimately, changes in the probability of crop abandonment converge to zero (see figure 8). Figure 9 illustrates how the changes in the probability of crop abandonment are associated with the correlation between the log yield and log price. In the extreme case in which log yield and log price are perfectly negatively correlated, the gross revenue remains constant regardless of the changes in yield and price. The probability of crop abandonment for the insured and the uninsured producers are close to zero. Due to the purchase of crop insurance, the probability of crop abandonment increases as the price-yield correlation increases.

The last two sensitivity analyses examine how the probability of crop abandonment changes in response to contract yield and contract price. Zero contract yields and prices correspond to the polar case in which no crop insurance is purchased. From figure 10 and figure 11, increases in contract yield and contract price raise the probability of crop abandonment among insured producers. In other words, the insured producers are more likely to abandon the crop if higher coverage levels are selected.

Empirical Analysis

In this section, we discuss empirical analysis of the effects of insurance on crop abandonment for corn in North Central and Central Plains regions and for corn and upland cotton in Southeast, Delta States and Southern Plains regions.

Data and Econometric Model

We measured crop abandonment as the ratio of total planted acres less harvested acres divided by total planted acres. Given that the dependent variable is a proportion, a simple Logit model with proportional data is estimated using weighted least-squares method also known as the *minimum logit chi-square method* (Maddala 1983, p.30). Specifically, I posit that

(10) $$\log \frac{\hat{p}_{it}}{1-\hat{p}_{it}} = x'_{it}\beta_i + u_{it}, \qquad i = 1,\ldots,n,\ t = 1,\ldots,T$$

where $\hat{p}_{it}$ is the proportion of planted acres abandoned in county *i* in year *t*, x_{it} denotes a vector of independent explanatory variables observed for county *i* in year *t* and u_{it} is normally distributed with $E(u_{it}) = 0$ and $Var(u_{it}) = \sigma^2$. Note that $\hat{p}_{it}/(1-\hat{p}_{it})$, the probability of abandonment divided by the probability of non-abandonment, gives the odds of abandonment. The parameter β_i therefore represents the percentage change in the odds of abandonment resulting from a unit increase in the value of i^{th} predictor.

One major challenge in this empirical study is that individual farm level data are not generally available. Thus, I used pooled cross-sectional, time series of county-level yields and crop insurance participation during 1989-2004 published in the *Ag Statistic Data Base* of National Agricultural Statistics Service (NASS) and *Summary of Business Statistics* of Risk Management Agency (RMA).

One possible measure of crop insurance participation is the ratio of insured planted acres to total planted acres (Goodwin 1993). It is important to recognize, however, that insured and total planted acres data are collected by different U.S. Department of Agriculture (USDA) agencies using different methods and are often inconsistent. Specifically, county-level planted acres data are compiled by the National Agricultural Statistics Service (NASS) using sample surveys of farm operators, while insured planted acres data are compiled by the Risk Management Agency (RMA) from individual crop insurance policy data. The magnitudes of sampling and nonsampling errors[2] in both series are unknown. If most farm enterprises are generally small in a

[2] See Lohr for more detailed discussion.

given county, the magnitudes of sampling and nonsampling errors are likely to be severe. In fact, in some counties, the insured planted acres reported by RMA exceed the total planted acres reported by NASS.

Another drawback of using the ratio of insured planted acres to total plated acres as a measure of insurance participation was pointed out by Goodwin, Vandeveer and Deal (2004). It is often likely that the producers change their level of participation by choosing different price elections or yield coverage levels rather than by changing the number of acres insured. As an alternative, Goodwin, Vandeveer and Deal proposed measuring program participation as the ratio of total liability divided by total possible liability; total possible liability is the product of the futures market price, planted acres and 75% of the county average yield for the preceding 10 years. However, maximum yield coverage levels have been extended to 85% or 90% across crops and insurance contracts over the past decade. As a result, computing total possible liability assuming 75% coverage will often produce a program participation ratio greater than one for recent years. In this study, we therefore measure insurance participation as the ratio of liability to expected value of production; with the latter set equal to product of total planted acres, the expected market price and the expected harvest yield.

It is important that the independent variables used in my empirical analysis effectively capture crop abandonment effects. Changes in the crop price is an important factor that explains crop abandonment decisions. Crop producers are more likely to abandon their crop, with or without insurance, if prices drop during the growing season. Using corn futures price data from Chicago Board of Trade and upland cotton futures price data from New York Board of Trade, changes in harvest price expectations during the growing season are calculated by taking the difference between the harvest-time futures price observed in mid-season and the harvest-time futures price observed at planting time. The assumed planting time, seasonal mid-point, and harvest time varied across crops and regions, as documented in table 2.

Similarly, crop producers are more likely to abandon their crop, with or without insurance, if weather worsens during the growing season. Here, we used the monthly Palmer Drought Severity Index (PDSI) to measure changes in growing conditions during the growing season. The PDSI is published by National Climatic Data Center (NCDC) of National Oceanic and Atmospheric Administration (NOAA). The PDSI is calculated from precipitation, temperature and soil moisture measures for each Climate Division in the U.S. Its values generally range between -6.0 and 6.0, which classifies moisture condition from dry to wet. As a result, a categorical variable, *unfavorable weather*, is created to represent the weather factor in the model (see table 3). If the averaged monthly PDSI between the assumed planting time and seasonal mid-point is within the normal range, from -0.49 to 0.49, *unfavorable weather* is equal to one. If the averaged monthly PDSI between the assumed planting time and seasonal mid-point falls into the category of developing wet spell or drought, $(0.49, 0.99]$ or $[-0.99, -0.49)$, *unfavorable weather* is equal to two. Any averaged monthly PDSI values above +3.99 or below -3.99 is considered as extreme category of wet spell or drought and *unfavorable weather* is scaled up to six. A positive relationship between *unfavorable weather* and crop abandonment is expected.

Though our theoretical model predicts that many factors affect producers' crop abandonment decisions, the effects of some, such as price-yield correlation, net harvest cost, contract yield, and contract price, will be difficult to detect empirically. For example, NASS provides estimates of harvest costs. The census, however, is collected every five years, making it infeasible to use the variable to measure inter-year variations. These costs, moreover, vary very little over time. Similarly, the contract yield and contract price are defined as selected coverage level of predetermined yield and predetermined price. In reality, most producers in a given county tend to select the same coverage level for price or yield. Given that county-level data are used in the study, the impacts of contract yield and contract price on producers' crop abandonment decisions would be difficult to assess. Therefore, we do not include these variables in the empirical analysis.

Estimation Results

Our theoretical dynamic economic decision model assumes that crop producers make decisions on whether to abandon the crop at an intermediate point in time between planting and harvest. Given that producers can curtail crop production in any month during the growing season, we have explored different choices for the intermediate abandonment decision point. The specification that provides results that are the most consistent with the life cycle of crop development and satisfying the hypothesis were selected (USDA 1997). Table 4 provides descriptive statistics of the variables used in the empirical study. The mean crop abandonment ratios are relatively high in the Southeast and Plains regions for corn and in Southern Plain for upland cotton. In addition, unfavorable weather, as indicated by the Palmer drought index, is more likely to be observed in the Plains regions. Based on our theoretical dynamic model, we anticipate finding significant positive effects of unfavorable weather on crop abandonment in Central Plains and Southern Plains regions.

The estimates presented in table 5 are mostly consistent with our expectations. Unfavorable weather significantly increases crop abandonment among corn and cotton producers in major production regions. Intuitively, adverse weather reduces yield and thus revenue expectations, providing incentives for producers to abandon their crops. This is also consistent with the results of Coble et al. (1997). As table 5 shows, the estimates of *unfavorable weather* are statistically significant and positive for corn and upland cotton in most regions at 5% significant level, which implies that unfavorable weather increases the rate of crop abandonment among corn producers in North Central, Central Plains and Southeast regions and among upland cotton producers in all Southern regions.

Our results also indicate that crop insurance participation promotes abandonment of corn in the Central Plains and Southern Plains regions and abandonment of upland cotton in the Southeast, Delta States and Southern Plains regions. The odds of abandonment of corn in the Central Plains and Southern Plain regions, respectively, are estimated to rise by 0.3% and 1.14% per percent increase in insurance participation. Also, the odds of abandonment of upland cotton in Southeast, Delta States and Southern Plains regions, respectively, are estimated to rise by 3.4%, 0.58% and 0.77% per percent increase in insurance participation.

In contrast, insurance participation significantly reduces crop abandonment for corn in North Central, Southeast and Delta States regions. It is not clear why insurance participation decreases crop abandonment in these regions. However, the Federal Crop

Insurance Program in the North Central region is, for the most part, actuarially sound (see figure 1), suggesting that the conditions necessary for moral hazard would be difficult to detect here. In addition, corn is rarely produced in the Southeast and Delta States regions. It is often planted as an alternative to cotton.

As expected, the rate of crop abandonment increases if the futures price declines during the growing season. Price declines have a positive effect on crop abandonment for both upland cotton and corn in most regions, except for corn in Southern Plains and upland cotton in Southeast. The odds of abandoning corn in the North Central, Central Plains, Southeast and Delta States regions, respectively, are estimated to increase by 0.16%, 0.7%, and 2.07% per one cent decrease in the futures price of corn.

Summary and Conclusions

In this study, we have constructed a theoretical intra-seasonal dynamical optimization model that can explicitly explain producers' crop abandonment decisions. Assuming that each producer's objective is to maximize expected wealth at harvest, the model allows each producer to re-evaluate price and yield expectations in mid-season and to abandon his/her crop if the expected future rewards from continuing to cultivate do not exceed the expected future rewards of abandoning. The model was solved numerically and sensitivity analyses were performed to explore the relationship between crop abandonment, with and without crop insurance, and key model parameters.

Our empirical analysis of the effect of crop insurance participation on crop abandonment decisions using a Logit model provides strong evidence that participation encourages abandonment for corn in Central Plains and Southern Plains regions and for upland cotton in Southeast, Delta States and Southern Plains regions.

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Variable	Parameter	Values in the Dynamic Model
contract price	p^*	1.00
contract yield	y^*	0.85
net harvest cost	c_2	0.10
price variance at period 1	vp_1	0.02
price variance at period 2	vp_2	0.02
yield variance at period 1	vy_1	0.02
yield variance at period 2	vy_2	0.02
log price-yield correlation	ρ	0.00
initial futures log price	$\bar{p}$	$-(vp_1 + vp_2)/2$
initial futures log yield	$\bar{y}$	$-(vy_1 + vy_2)/2$

Note: i) Contract price and contract yield are normalized to one, and 100% price protection level and 85% yield coverage level are selected, respectively. ii) Variances of price and yield at periods 1 and 2 are normalized to imply a 20% annual volatility, which is reasonable for U.S. field crops.

Table 1: Initial values for simulation model

Crop / Region	Description
<u>CORN</u>	
North Central	averaged monthly PDSI between April - June changes in December futures price observed in April and in June
Central Plains	averaged monthly PDSI between March - April changes in December futures price observed in March and in May
Southeast	averaged monthly PDSI between March - June changes in December futures price observed in March and in July
Delta States	averaged monthly PDSI between March - June changes in December futures price observed in March and in July
Southern Plains	averaged monthly PDSI between March - April changes in December futures price observed in March and in May
<u>COTTON</u>	
Southeast	averaged monthly PDSI between March - May changes in December futures price observed in March and in May
Delta States	averaged monthly PDSI between July - August changes in December futures price observed in July and in August
Southern Plains	
North	averaged monthly PDSI between April - June changes in December futures price observed in April and in July
Central	averaged monthly PDSI between April - May changes in December futures price observed in April and in June
South	averaged monthly PDSI between March - April changes in December futures price observed in March and in April

Table 2: Planting time and mid-season specification

Variable	**Description**
Crop Abandonment Ratio	= (planted acres – harvested acres) / planted acres
Unfavorable Weather	= 1, if averaged monthly PDSI between the assumed planting time and seasonal mid-point falls into the category of normal range, from -0.49 to 0.49. = 2, if averaged monthly PDSI between the assumed planting time and seasonal mid-point falls into the "developing" category of wet spell, from 0.49 to 0.99, or drought, from -0.99 to -0.49. = 3, if averaged monthly PDSI between the assumed planting time and seasonal mid-point falls into the "mild" category of wet spell, from 0.99 to 1.99, or drought, from -1.99 to -0.99. = 4, if averaged monthly PDSI between the assumed planting time and seasonal mid-point falls into the "moderate" category of wet spell, from 1.99 to 2.99, or drought, from -2.99 to -1.99. = 5, if averaged monthly PDSI between the assumed planting time and seasonal mid-point falls into the "severe" category of wet spell, from 2.99 to 3.99, or drought, from -3.99 to -2.99. = 6, if averaged monthly PDSI between the assumed planting time and seasonal mid-point falls into the "extreme" category of wet spell, above 3.99, or drought, below -3.99.
Insurance Participation	= (planted acres insured*coverage level) / planted acres
Price Change	= December futures price observed in mid-season – December futures price observed at planting time

Table 3: Variable descriptions

Variable	CORN Mean	CORN Std. Dev	COTTON Mean	COTTON Std. Dev
NORTH CENTRAL				
Crop Abandonment Ratio	0.08	0.11		
Unfavorable Weather	3.01	1.36		
Insurance Participation	0.34	0.18		
Price Change	-0.07	0.17		
CENTRAL PLAINS				
Crop Abandonment Ratio	0.15	0.18		
Unfavorable Weather	3.71	1.54		
Insurance Participation	0.43	0.19		
Price Change	-0.01	0.09		
SOUTHEAST				
Crop Abandonment Ratio	0.19	0.21	0.03	0.07
Unfavorable Weather	2.80	1.37	2.97	1.26
Insurance Participation	0.26	0.17	0.40	0.22
Price Change	-0.08	0.21	-0.00	0.03
DELTA STATES				
Crop Abandonment Ratio	0.08	0.09	0.02	0.02
Unfavorable Weather	2.53	1.17	3.01	1.33
Insurance Participation	0.35	0.18	0.35	0.23
Price Change	-0.08	0.21	-0.01	0.02
SOUTHERN PLAINS				
Crop Abandonment Ratio	0.12	0.13	0.16	0.20
Unfavorable Weather	3.25	1.39	3.20	1.40
Insurance Participation	0.38	0.21	0.48	0.19
Price Change	-0.01	0.09	-0.00	0.02

Note: price units for corn and upland cotton are cents per bushel and cents per pound.

Table 4: Descriptive statistics

	CORN		COTTON	
Variable	Estimate	Std. Error	Estimate	Std. Error
NORTH CENTRAL				
Intercept	-1.65*	0.04		
Unfavorable Weather	0.05*	0.01		
Insurance Participation	-2.23*	0.07		
Price Change	-0.16*	0.07		
Number of Observation	*9957*			
CENTRAL PLAINS				
Intercept	-2.25*	0.07		
Unfavorable Weather	0.02*	0.01		
Insurance Participation	0.30*	0.10		
Price Change	-0.70*	0.21		
Number of Observation	*4233*			
SOUTHEAST				
Intercept	-1.33*	0.05	-5.53*	0.15
Unfavorable Weather	0.09*	0.01	0.39*	0.03
Insurance Participation	-1.38*	0.12	3.40*	0.24
Price Change	-0.26*	0.09	2.58	1.65
Number of Observation	*5000*		*1391*	
DELTA STATES				
Intercept	-1.91*	0.19	-4.09*	0.12
Unfavorable Weather	-0.02	0.05	0.10*	0.03
Insurance Participation	-1.20*	0.33	0.58*	0.16
Price Change	-2.07*	0.29	-5.78*	1.64
Number of Observation	*397*		*792*	
SOUTHERN PLAINS				
Intercept	-2.20*	0.10	-1.91*	0.18
Unfavorable Weather	-0.03	0.02	0.12*	0.03
Insurance Participation	1.14*	0.14	0.77*	0.28
Price Change	-0.31	0.27	-9.24*	1.53
Number of Observation	*1270*		*1576*	

Note: Asterisk (*) denotes variables significant at 5% or smaller level.

Table 5: Parameter estimates of Logit model

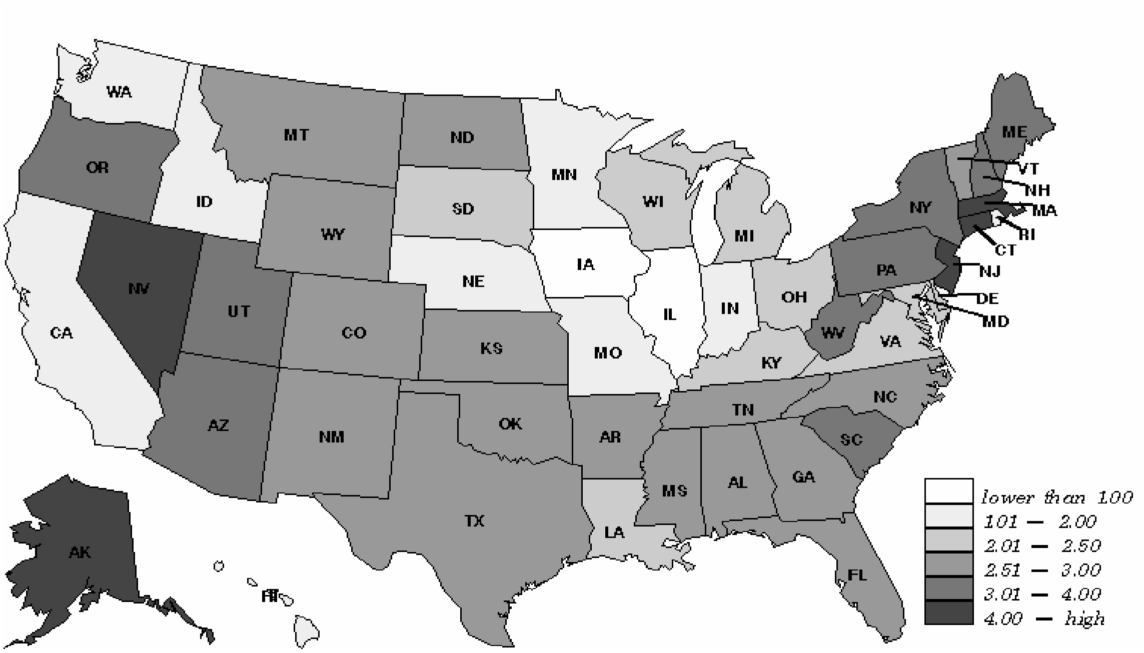

Figure 1: Loss ratio (indemnities / producer-paid premiums) of U.S. Federal Crop Insurance Program, 1989-2004

Source: U.S. Department of Agriculture, Risk Management Agency

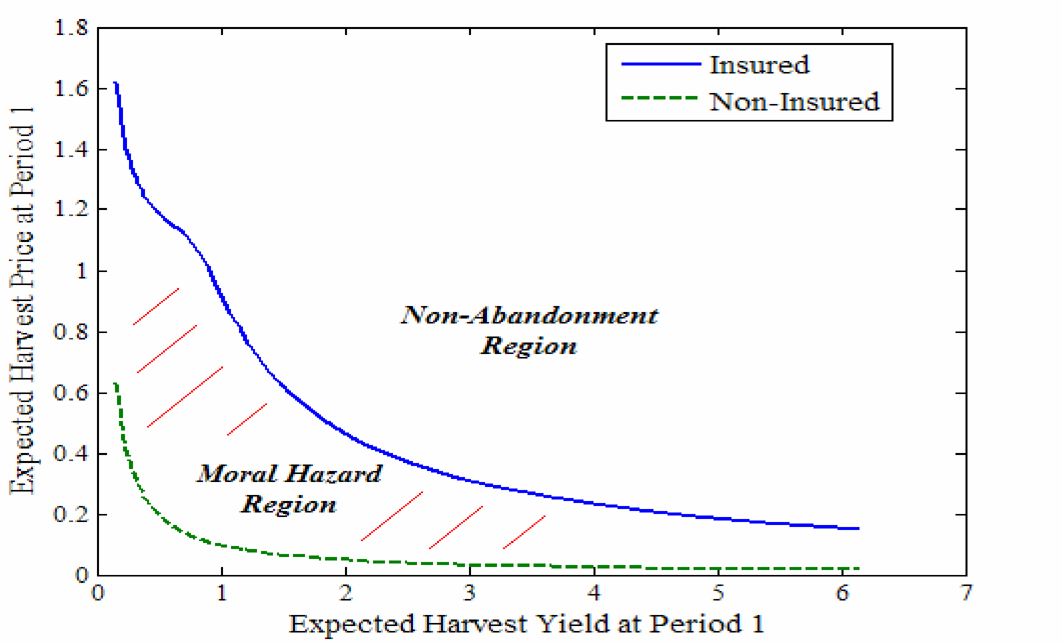

Figure 2: Crop abandonment decision boundary

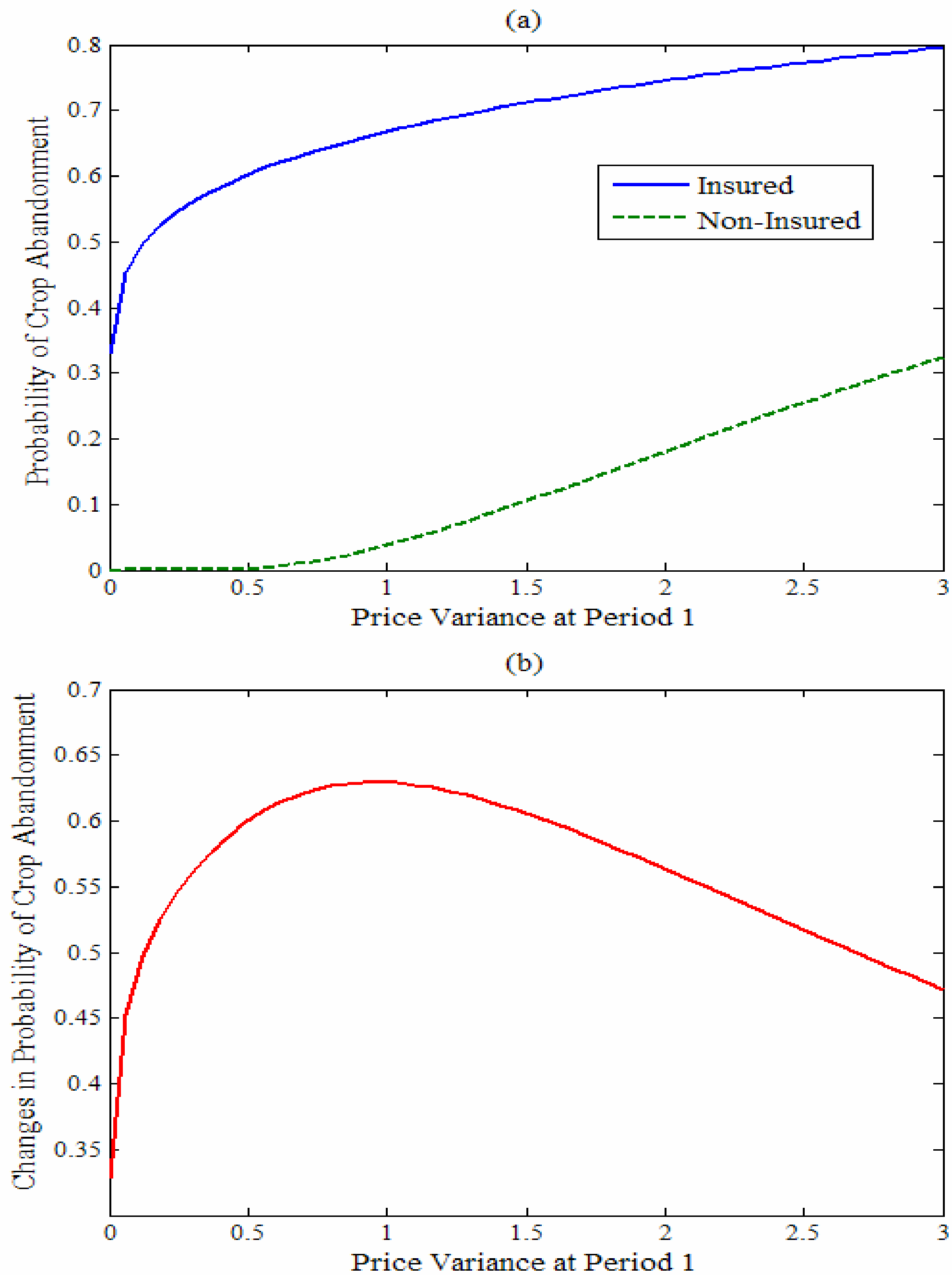

Figure 3: Sensitivity analysis of crop abandonment vs. price variance at period 1: (a) insured vs. uninsured; (b) changes in the probability of crop abandonment

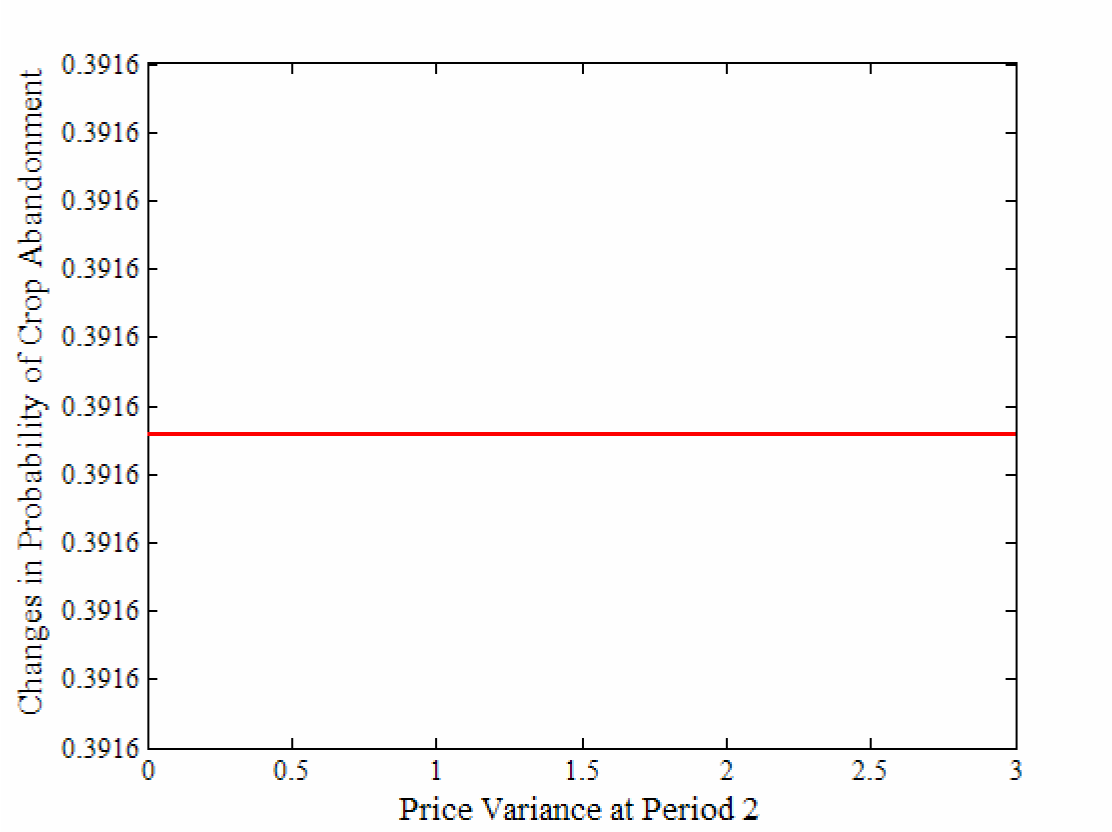

Figure 4: Changes in the probability of crop abandonment vs. price variance at period 2

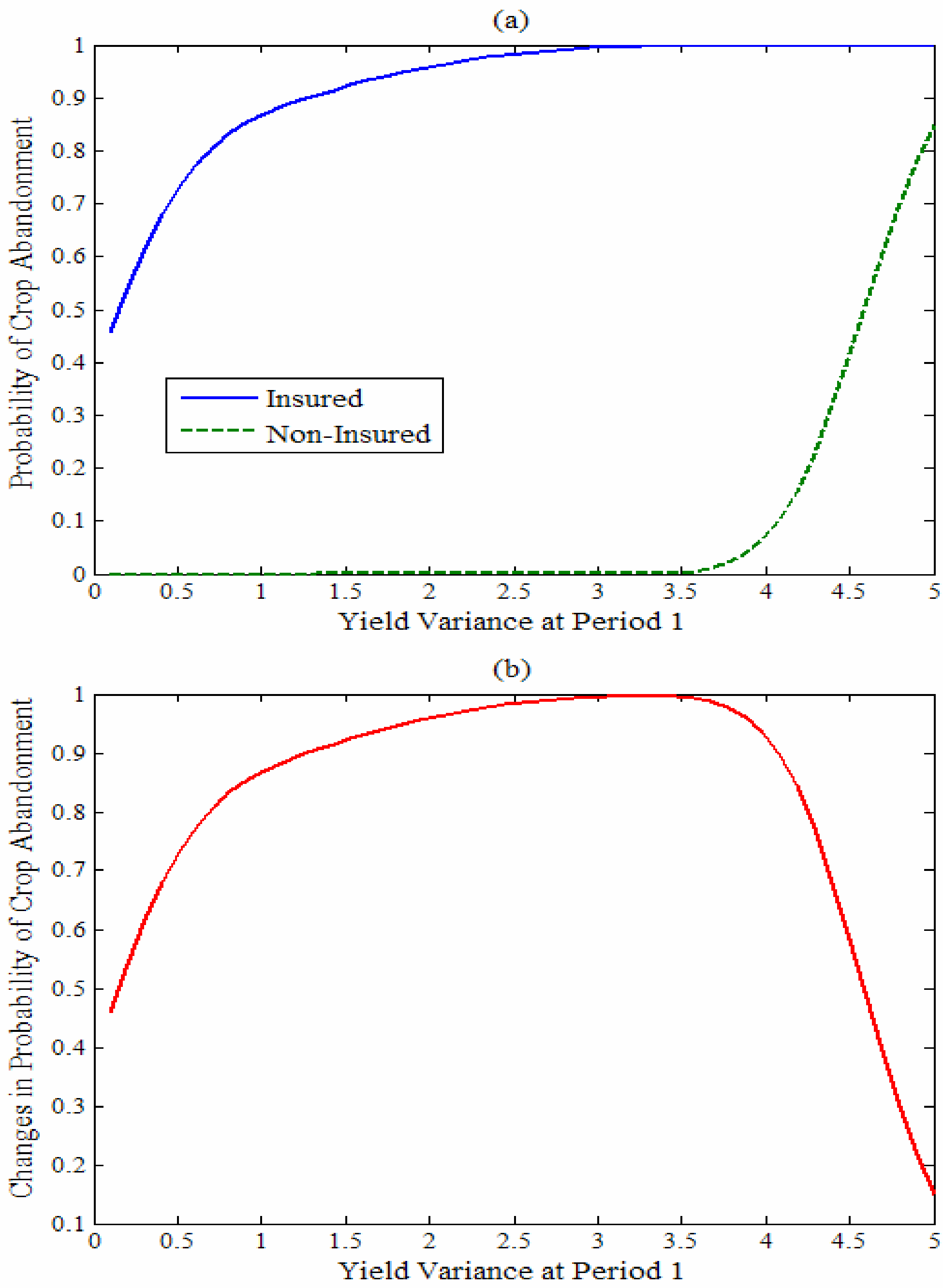

Figure 5: Sensitivity analysis of crop abandonment vs. yield variance at period 1: (a) insured vs. uninsured; (b) changes in the probability of crop abandonment

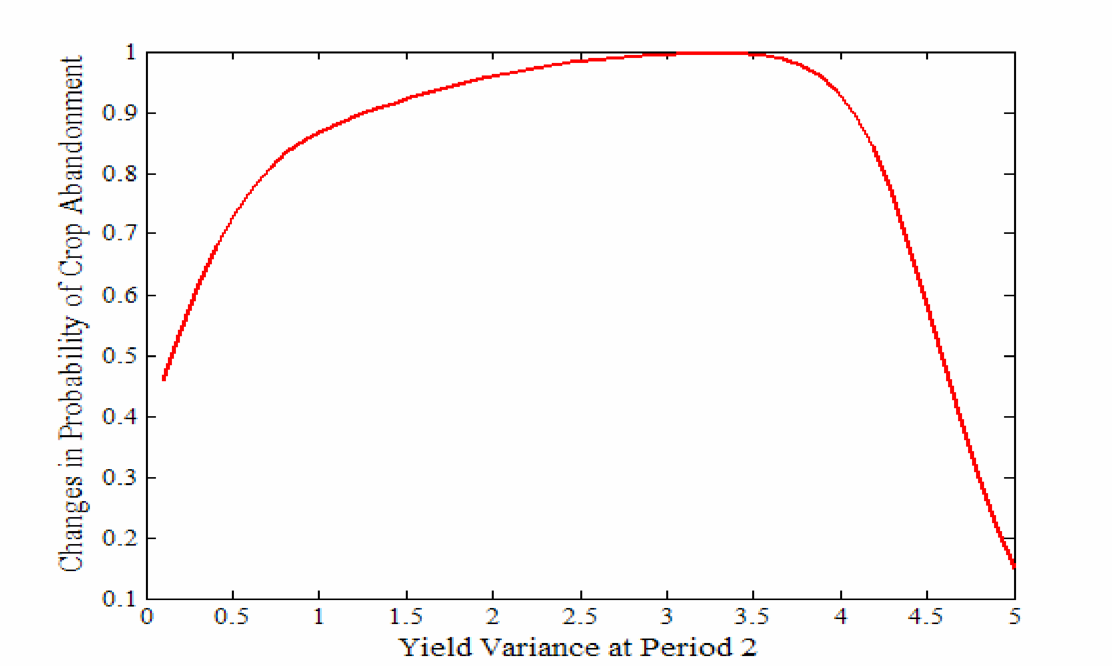

Figure 6: Changes in the probability of crop abandonment vs. yield variance at period 2

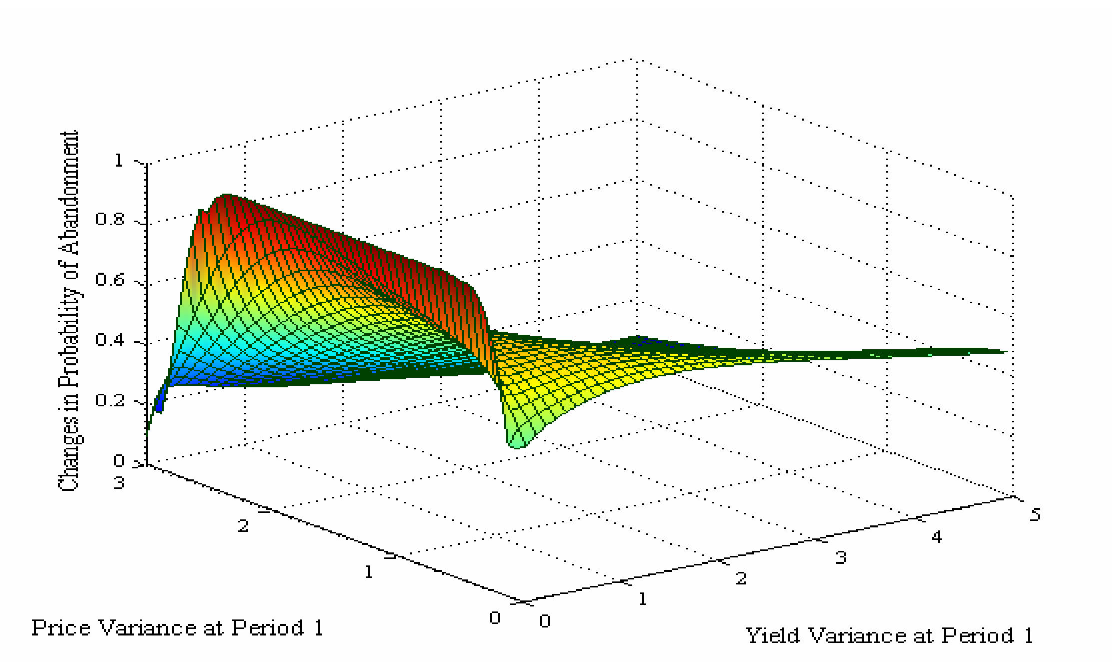

Figure 7: Changes in the probability of crop abandonment vs. joint distribution of yield and price variances at period 1

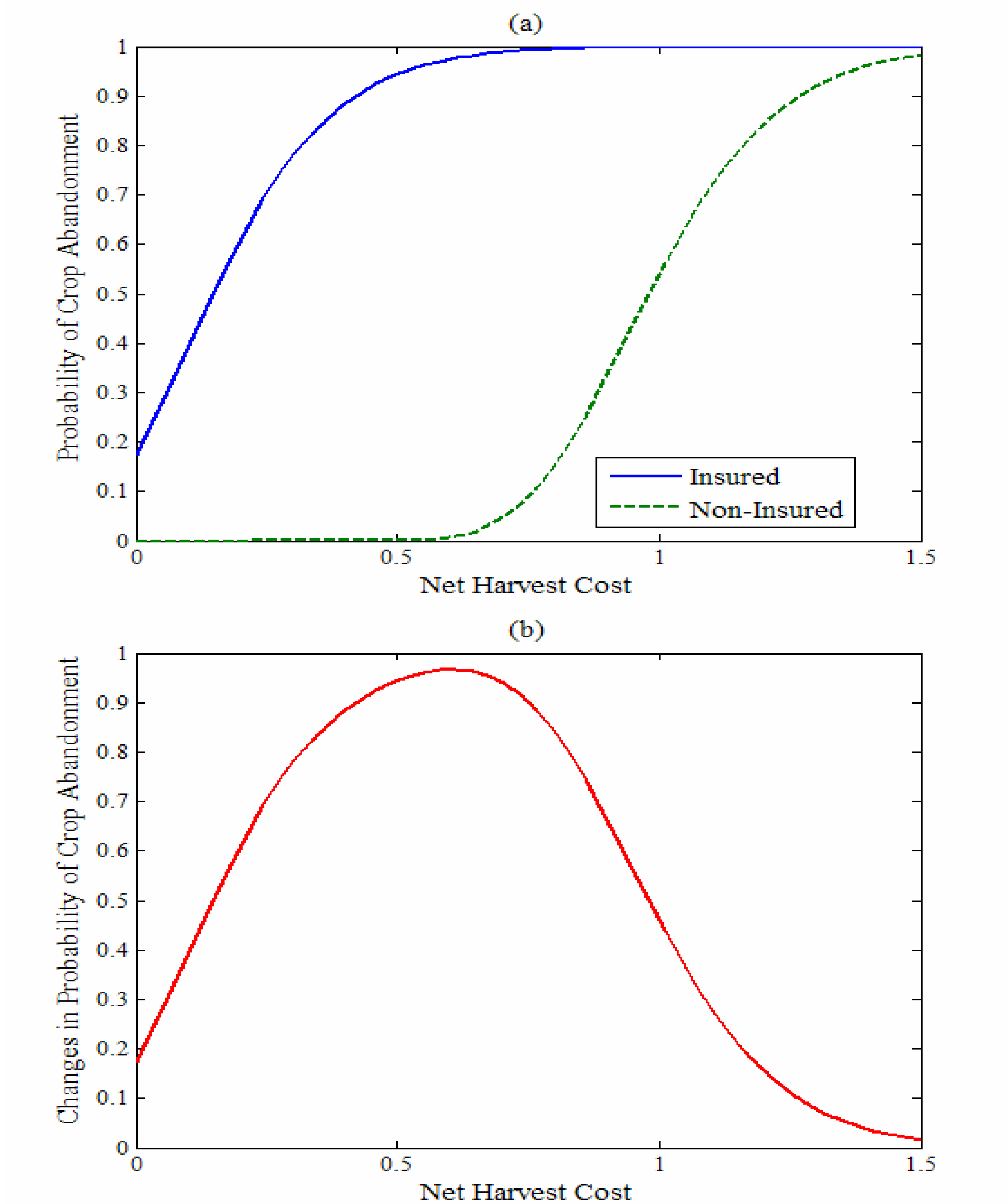

Figure 8: Sensitivity analysis of crop abandonment vs. net harvest cost: (a) insured vs. uninsured; (b) changes in the probability of crop abandonment

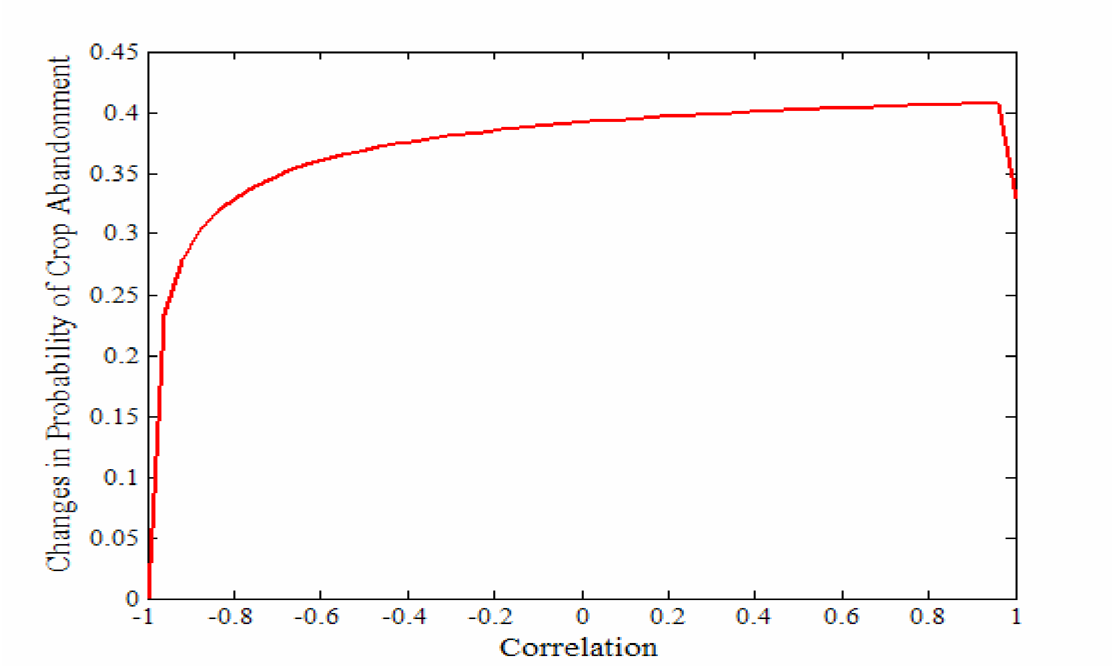

Figure 9: Changes in the probability of crop abandonment vs. correlation

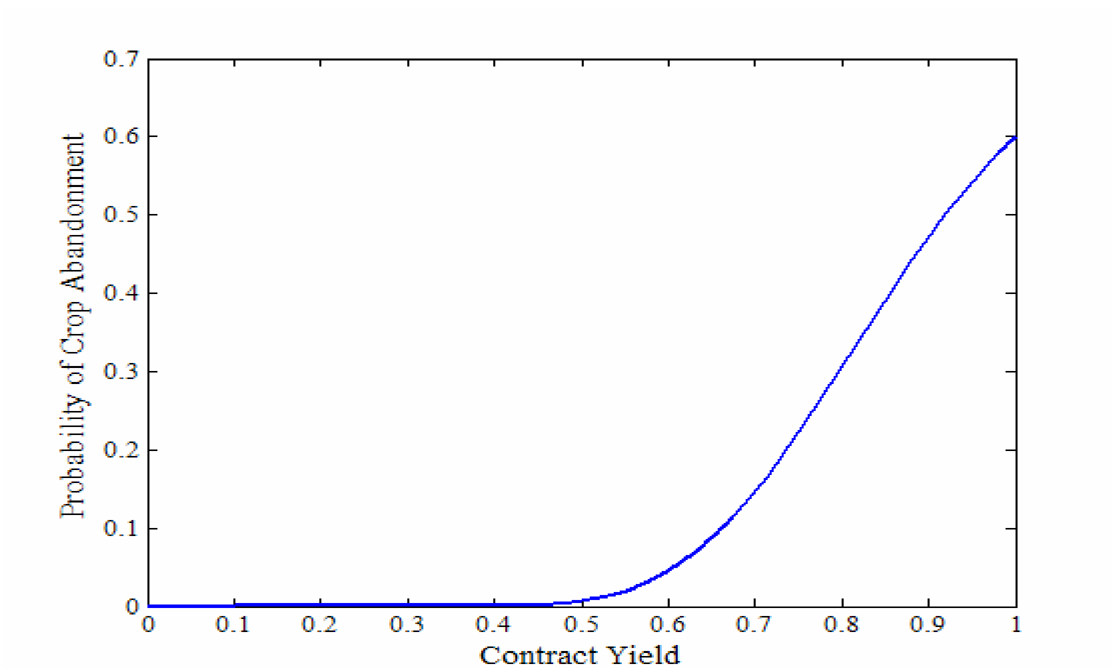

Figure 10: Probability of crop abandonment vs. contract yield

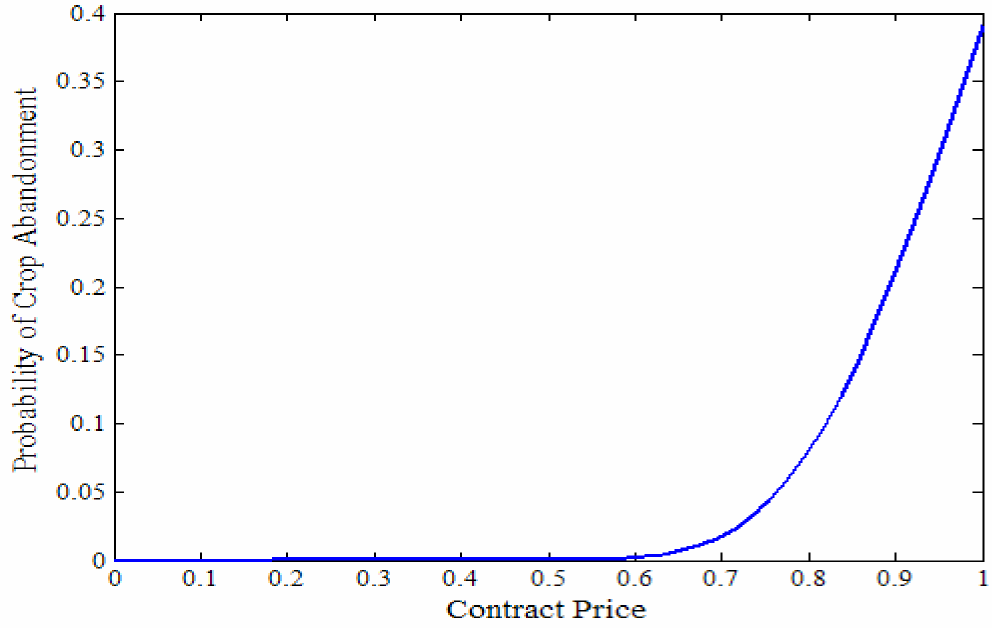

Figure 11: Probability of crop abandonment vs. contract price