Journal of Agricultural and Resource Economics 28(1):116–137

Efficiency Costs of Subsidy Rules for Crop Insurance

H. Holly Wang, Steven D. Hanson, and J. Roy Black

Participation in federal crop insurance programs has been encouraged through premium subsidies. The current subsidy depends on contract features as well as coverage levels. This type of subsidy rule causes farmers to choose contract designs and coverages that are not efficient for managing risk, in order to capture subsidy. Farmers are found to be as well off with a flat subsidy that is up to 25% less than the value of the current regressive proportional subsidy.

Key words: crop insurance, futures, risk management, subsidy

Introduction

Farmer, lender, and congressional interest in the use of alternative instruments to manage income risk has led to a proliferation of federally facilitated insurance products. The development of new insurance products is likely to continue because the Agricultural Risk Protection Act (ARPA) of 2000 provides financial incentives for the development of new private-sector insurance products and increases insurance premium subsidies to encourage higher participation and coverage levels.

Farmers now have a wide array of instruments for managing income risk. Futures, forward contracts, and other derivative pricing contracts allow flexible pricing strategies, while multiple-peril (MP) yield insurance, which triggers payoffs based on individual-farm yield shortfalls, has long been an option to manage yield risk. More recently, area-yield insurance, which triggers payoffs based on county-yield shortfalls, has been made available to many farmers. Revenue insurance is the latest risk-management innovation available to farmers. By providing direct protection against revenue shortfalls, revenue insurance may be easier for farmers to use and may offer better risk protection than existing price and yield management contracts. Revenue insurance, like yield insurance, can potentially feature a variety of designs including indemnification based on an individual-farm index, an area index, or some alternative method to value shortfalls.

In an effort to encourage participation in insurance programs, premiums charged to farmers using federally sponsored insurance products have historically included what was intended to be a "flat" per acre subsidy across insurance products and coverage levels. In practice, the subsidy differed across farmers in different risk classification categories. Recently, the subsidy structure has been modified to a regressive proportional subsidy

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Review coordinated by Gary D. Thompson.

where the subsidy is proportional to the premium charged to farmers but the rate of subsidy declines as the coverage level increases. The available subsidy levels are significantly higher under the new subsidy structure than in the past.

Even in the absence of a subsidy, other factors such as imperfect risk classification and asymmetric information cause farmers to pay premiums that differ from their actuarially fair level. The relationship between the premium charged to the farmer and the actuarially fair premium can be characterized as a "wedge," defined as the ratio of the actual premium to the actuarially fair premium. While the premium wedge can be greater or less than one for any individual farmer, there is evidence showing most farmers face a subsidy-free wedge that is significantly greater than one (Just, Calvin, and Quiggin; Skees; Coble et al.). Both the premium wedge and the subsidy have the potential to alter farmer incentives to use insurance for managing risk.

The primary objectives of this study are: (*a*) to investigate the ability of alternative insurance contracts to manage risk, (*b*) to study the effect of the regressive proportional subsidy on contract choice, and (*c*) to measure the cost to the farmer from bearing additional risk which results from using the portfolio chosen under the regressive proportional subsidy as opposed to a flat subsidy. Performance is measured by a willingness-to-pay measure in an expected utility framework for an individual corn farmer. The farmer is eligible for loan deficiency payments and is allowed to use various portfolios of risk management instruments including combinations of pre-harvest-pricing contracts and yield or revenue insurance. Insurance contracts are included in portfolios under a variety of design specifications to investigate the impact of each design feature on performance.

Modeling is conducted under four cases: (*a*) with and without a pre-subsidy premium wedge, (*b*) with both a flat and regressive proportional subsidy, (*c*) for high and low loan deficiency trigger rates, and (*d*) with zero and negative price-yield correlation. Numerical simulation and optimization methods are used because of the complex nature of the decision problem.

Previous Studies

Programs currently administered by the U.S. Department of Agriculture's (USDA's) Risk Management Agency (RMA) have provided crop insurance to farmers since 1938. The design of insurance contracts offered to farmers has evolved over time in an effort to increase participation and address problems related to moral hazard, adverse selection, and administrative costs (Skees; Skees and Barnett; Skees, Black, and Barnett). As a result, farmers currently have a wide variety of crop insurance contracts for use in conjunction with other pricing contracts to manage income risk. These insurance contracts permit insuring yields or revenues where indemnification is based on individual or area indices. In addition, for each insurance contract, the indemnity can effectively be priced using *replacement price coverage*, which is the greater of the realized harvest futures price and the pre-plant harvest futures price. Most of the available crop insurance contracts have been studied to some extent in previous work.

Miranda explored insurance indemnification based on area-yield indices and found the lower transaction costs associated with area-yield insurance, in combination with potentially higher coverage levels, could allow better risk protection than individual-yield insurance for many farmers. In a study of the optimal design of area-yield insurance contracts, Mahul concluded optimal contract design depends on the sensitivity of farm yield to area yield. The implications of combining insurance with other risk management contracts in a farmer's portfolio are not addressed in these studies. The simultaneous use of yield insurance and futures contracts is considered by Myers. While these studies provide helpful insights into the use of insurance contracts in a portfolio setting, they are limited by restrictive assumptions on price and yield distributions, farmer preferences, and contract designs.

The impacts of alternative yield insurance designs on portfolio choice and welfare were investigated by Wang et al. for an individual corn farmer. Futures, options, and yield insurance were considered in various combinations in the farmer's risk management portfolio. Their findings indicate area-yield insurance can perform nearly as well as, or better than, individual-yield insurance. The performance of individual-yield relative to area-yield insurance was found to be sensitive to the premium wedge on individual-yield insurance as well as the incorporation of pricing contracts in the portfolio. Revenue insurance was not considered in the above studies.

Incorporating recent developments in the theory of insurance under incomplete markets, Mahul and Wright evaluated the optimal design of revenue insurance. Based on their results, if the indemnity schedule depends only on individual yield and price, and the revenue insurance contract is unrestricted and actuarially fair, crop yield insurance and price hedging instruments are redundant to the optimally designed revenue insurance contract. However, Mahul and Wright also found that if coverage levels are restricted or insurance instruments are not priced actuarially fair, then separate contracts for yield and price risk may play a key role even if some form of revenue insurance is available. In practice, revenue coverage levels are restricted and the premiums charged to individual farmers are seldom actuarially fair—leaving unanswered questions regarding the role of revenue insurance as a risk management tool.

A number of studies have begun to address the role of revenue insurance and its ability to manage risk under imperfect market conditions. A stylized model was employed by Poitras to examine the simultaneous use of futures and revenue insurance. Heifner and Coble assessed the performance of alternative insurance contract designs for representative farms. Individual insurance contracts, including a form of individual-revenue insurance, were evaluated in portfolios with and without replacement price coverage. Revenue insurance was found to outperform yield insurance when no pre-harvest pricing was used. However, when pre-harvest pricing is included in the portfolio, yield insurance becomes competitive with revenue insurance. Heifner and Coble's study assumes fixed coverage levels and that all farmers pay an actuarially fair premium and receive a flat subsidy; area insurance designs are not considered.

In a recent study, Coble, Heifner, and Zuniga examined the optimal futures hedge and put hedge when individual-revenue and individual-yield insurance are available. Numerical methods were used to quantify price hedging ratios for different insurance contract designs and coverage levels. The results show a positive relationship between the price hedging ratios and the use of yield insurance. Further, replacement pricing was also found to be complementary to hedging, and individual revenue insurance emerged as a strong substitute for hedging, especially at high coverage levels.

Hennessy, Babcock, and Hayes compared the efficiency of revenue insurance versus combinations of price and yield insurance. Their findings reveal revenue insurance is less costly than price and yield insurance. Similarly, area-index revenue insurance is found to be less costly than individual-index revenue insurance. The results also show a revenue insurance can significantly reduce government outlays relative to the 1990 farm program mix. Revenue insurance was found to increase the efficiency of income redistribution because it only provides protection when needed. The role of futures contracts and replacement pricing are not addressed in the analysis.

Premium Wedges

Each of the foregoing studies on revenue insurance assumes the insurance premium is actuarially fair or that the farmer pays the fair premium and receives a flat subsidy. In practice, the subsidy has varied across farmers in different risk classification categories. Beginning in 2001 with ARPA, the subsidy is set proportional to the premium, and the subsidy proportion decreases as the coverage level increases. In addition, even in the absence of a subsidy, farmers may face a premium that is not actuarially fair because of factors such as asymmetric information and imperfect risk classification. For example, RMA reinsurance policies require all farmers in a given location and risk class be charged the same premium, which may result in a difference between the premium paid by the farmer and the farmer's actuarially fair premium. RMA allows insurance providers to reclassify farmers for reinsurance purposes only, suggesting both RMA and the insurance providers recognize these pre-subsidy wedges exist and can vary significantly across farmers.

The wedge faced by any farmer can be less than one, where the farmer's premium is below the actuarially fair premium, or greater than one, where the farmer's premium is above the actuarially fair premium.[1] For example, a farmer in a given risk class with relatively high (low) risk might face a wedge that is less (greater) than one. Just, Calvin, and Quiggin decompose farmer incentives to participate in crop insurance programs into risk, subsidy, and asymmetric information incentives. Using a national farm-level database for corn and soybeans, they found the asymmetric information incentive is almost always negative, showing, in the absence of subsidies, the majority of farmers pay a premium well above their actuarially fair level. Hypothesizing one reason for this finding, the authors note that yields used to calculate insurance premiums have been well below farmers' actual yields, resulting in an upward bias in farmers' insurance premiums. Furthermore, without subsidies, no farmers would view crop yield insurance desirable for risk management. In a recent investigation of crop insurance reform, Skees reports, despite federal subsidies, farmers using individual-insurance products often pay premiums above the actuarially fair level because the current risk classification approach is imperfect.

Farmers who pay a premium above their actuarially fair price will have less incentive to transfer risk through insurance. The regressive proportional subsidy faced by farmers can increase incentives to use insurance but also increase the likelihood of farmers choosing insurance strategies that are not the most efficient means of managing risk.[2] For example, the regressive feature of the current subsidy may affect the optimal coverage level as farmers attempt to capture subsidy income. In addition, because the subsidy

[1] Risk-averse farmers might be willing to pay a premium above the actuarially fair level if the insurance instrument provides sufficient risk protection.

[2] Efficient risk management refers to the portfolio of risk management instruments which maximizes expected utility in the absence of any subsidy distortions. When the efficient risk management portfolio is altered in an effort to capture subsidy income, the portfolio under subsidy is termed a "less efficient" means of managing risk, because if the subsidy is removed, that portfolio would produce a lower level of expected utility than the efficient risk management portfolio.

level differs across insurance contracts, farmers may choose contracts that provide higher levels of subsidy income but offer less risk protection.

This study extends previous work by further examining the risk management ability of alternative insurance contracts and the effects of premium wedges. However, the primary focus of this analysis is to examine the impact of the regressive proportional subsidy on optimal insurance contract choice and risk management.

The Model

The decision problem is characterized by an individual farmer who is assumed to choose a portfolio of risk management instruments prior to planting that maximizes expected utility of wealth at harvest. Choices are modeled in a two-period context. Prior to planting, the farmer forms an estimate of the conditional joint distribution of harvest prices and yields. Prices and yields are then realized at harvest, and profit is determined. Prior to planting, the farmer chooses the portfolio of risk management instruments, $\mathbf{x}$, that maximize the expected utility of wealth:

$$\max_{\mathbf{x}} \int_0^\infty \int_0^\infty u[w + \pi(\mathbf{p}, \mathbf{y}, \mathbf{x})] g(\mathbf{p}, \mathbf{y} \mid \Omega)\, d\mathbf{p}\, d\mathbf{y}, \tag{1}$$

where $u(\cdot)$ is an increasing and concave von Neumann-Morgenstern utility function, w is the initial wealth level per acre, $\pi(\cdot)$ is the profit per acre, and $g(\cdot \mid \Omega)$ is the joint density for harvest prices and yields conditional on Ω, the set of information available when the portfolio is selected prior to planting.[3] The random price vector $\mathbf{p}$ consists of cash and futures prices for corn at harvest, as well as the prices used to indemnify the alternative insurance instruments. The random yield vector $\mathbf{y}$ contains the farmer's individual yield at harvest and the yield indices used to indemnify the alternative insurance instruments. Constant relative risk aversion is assumed where $u(w + \pi) = (1 - \theta)^{-1}(w + \pi)^{1-\theta}$, and the constant relative risk-aversion parameter is set at $\theta = 2$.[4]

The profit function consists of up to five components:

$$\pi(\mathbf{p}, \mathbf{y}, \mathbf{x}) = NP + PHP + YI + RI + LDP, \tag{2}$$

where

$$\begin{aligned}
NP &= py - c(y); \\
PHP &= h(f_0 - f) - hg; \\
YI &= s_c p_c \max[0, x_c E(y_c) - y_c] - \lambda_c(x_c) a_c[s_c, x_c, p_c, E(y_c)]; \\
RI &= s_r \max[0, x_r p_r E(y_r) - f y_r] - \lambda_r(x_r) a_r[s_r, x_r, p_r, E(y_r), f_0]; \text{ and} \\
LDP &= E(y) \max[0, dE(p) - p].^5
\end{aligned}$$

[3] Profits and wealth are expressed on a per acre basis. The results can be extended to the whole farm by multiplying by the number of acres.

[4] The relative risk-aversion parameter of 2.0 falls within the range estimated in studies by Antle; Arrow; Binswanger; Hamal and Anderson; and Myers.

[5] For any value z, the operator $\max[0, z]$ chooses the maximum of zero or z.

The profit function in (2) contains stylized versions of the major types of risk management instruments now available to U.S. farmers. The choice vector $\mathbf{x} = (h, x_c, x_r, s_c, s_r)$ consists of decisions surrounding the amount of futures to trade and the amount of insurance to purchase. It is assumed decisions are made simultaneously in a portfolio setting given the known parameters and probability distributions.

The *NP* component is the net profit from producing and selling corn without using any risk management instruments. Therefore p is the local cash price at harvest, y is the farmer's yield at harvest, and $c(\cdot)$ is production cost.[6] The *PHP* component is the net return from pre-harvest pricing. Here, h is the amount of futures contracts sold (purchased if negative) prior to planting, f_0 is the initial futures price when h is selected, f is the futures price at harvest, and g is the transaction costs per unit of futures contracts bought or sold.[7]

The *YI* and *RI* components are net returns from using yield insurance and revenue insurance, respectively. When using individual-index insurance, the farmer is required to insure all planted acres; thus, the acreage scaling factors for both yield and revenue insurance (s_c and s_r, respectively) are restricted to equal one. If the farmer elects to use area insurance, the amount of insurance per acre can be adjusted by selecting acreage scaling factors that differ from one, allowing the farmer to effectively cross-hedge with area insurance.

In the *YI* component, the term p_c is the price used to indemnify the yield shortfalls for the chosen insurance contract; y_c is the yield index, which may or may not be the farmer's actual yield, used to determine yield shortfalls; $E(y_c)$ is the expected value at planting of the yield index; x_c is the proportion of expected yield index that will trigger indemnification; and $a_c(\cdot)$ is the actuarially fair yield insurance premium. The wedge (λ_c), which may vary across coverage levels, is used to adjust the insurance premium if it differs from the actuarially fair premium because of a subsidy or other factors.[8] The price index (p_c) could be set at the initial futures price, the realized futures price, or some other notion of expected price. For contracts with replacement price coverage, $p_c = \max(f, f_0)$. The random yield index y_c could reflect the farmer's actual yield level as in the multiple-peril (MP) contract, or some area-yield index as in the Group Risk Plan (GRP) contract.

The *RI* component is the net return from using revenue insurance. Here, p_r is the price index used to determine the trigger revenue, y_r is the yield index, $E(y_r)$ is the expected value at planting of the yield index, and x_r is the proportion of expected revenue that will trigger indemnification. Using the farmer's yield as the yield index results in individual-revenue insurance as in the Income Protection (IP) contract, while using an area-yield index produces area-revenue insurance as in the Group Risk Income Protection (GRIP) contract. Replacement price coverage sets $p_r = \max(f, f_0)$ as in the yield insurance case. The actuarially fair revenue insurance premium is $a_r(\cdot)$, and the wedge λ_r, which may vary across coverage levels, is used to adjust the insurance premium if it differs from the actuarially fair premium because of a subsidy or other factors.

[6] The farmer's yield at harvest is exogenous in the sense that all production decisions are assumed to be fixed at planting.

[7] Commodity options were also included as a pre-harvest pricing instrument. Consistent with Wang et al., and Heifner and Coble, adding options to portfolios containing futures and insurance sometimes results in complex hedging positions, but adds little value in terms of risk management. In the interest of space, we report only the results for pre-harvest pricing with futures.

[8] The premium charged to a farmer almost always differs from the actuarially fair premium because of asymmetric information, risk class pooling, or subsidies. In this study, we characterize these effects by making the appropriate proportional adjustment to the farmer's actuarially fair premium.

Finally, the *LDP* component is the return from the loan deficiency payment. The term d designates the trigger price as a proportion of expected cash price. It is assumed there is no premium charged to the farmer and no "set-aside" requirement to participate, so the *LDP* is essentially a free put option on the cash price where the exercise price is $dE(p)$.

Model Parameterization

As a starting point, we use the joint price-yield generating process at harvest conditional on information available at planting, estimated by Wang et al., for an individual farmer in southwest Iowa for the 1994–95 crop year. The model is calibrated using a bivariate ARCH model with seasonality to estimate the price-generating process for harvest prices (Engle; Fackler). Weekly cash prices for the southwestern Crop Reporting District in Iowa and weekly Chicago Board of Trade futures settlement prices are used to parameterize the model.

An inverse hyperbolic sine function is then used to estimate the yield-generating process at the county level (Moss and Shonkwiler). Individual farm yield data were available for only 10 years, making it difficult to estimate yield distributions for individual farms with the desired level of precision. As a result, farm-level yield distributions are generated by employing the central tendency and variance from farm-level data to rescale the county-level yield distribution. Correlation between harvest prices and yields is imposed according to the normal transformation procedure proposed by Taylor. There is no closed-form solution for the conditional joint price-yield distribution at planting, and so a discrete estimate of the joint distribution is generated using stochastic simulation (Myers and Hanson). The frequency distribution of the simulated harvest prices and yields is then used as an estimate of the joint distribution of prices and yields at harvest, conditional on information available at planting.

There is evidence suggesting the simulated harvest distribution is reflective of a historically low price risk environment. The coefficient of variation for futures prices in the simulated distribution was about 15%, while Coble and Heifner found a typical range of 18% to 20% for the coefficient of variation of futures prices for corn. In this study, the joint price-yield distribution is generated using the Wang et al. approach, but proportionally increasing the ARCH parameters by 140%, thereby shifting the scale of the distribution but retaining the original mean levels. This procedure produces a coefficient of variation for futures prices of around 20%. A corresponding joint distribution was simulated with zero price-yield correlation. Analyzing the performance of alternative insurance instruments based on each simulated distribution allows results to be generalized across different risk environments. Table 1 shows the sample moments and correlations for the simulated distributions.

The remaining parameters were selected to be representative of farmers in southwest Iowa during the mid-1990s. The initial wealth term, reflecting equity claims to such assets as land and machinery used in the farming operation, is set at \$500 per acre (consistent with both Jolly and Olson). Production cost, adapted from Jolly and from Olson, is specified as $\$2.18(E[y \mid \Omega]) + \$0.17y$, where $E[y \mid \Omega]$ is the expected yield conditional on information at planting. The first term in the cost function reflects the costs of planting, applying fertilizer and chemicals, and other incurred fixed costs in the production process. The second term reflects uncertain variable costs which depend on

Table 1. Sample Moments and Correlations for Simulated Distributions for a Corn Farmer in Southwest Iowa

	Sample Moments				Sample Correlation			
Variable	Mean	Standard Deviation	Skewness	Kurtosis	Futures Price	Cash Price	County Yield	Farm Yield
	NEGATIVE PRICE-YIELD CORRELATION							
Futures Price	$2.56	$0.49	0.41	3.10	1.00	0.85	-0.40	-0.33
Cash Price	$2.48	$0.51	0.50	3.45		1.00	-0.46	-0.38
County Yield	117.5 bu/ac	30.40 bu/ac	-1.20	4.07			1.00	0.83
Farm Yield	117.5 bu/ac	36.48 bu/ac	-0.97	3.28				1.00
Revenue	$284.63	$92.94	-0.32	3.22				
	ZERO PRICE-YIELD CORRELATION							
Futures Price	$2.56	$0.49	0.41	3.10	1.00	0.85	0.00	0.05
Cash Price	$2.48	$0.51	0.50	3.45		1.00	0.01	0.03
County Yield	117.5 bu/ac	30.40 bu/ac	-1.20	4.07			1.00	0.83
Farm Yield	117.5 bu/ac	36.48 bu/ac	-0.97	3.28				1.00
Revenue	$292.43	$109.38	-0.15	2.84				

Notes: Sample correlations between prices and yields for the case of zero price-yield differ from zero as a result of sampling error. The data used to generate the simulated distributions are described in Wang et al.

realized harvest levels, such as combining costs, grain drying, and transportation costs from the field to the point of sale. Futures prices are restricted to be unbiased in the sense that expected gains from trading are zero, so the futures price at planting is set equal to expected future price at harvest conditional on information available at planting. The transaction costs associated with using futures (brokerage costs, etc.) are set at $0.015 per bushel. Finally, the trigger for the loan deficiency payment is set both at the expected cash price ($d = 1.0$) and below the expected cash price ($d = 0.75$) in order to evaluate the effect of different levels of price support.

In practice, coverage levels are restricted by the Risk Management Agency. To reflect these restrictions, coverage for individual-index insurance is allowed to be no more than 85% of expected index value, and the number of acres for which insurance is purchased (scaled acres) is restricted to 100% of planted acres, which approximates the levels used by RMA to reduce exposure to potential moral hazard problems. Coverage for area-index insurance in the restricted cases is set at no more than 90% of the expected index value, which also reflects RMA policy. However, if the subsidy does not change as coverage increases beyond 90% of the expected index value, the area-insurance restriction could be set higher because area-based instruments eliminate moral hazard and adverse selection problems associated with individual-index insurance. For similar reasons, there is no need to restrict area insurance scaled acres under a flat subsidy. However, under the regressive subsidy, scaled acres for area insurance need to be restricted in order to avoid incentives to capture large amounts of subsidy. Under the regressive subsidy, area insurance is evaluated with scaled acres restricted to be no more than 150% of planted acres, reflecting current RMA policy.

Actuarially fair insurance premiums are set equal to the expected insurance payout. However, imperfect risk classification, asymmetric information, and transaction costs typically cause farmers using individual-index insurance to pay premiums that differ from actuarially fair levels. Black and Hu estimated the wedge for the median Iowa corn farmer purchasing crop insurance during a 10-year period from 1985 to 1995 to be about

Table 2. Regressive Proportional Subsidy Rates

Coverage Level in Proportion to Expected Index Value	Subsidy Amount in Proportion to Actuarially Fair Premium: Individual Insurance	Subsidy Amount in Proportion to Actuarially Fair Premium: Area Insurance
50%	67%	—
55%	64%	—
60%	64%	—
65%	59%	67%
70%	59%	64%
75%	55%	64%
80%	48%	59%
85%	38%	59%
90%	—	55%

Source: Agricultural Risk Protection Act of 2000.

1.3. To gain insights into the impacts of the premium wedge faced by farmers, individual-index products are analyzed at two possible pre-subsidy premium levels: (*a*) an actuarially fair premium, and (*b*) a premium 30% above the actuarially fair level.

We did also examine a number of other wedge levels. The insurance value to the farmer naturally increases for pre-subsidy premiums below the actuarially fair level because of the income effect. However, the insurance and futures positions chosen by the farmer are very similar to the case of an actuarially fair pre-subsidy premium because the farmer is at, or near, the maximum insurance coverage levels in both cases. For other wedges where the premium is above the actuarially fair pre-subsidy premium, both the insurance and futures positions and the insurance value to the farmer change, but the basic results remain the same, in a relative sense, as for the 1.3 pre-subsidy premium wedge case reported by Black and Hu.

Area-index insurance is characterized by low transaction costs, and all farmers face the same area-index distribution. Therefore, if adequate data are available to estimate the area-index distribution, pre-subsidy premiums should always be near actuarially fair. Consequently, we consider only the case of an actuarially fair pre-subsidy premium when the farmer uses area-index insurance products.

The flat subsidy to the farmer is set at 55% of the actuarially fair premium for a 50% coverage individual-yield insurance contract, which is consistent with previous RMA policy. The subsidy is the same for all insurance products. Under current RMA policy, the subsidy, as a proportion of the insurance premium, differs by coverage level and contract type (individual versus area), as shown in table 2. A polynomial function is fit to each subsidy schedule and then used to represent the subsidy function available to the farmer when adopting individual or area insurance.

Numerical Results

To evaluate the performance of the alternative contract designs and portfolios of risk management instruments, the decision problem in (1) is solved, subject to constraints on coverage and acreage scaling, using the numerical secant method of Broyden, Fletcher, Goldfarb, and Shanno in the OPTMUM module of GAUSS (Aptech Systems, Inc.).[9] We evaluate the performance of six portfolios, each including a loan deficiency program: (*a*) individual-yield insurance with futures, (*b*) area-yield insurance with futures, (*c*) individual-revenue insurance, (*d*) area-revenue insurance, (*e*) individual-revenue insurance with futures, and (*f*) area-revenue insurance with futures.

The performance of the alternative risk management portfolios is evaluated using a "willingness-to-pay" measure, defined as how much certain income must be added to the farmer's income stream in a portfolio with no risk management instruments to generate the same level of expected utility achieved with optimal use of the risk management instruments available in the portfolio. The focus of the discussion is on the relative risk management performance of the different insurance contracts under the current regressive proportional subsidy as opposed to a flat subsidy. For completeness, the optimal futures, insurance coverage, and insured acreage hedge ratios are also shown for each portfolio.

Tables 3 and 4 respectively show the optimal hedge ratios and willingness-to-pay values for the flat subsidy without and with replacement pricing for the six alternative risk management portfolios under various conditions the farmer might face. Likewise, tables 5 and 6 respectively show the optimal hedge ratios and willingness-to-pay values for a regressive proportional subsidy without and with replacement pricing for the same risk management portfolios and conditions. These results provide important insights into performance of different portfolios, subsidy structures, and contract designs.

Insurance Contract Choice Under a Flat Subsidy

We start by examining the results for a flat subsidy where the farmer receives the same subsidy across policies and coverage levels. The flat subsidy transferred to the farmer was $2.78 per acre regardless of the type of insurance contract used. Because the flat subsidy is the same for all contracts, it simply provides a wealth effect to the farmer. The flat subsidy causes almost no change in the optimal hedge ratios or the relative performance of the insurance instruments when compared to the case where no subsidy is received.[10] Therefore, examining performance under the flat subsidy permits important insights into the risk management ability of different contract designs.

Insurance Under a Flat Subsidy Without Replacement Pricing

The ability of revenue insurance to substitute for futures and yield insurance when insurance contracts are designed without replacement pricing is first examined. An obvious result from table 3 is that the risk environment faced by the farmer affects the performance of each portfolio. Negative price-yield correlation decreases the value of each portfolio because the "natural hedge" associated with the tendency of price and yield to move in opposite directions causes some stabilization in income and reduces the incentive to eliminate price and yield risks. The impact of the risk environment on the

[9] Because the utility function is strictly concave, the second-order conditions are satisfied.

[10] Because the flat subsidy has only a wealth effect, we do not report the results for the zero subsidy case in interest of space. At the level of precision reported in the tables, the only difference between the results is that the WTP for the flat subsidy portfolios is between $2.68 and $2.76 higher than for the portfolios with no subsidy.

Table 3. Hedge Ratios and Willingness to Pay with Flat Subsidy and Without Replacement Price Coverage

	Unrestricted Coverage				Restricted Coverage			
Description	Futures	Coverage	Scaled Acres	WTP	Futures	Coverage	Scaled Acres	WTP
	<---------------- ZERO PRICE-YIELD CORRELATION ---------------->							
ACTUARIALLY FAIR								
LDP Trigger = 0.75:								
▸ IY with Futures					0.62	0.85	1.00	$19.33
▸ IR					—	0.85	1.00	$18.26
▸ IR with Futures					0.39	0.85	1.00	$19.17
▸ AY with Futures	0.71	max	0.92	$19.34	0.70	0.90	1.26	$16.27
▸ AR	—	max	0.89	$20.79	—	0.90	1.34	$15.68
▸ AR with Futures	0.00	max	0.89	$20.79	0.34	0.90	1.24	$16.33
LDP Trigger = 1.0:								
▸ IY with Futures					0.30	0.85	1.00	$40.24
▸ IR					—	0.85	1.00	$40.20
▸ IR with Futures					0.06	0.85	1.00	$40.22
▸ AY with Futures	0.39	max	1.00	$40.42	0.41	0.90	1.37	$36.84
▸ AR	—	max	0.84	$40.36	—	0.90	1.36	$37.16
▸ AR with Futures	0.19	max	0.90	$40.50	0.00	0.90	1.36	$37.16
ACTUARIALLY UNFAIR								
LDP Trigger = 0.75:								
▸ IY with Futures					0.61	0.77	1.00	$13.06
▸ IR					—	0.76	1.00	$11.18
▸ IR with Futures					0.45	0.72	1.00	$12.41
LDP Trigger = 1.0:								
▸ IY with Futures					0.30	0.81	1.00	$33.75
▸ IR					—	0.76	1.00	$33.06
▸ IR with Futures					0.12	0.75	1.00	$33.14
	<------------- NEGATIVE PRICE-YIELD CORRELATION ------------->							
ACTUARIALLY FAIR								
LDP Trigger = 0.75:								
▸ IY with Futures					0.33	0.85	1.00	$15.93
▸ IR					—	0.85	1.00	$15.85
▸ IR with Futures					0.11	0.85	1.00	$15.92
▸ AY with Futures	0.47	max	0.84	$13.52	0.31	0.90	1.15	$11.81
▸ AR	—	1.61	0.79	$14.52	—	0.90	1.17	$11.98
▸ AR with Futures	-0.03	1.61	0.79	$14.53	0.02	0.90	1.17	$12.01
LDP Trigger = 1.0:								
▸ IY with Futures					0.00	0.85	1.00	$39.57
▸ IR					—	0.85	1.00	$39.37
▸ IR with Futures					0.00	0.85	1.00	$39.37
▸ AY with Futures	0.15	max	0.93	$38.16	0.00	0.90	1.24	$35.45
▸ AR	—	1.58	0.77	$36.46	—	0.90	1.28	$35.22
▸ AR with Futures	-0.40	1.76	0.85	$37.35	0.06	0.90	1.28	$35.24
ACTUARIALLY UNFAIR								
LDP Trigger = 0.75:								
▸ IY with Futures					0.24	0.72	1.00	$9.86
▸ IR					—	0.72	1.00	$9.85
▸ IR with Futures					0.08	0.72	1.00	$9.91
LDP Trigger = 1.0:								
▸ IY with Futures					0.00	0.77	1.00	$33.23
▸ IR					—	0.76	1.00	$33.10
▸ IR with Futures					0.00	0.76	1.00	$33.10

Notes: Abbreviations and acronyms are defined as follows: WTP = willingness to pay, IY = individual-yield insurance, IR = individual-revenue insurance, AY = area-yield insurance, AR = area-revenue insurance, LDP = loan deficiency payment, and max = maximum possible coverage (zero deductible). The maximum index value as a proportion of the expected index value for the zero (negative) price-yield correlation case is 1.43 (1.43) for IY insurance, 1.34 (1.34) for AY insurance, 1.97 (1.90) for IR insurance, and 1.87 (1.79) for AR insurance. Actuarially fair and unfair refer to the pre-subsidy premium levels.

performance of each portfolio also depends on coverage restrictions, insured acreage restrictions, and the size of any premium wedge faced by the farmer. Restricting insurance coverage levels or increasing the premium wedge reduces the value of each portfolio.

If the value of a portfolio of individual-yield insurance and futures is compared to individual-revenue insurance, a combination of yield insurance and futures always outperforms revenue insurance by itself under contract restrictions. When revenue insurance coverage is restricted, the farmer faces unprotected price and yield risk even when taking the maximum allowed coverage. In contrast to direct individual-revenue insurance, the use of futures—which are not restricted in terms of hedging position or trigger price—in portfolios with individual-yield insurance allows the farmer to adjust the amount of price protection to better manage risk. The results are mixed for area insurance, with direct area-revenue insurance sometimes outperforming area-yield insurance and futures. If the farmer uses both revenue insurance and futures in a portfolio, the performance improves compared to revenue insurance by itself. However, individual-yield insurance and futures can still outperform individual-revenue insurance and futures.

Under current contract restrictions, the preferred indemnification index (individual versus area) depends on the premium wedge faced by the farmer when using individual insurance. When the coverage restrictions are in place, portfolios with area insurance outperform portfolios with individual insurance when the farmer faces the 1.3 pre-subsidy premium wedge (30% above the actuarially fair level) on individual insurance. Here the less restrictive, lower-cost, area design more than offsets the associated index basis risk. However, when the farmer faces the 1.0 pre-subsidy actuarially fair wedge, portfolios with individual insurance outperform portfolios with area insurance. The benefits of the area design are not enough to offset the additional basis risk. These results are consistent for both revenue and yield insurance under current coverage restrictions.

As discussed previously, the use of area insurance eliminates the majority of moral hazard, adverse selection, and transaction costs problems that hinder individual insurance. Because of its advantages, area insurance can potentially be offered to farmers under a flat subsidy with fewer restrictions and at a relatively lower cost than individual insurance. If the "ad hoc" area coverage restriction is removed, the additional flexibility improves the performance of portfolios with area insurance. Nevertheless, portfolios of individual insurance and futures may still outperform unrestricted area insurance and futures.

The results show, with a flat (or zero) subsidy and without replacement pricing, the preferred portfolio under current coverage restrictions is individual-yield insurance and futures whenever the farmer pays an actuarially fair pre-subsidy premium. When the farmer faces the 1.3 pre-subsidy wedge, portfolios containing area insurance are preferred. Relaxing the area-insurance coverage restrictions improves the performance of area insurance enough that it is sometimes preferred to pre-subsidy actuarially fair individual insurance. However, without replacement pricing, revenue insurance is unable to completely substitute for yield insurance in many cases.

Insurance Under a Flat Subsidy with Replacement Pricing

The use of replacement price coverage can significantly change the way each insurance instrument performs in a given portfolio, as seen in table 4. When the farmer faces an actuarially fair pre-subsidy premium, replacement price coverage increases the value of portfolios containing individual insurance, especially individual-revenue insurance.

Table 4. Hedge Ratios and Willingness to Pay with Flat Subsidy and with Replacement Price Coverage

	Unrestricted Coverage				Restricted Coverage			
Description	Futures	Coverage	Scaled Acres	WTP	Futures	Coverage	Scaled Acres	WTP
	<---------------- **ZERO PRICE-YIELD CORRELATION** ---------------->							
ACTUARIALLY FAIR								
LDP Trigger = 0.75:								
▸ IY with Futures					0.67	0.85	1.00	$19.65
▸ IR					—	0.85	1.00	$18.56
▸ IR with Futures					0.54	0.85	1.00	$20.15
▸ AY with Futures	0.85	1.29	0.84	$19.11	0.76	0.90	1.16	$16.27
▸ AR	—	1.23	0.94	$17.98	—	0.90	1.20	$15.24
▸ AR with Futures	0.45	1.24	0.87	$18.97	0.54	0.90	1.13	$16.85
LDP Trigger = 1.0:								
▸ IY with Futures					0.35	0.85	1.00	$40.48
▸ IR					—	0.85	1.00	$40.84
▸ IR with Futures					0.20	0.85	1.00	$41.05
▸ AY with Futures	0.53	1.28	0.91	$39.92	0.46	0.90	1.25	$36.70
▸ AR	—	1.24	0.94	$39.18	—	0.90	1.25	$37.15
▸ AR with Futures	0.11	1.24	0.92	$39.23	0.21	0.90	1.22	$37.39
ACTUARIALLY UNFAIR								
LDP Trigger = 0.75:								
▸ IY with Futures					0.65	0.75	1.00	$13.11
▸ IR					—	0.71	1.00	$10.94
▸ IR with Futures					0.56	0.69	1.00	$12.80
LDP Trigger = 1.0:								
▸ IY with Futures					0.34	0.78	1.00	$33.69
▸ IR					—	0.72	1.00	$33.04
▸ IR with Futures					0.24	0.72	1.00	$33.34
	<-------------- **NEGATIVE PRICE-YIELD CORRELATION** -------------->							
ACTUARIALLY FAIR								
LDP Trigger = 0.75:								
▸ IY with Futures					0.45	0.85	1.00	$16.24
▸ IR					—	0.85	1.00	$16.09
▸ IR with Futures					0.34	0.85	1.00	$16.77
▸ AY with Futures	0.60	1.24	0.74	$13.49	0.35	0.90	0.96	$11.65
▸ AR	—	1.19	0.73	$13.37	—	0.90	0.90	$11.80
▸ AR with Futures	0.22	1.20	0.74	$13.64	0.22	0.90	0.95	$12.12
LDP Trigger = 1.0:								
▸ IY with Futures					0.07	0.85	1.00	$39.69
▸ IR					—	0.85	1.00	$40.34
▸ IR with Futures					0.00	0.85	1.00	$40.34
▸ AY with Futures	0.28	1.28	0.80	$37.57	0.00	0.90	1.01	$35.02
▸ AR	—	1.20	0.80	$36.99	—	0.90	1.03	$35.51
▸ AR with Futures	0.00	1.20	0.80	$36.99	0.00	0.90	1.03	$35.51
ACTUARIALLY UNFAIR								
LDP Trigger = 0.75:								
▸ IY with Futures					0.30	0.68	1.00	$9.72
▸ IR					—	0.63	1.00	$9.48
▸ IR with Futures					0.23	0.65	1.00	$9.80
LDP Trigger = 1.0:								
▸ IY with Futures					0.00	0.71	1.00	$32.85
▸ IR					—	0.69	1.00	$32.92
▸ IR with Futures					0.00	0.69	1.00	$32.92

Notes: Abbreviations and acronyms are defined as follows: WTP = willingness to pay, IY = individual-yield insurance, IR = individual-revenue insurance, AY = area-yield insurance, AR = area-revenue insurance, and LDP = loan deficiency payment. Actuarially fair and unfair refer to the pre-subsidy premium levels.

Replacement pricing helps reduce unprotected income risk resulting from coverage restrictions. However, replacement pricing can significantly reduce the value of portfolios containing area insurance. This is because, in the absence of coverage restrictions and replacement pricing, the farmer is able to choose high area coverage in an effort to reduce income risk. At high coverage levels, replacement pricing can add up-side price risk that increases income risk and consequently decreases the value of the portfolio. The result also holds when coverage is restricted, because the farmer is able to maintain "high coverage" by increasing scaled acreage to substitute for restricted coverage. Negative price-yield correlation and high LDP trigger prices can reduce or eliminate the effect. In contrast, portfolios with restricted area-revenue insurance and futures show gains from using replacement pricing because the combination of replacement pricing and futures can be used to reduce unwanted income risk resulting from the coverage restriction.

Using replacement pricing when the farmer faces the 1.3 pre-subsidy wedge causes a larger income decline because replacement pricing increases the size of the actuarially fair pre-subsidy premium from which the proportional wedge is calculated. Replacement pricing will only have value if it can decrease income risk enough to offset the cost associated with the additional decline in expected income. Portfolios of individual-revenue insurance by itself are always hurt by replacement pricing, but portfolios containing insurance and futures can sometimes benefit from replacement pricing even with the 1.3 pre-subsidy wedge.

Under current restrictions, the combination of individual-revenue insurance and futures is now the farmer's preferred portfolio when the pre-subsidy premium is actuarially fair. When the farmer faces the 1.3 pre-subsidy wedge, area-revenue contracts are included in the preferred portfolio. These portfolios are also preferred to the portfolios without replacement pricing—indicating, under a flat subsidy and current restrictions, a form of revenue insurance with replacement pricing is the preferred contract design.

If the coverage restrictions are lifted, the value of area insurance again increases. With the actuarially fair pre-subsidy premium, the farmer still prefers individual-revenue insurance and futures. However, in the presence of the 1.3 pre-subsidy wedge, the farmer sometimes prefers area-yield insurance with futures. As expected, the farmer often prefers unrestricted area-insurance contracts without replacement pricing to avoid the associated up-side price risk that occurs with high coverage levels and replacement pricing.

With a flat (or zero) subsidy and with replacement pricing, the results show the preferred portfolio under current coverage restrictions is individual-revenue insurance with futures whenever the farmer pays an actuarially fair pre-subsidy premium. This is in contrast to the case without replacement pricing, where individual-yield insurance with futures was preferred. Once again, when the farmer faces the 1.3 pre-subsidy wedge, area insurance contracts are preferred. However, when the area-insurance coverage restrictions are relaxed, the farmer often prefers contracts without replacement pricing.

Insurance Contract Choice Under a Regressive Proportional Subsidy

The subsidy level for each optimal portfolio in tables 5 and 6 shows the farmer clearly prefers the current subsidy to the former flat subsidy ($2.78) because of the greater income transfer. Moreover, because the current subsidy received by the farmer differs across contracts, the farmer now faces an income incentive (from the subsidy) in addition to a risk management incentive when selecting a contract. As shown in table 2, area

Table 5. Hedge Ratios and Willingness to Pay with Regressive Subsidy and Without Replacement Price Coverage

	Unrestricted Coverage					Restricted Coverage				
Description	Futures	Cover-age	Scaled Acres	Subsidy	WTP	Futures	Cover-age	Scaled Acres	Subsidy	WTP
	<------------------ **ZERO PRICE-YIELD CORRELATION** ------------------>									
ACTUARIALLY FAIR										
LDP Trigger = 0.75:										
▸ IY with Futures						0.62	0.84	1.0	$8.74	$24.97
▸ IR						—	0.84	1.0	$9.92	$25.07
▸ IR with Futures						0.40	0.84	1.0	$9.99	$25.98
▸ AY with Futures	0.73	1.05	1.5	$17.13	$30.85	0.71	0.90	1.5	$17.13	$30.07
▸ AR	—	1.14	1.5	$20.80	$34.74	—	0.90	1.5	$20.80	$33.15
▸ AR with Futures	0.00	1.14	1.5	$20.80	$34.74	0.30	0.90	1.5	$20.80	$33.63
LDP Trigger = 1.0:										
▸ IY with Futures						0.29	0.85	1.0	$8.66	$45.86
▸ IR						—	0.85	1.0	$9.92	$47.01
▸ IR with Futures						0.07	0.84	1.0	$9.94	$47.03
▸ AY with Futures	0.40	1.36	1.5	$17.13	$51.98	0.41	0.90	1.5	$17.13	$50.85
▸ AR	—	1.04	1.5	$20.80	$55.28	—	0.90	1.5	$20.80	$54.71
▸ AR with Futures	0.00	1.04	1.5	$20.80	$55.28	-0.00	0.90	1.5	$20.80	$54.71
ACTUARIALLY UNFAIR										
LDP Trigger = 0.75:										
▸ IY with Futures						0.61	0.80	1.0	$9.05	$21.68
▸ IR						—	0.80	1.0	$10.23	$21.26
▸ IR with Futures						0.42	0.80	1.0	$10.21	$22.29
LDP Trigger = 1.0:										
▸ IY with Futures						0.29	0.81	1.0	$9.05	$42.46
▸ IR						—	0.80	1.0	$10.23	$43.19
▸ IR with Futures						0.09	0.80	1.0	$10.23	$43.23
	<---------------- **NEGATIVE PRICE-YIELD CORRELATION** ---------------->									
ACTUARIALLY FAIR										
LDP Trigger = 0.75:										
▸ IY with Futures						0.32	0.84	1.0	$8.84	$21.66
▸ IR						—	0.85	1.0	$8.79	$21.66
▸ IR with Futures						0.10	0.85	1.0	$8.79	$21.73
▸ AY with Futures	0.50	0.99	1.5	$17.13	$25.77	0.39	0.90	1.5	$17.13	$25.29
▸ AR	—	0.95	1.5	$17.67	$26.36	—	0.90	1.5	$17.67	$26.30
▸ AR with Futures	0.00	0.95	1.5	$17.67	$26.36	0.30	0.90	1.5	$17.67	$26.30
LDP Trigger = 1.0:										
▸ IY with Futures						0.00	0.84	1.0	$8.77	$45.30
▸ IR						—	0.85	1.0	$8.75	$45.20
▸ IR with Futures						0.00	0.85	1.0	$8.75	$45.20
▸ AY with Futures	0.19	1.04	1.5	$17.13	$50.14	0.02	0.90	1.5	$17.13	$49.42
▸ AR	—	0.93	1.5	$17.67	$49.82	—	0.90	1.5	$17.67	$49.79
▸ AR with Futures	0.09	0.95	1.5	$17.67	$49.87	-0.05	0.90	1.5	$17.67	$49.80
ACTUARIALLY UNFAIR										
LDP Trigger = 0.75:										
▸ IY with Futures						0.29	0.80	1.0	$9.04	$18.46
▸ IR						—	0.80	1.0	$8.99	$18.27
▸ IR with Futures						0.10	0.80	1.0	$8.99	$18.33
LDP Trigger = 1.0:										
▸ IY with Futures						0.00	0.80	1.0	$9.05	$41.98
▸ IR						—	0.81	1.0	$9.00	$41.70
▸ IR with Futures						0.00	0.81	1.0	$9.00	$41.70

Notes: Abbreviations and acronyms are defined as follows: WTP = willingness to pay, IY = individual-yield insurance, IR = individual-revenue insurance, AY = area-yield insurance, AR = area-revenue insurance, and LDP = loan deficiency payment. Actuarially fair and unfair refer to the pre-subsidy premium levels.

Table 6. Hedge Ratios and Willingness to Pay with Regressive Subsidy and with Replacement Price Coverage

	Unrestricted Coverage					Restricted Coverage				
Description	Futures	Cover-age	Scaled Acres	Subsidy	WTP	Futures	Cover-age	Scaled Acres	Subsidy	WTP
	<------------------ **ZERO PRICE-YIELD CORRELATION** ------------------>									
ACTUARIALLY FAIR										
LDP Trigger = 0.75:										
▸ IY with Futures						0.67	0.84	1.0	$9.36	$25.83
▸ IR						—	0.84	1.0	$11.53	$26.81
▸ IR with Futures						0.54	0.84	1.0	$11.58	$28.39
▸ AY with Futures	0.80	1.01	1.5	$19.90	$31.54	0.78	0.90	1.5	$19.90	$31.18
▸ AR	—	1.05	1.5	$24.72	$36.87	—	0.90	1.5	$24.72	$36.23
▸ AR with Futures	0.45	0.96	1.5	$24.72	$37.63	0.50	0.90	1.5	$24.72	$37.56
LDP Trigger = 1.0:										
▸ IY with Futures						0.34	0.85	1.0	$9.28	$46.67
▸ IR						—	0.84	1.0	$11.51	$49.09
▸ IR with Futures						0.20	0.84	1.0	$11.53	$49.30
▸ AY with Futures	0.49	1.03	1.5	$19.90	$52.71	0.47	0.90	1.5	$19.90	$51.91
▸ AR	—	0.99	1.5	$24.72	$58.58	—	0.90	1.5	$24.72	$58.32
▸ AR with Futures	0.09	0.98	1.5	$24.72	$58.61	0.17	0.90	1.5	$24.72	$58.47
ACTUARIALLY UNFAIR										
LDP Trigger = 0.75:										
▸ IY with Futures						0.66	0.80	1.0	$9.62	$22.39
▸ IR						—	0.80	1.0	$11.74	$22.66
▸ IR with Futures						0.55	0.79	1.0	$11.73	$24.34
LDP Trigger = 1.0:										
▸ IY with Futures						0.34	0.80	1.0	$9.64	$43.11
▸ IR						—	0.80	1.0	$11.74	$44.89
▸ IR with Futures						0.22	0.80	1.0	$11.74	$45.16
	<---------------- **NEGATIVE PRICE-YIELD CORRELATION** ---------------->									
ACTUARIALLY FAIR										
LDP Trigger = 0.75:										
▸ IY with Futures						0.43	0.82	1.0	$10.33	$23.32
▸ IR						—	0.83	1.0	$11.91	$24.75
▸ IR with Futures						0.33	0.83	1.0	$11.89	$25.38
▸ AY with Futures	0.50	0.90	1.5	$18.55	$27.21	0.50	0.90	1.5	$18.55	$27.21
▸ AR	—	0.90	1.5	$24.07	$31.01	—	0.90	1.5	$24.07	$31.01
▸ AR with Futures	0.32	0.90	1.5	$24.07	$31.58	0.31	0.90	1.5	$24.07	$31.58
LDP Trigger = 1.0:										
▸ IY with Futures						0.00	0.83	1.0	$10.28	$46.74
▸ IR						—	0.83	1.0	$11.85	$48.93
▸ IR with Futures						0.00	0.83	1.0	$11.85	$48.93
▸ AY with Futures	0.26	0.99	1.5	$18.55	$51.13	0.13	0.90	1.5	$18.55	$50.92
▸ AR	—	0.90	1.5	$24.07	$55.47	—	0.90	1.5	$24.07	$55.47
▸ AR with Futures	0.00	0.90	1.5	$24.07	$55.47	0.00	0.90	1.5	$24.07	$55.47
ACTUARIALLY UNFAIR										
LDP Trigger = 0.75:										
▸ IY with Futures						0.40	0.79	1.0	$10.44	$19.81
▸ IR						—	0.78	1.0	$11.87	$20.82
▸ IR with Futures						0.37	0.79	1.0	$11.90	$21.39
LDP Trigger = 1.0:										
▸ IY with Futures						0.02	0.79	1.0	$10.46	$43.16
▸ IR						—	0.79	1.0	$11.93	$44.83
▸ IR with Futures						0.00	0.79	1.0	$11.93	$44.83

Notes: Abbreviations and acronyms are defined as follows: WTP = willingness to pay, IY = individual-yield insurance, IR = individual-revenue insurance, AY = area-yield insurance, AR = area-revenue insurance, and LDP = loan deficiency payment. Actuarially fair and unfair refer to the pre-subsidy premium levels.

insurance contracts are now subsidized at higher coverage levels, and the rate of subsidy is also higher than for individual contracts. Further, because the subsidy is proportional to the pre-subsidy premium, revenue contracts receive higher subsidy than yield insurance unless the level of price-yield correlation is extremely high.

Under the risk environments faced by the farmer, the subsidy levels provided across contract types differ significantly.[11] For example, at current coverage constraints with no price-yield correlation, no replacement pricing, and an actuarially fair pre-subsidy premium, the farmer subsidy per acre is \$20.80 for area-revenue, \$17.13 for area-yield with futures, \$9.92 for individual-revenue, and \$8.74 for individual-yield insurance with futures. In the cases considered here, the regressive proportional subsidy increases the incentive to use area insurance contracts, particularly area-revenue contracts, in an effort to capture the larger subsidy even when these contracts may not be the most efficient in terms of managing risk.

The current subsidy becomes even larger under replacement pricing, and therefore increases the incentive to adopt contracts with replacement pricing. Under the flat subsidy, adding replacement pricing to a contract often causes a decrease in the value of area insurance because of an increase in up-side price risk. However, under the regressive subsidy, the larger premium resulting from inclusion of replacement pricing in a contract provides enough additional subsidy income so that replacement pricing is preferred by the farmer in all contracts.

The current subsidy for individual insurance contracts when the farmer faces the 1.3 pre-subsidy wedge is higher than for an actuarially fair pre-subsidy premium because of both the regressive and proportional features of the subsidy. However, the increase in income under the current subsidy is still not enough to offset the 1.3 pre-subsidy wedge effect. Consequently, area contracts are still preferred under the regressive proportional subsidy.

The regressive proportional subsidy can also produce incentives for the farmer to choose coverage and acreage scaling which may increase or decrease income risk. Because the subsidy, as a percentage of the pre-subsidy premium, declines as the coverage increases, the farmer may choose a coverage level different from the level that would be chosen for purely risk management purposes. For example, under the current subsidy, the farmer maximizes expected subsidy income from the individual insurance contracts by choosing just over an 80% coverage level. Here, the "coverage effect" of the subsidy is observed for the individual insurance contracts in optimal coverage levels falling below the 85% coverage restriction which is chosen under the flat subsidy (to minimize risk) when the pre-subsidy contracts are priced actuarially fair. On the other hand, when the pre-subsidy wedge is 1.3, the coverage effect reverses, causing the farmer to increase coverage compared to the levels chosen under the flat subsidy in an effort to capture additional subsidy. If the pre-subsidy wedge is large enough, the regressive proportional subsidy can have the effect of moving the farmer toward a more efficient coverage level in terms of risk protection.

The farmer can also increase the amount of subsidy received at a given coverage level by increasing the scaled acres covered by insurance, resulting in a subsidy "scaling effect." This strategy has no effect on individual insurance where current policies essentially

[11] The relative subsidy levels for each type of insurance product may differ if a farmer faces risk situations differing from those faced by the farmer in this study.

set scaling at 100% of planted acres. However, current policies allow a farmer using area insurance to insure up to 150% of planted acres. The results show the farmer always chooses to scale acres at the 150% level under the regressive proportional subsidy. In contrast, the optimal area insurance acreage scaling under the flat subsidy is always below 150% of planted acres.

When the subsidy scaling and coverage effects are combined in area insurance contracts, hedge ratios can differ significantly from those chosen purely for risk management purposes. For example, with no coverage restrictions, the farmer chooses area insurance acreage scaling at 150% and coverage levels at, or slightly above, the 90% restriction. In contrast, under the flat subsidy, the farmer chooses area insurance acreage scaling below 100% and coverage levels at, or near, the maximum index value.

For the risk setting evaluated in this study, the results show the current regressive proportional subsidy structure favors contracts featuring area indices based on revenue with replacement pricing as well as contracts having 1.3 pre-subsidy wedges. In addition, the regressive proportional subsidy can impact the optimal scaling and coverage levels as the farmer attempts to capture subsidy income. As a result, the current subsidy can affect the risk management benefits farmers receive from using crop insurance.

Risk Management Costs Under the Regressive Proportional Subsidy

The results reported in tables 3–6 have demonstrated the regressive proportional subsidy structure can alter the optimal insurance contract choice from the optimal choice based on a risk management perspective. Table 7 shows the optimal contract designs under both the flat and regressive proportional subsidy for different cases the farmer might encounter, and table 8 presents the risk management costs of the regressive proportional subsidy. Risk management cost is measured as the difference in willingness to pay for the optimal portfolio chosen under the flat subsidy and the optimal portfolio chosen under the regressive proportional subsidy when the farmer uses each portfolio and only receives the flat subsidy. Comparing the difference in willingness to pay for the two portfolios when the farmer receives only the flat subsidy provides a measure of the cost to the farmer from bearing additional risk that results from using the portfolio chosen under the regressive proportional subsidy.

When the farmer faces the actuarially fair pre-subsidy premium and area insurance is restricted, individual-revenue insurance with replacement pricing is the optimal contract under the flat subsidy. However, the larger subsidy for area contracts causes the farmer to prefer area-revenue insurance with replacement pricing under the regressive proportional subsidy. In this case, the farmer switches from the individual-revenue insurance with replacement pricing, which is best at managing risk, to area-revenue insurance with replacement pricing to capture the additional subsidy. The cost in terms of less efficient risk protection from the switch ranges from \$3.95 per acre to \$6.18 per acre (table 8). When the area restrictions are removed, the farmer prefers either area-revenue with replacement pricing or individual-revenue without replacement pricing under the flat subsidy. However, the larger subsidy incentive again causes the farmer to always prefer area-revenue insurance with replacement pricing under the regressive proportional subsidy. The cost to the farmer from using the area-revenue contract with replacement pricing ranges between \$3.87 per acre and \$6.18 per acre.

Table 7. Optimal Contract Choice Under the Flat Subsidy and the Regressive Subsidy

Description	Actuarially Fair		Actuarially Unfair	
	Restricted Area Coverage	Unrestricted Area Coverage	Restricted Area Coverage	Unrestricted Area Coverage
	<------------------ FLAT SUBSIDY			------------------>
Zero Price-Yield Correlation:				
LDP Trigger = 0.75	IR, RP	AR	AR, RP	AR
LDP Trigger = 1.0	IR, RP	IR, RP	AR, RP	AR
Negative Price-Yield Correlation:				
LDP Trigger = 0.75	IR, RP	IR, RP	AR, RP	AR
LDP Trigger = 1.0	IR, RP	IR, RP	AR, RP	AY
	<---------------- REGRESSIVE SUBSIDY			---------------->
Zero Price-Yield Correlation:				
LDP Trigger = 0.75	AR, RP	AR, RP	AR, RP	AR, RP
LDP Trigger = 1.0	AR, RP	AR, RP	AR, RP	AR, RP
Negative Price-Yield Correlation:				
LDP Trigger = 0.75	AR, RP	AR, RP	AR, RP	AR, RP
LDP Trigger = 1.0	AR, RP	AR, RP	AR, RP	AR, RP

Notes: Acronyms are defined as follows: LDP = loan deficiency payment, AR = area-revenue insurance, IR = individual-revenue insurance, AY = area-yield insurance, and RP = replacement pricing. Actuarially fair and unfair refer to the pre-subsidy premium levels.

Table 8. Risk Management Costs of Regressive Proportional Subsidy

Description	Actuarially Fair		Actuarially Unfair	
	Restricted Area Coverage	Unrestricted Area Coverage	Restricted Area Coverage	Unrestricted Area Coverage
Zero Price-Yield Correlation:				
LDP Trigger = 0.75	\$3.95	\$4.51	\$0.65	\$4.51
LDP Trigger = 1.0	\$4.02	\$3.87	\$0.36	\$3.32
Negative Price-Yield Correlation:				
LDP Trigger = 0.75	\$6.18	\$6.18	\$1.53	\$3.94
LDP Trigger = 1.0	\$5.94	\$5.94	\$1.11	\$3.76

Notes: LDP denotes loan deficiency payment. Actuarially fair and unfair refer to the pre-subsidy premium levels.

When facing the 1.3 pre-subsidy wedge and area insurance is restricted, the farmer prefers area-revenue insurance with replacement pricing under both types of subsidy. Yet, because of impacts of the regressive proportional subsidy on acreage scaling and coverage levels, the farmer chooses a portfolio that is \$0.36 to \$1.53 per acre less efficient in terms of risk protection. When the area insurance restrictions are relaxed, the farmer prefers either area-revenue insurance without replacement pricing or area-yield insurance without replacement pricing under the flat subsidy. Still, under the regressive proportional subsidy, the farmer once again prefers the area-revenue insurance with replacement pricing in order to capture the largest subsidy. The cost of less efficient risk protection ranges from \$3.32 to \$4.51 per acre (table 8).

The farmer clearly prefers the current subsidy to the flat subsidy because of the significantly larger income transfer. Yet, in many cases, the regressive proportional subsidy causes the farmer to choose portfolios that are less efficient in the context of managing risk. The results show the cost to farmers from choosing riskier portfolios is sometimes over twice the level of the former flat subsidy, and farmers would be just as well off under a flat subsidy which is up to 25% less than the current regressive proportional subsidy.

Summary and Conclusions

In this study, we examine the risk management ability of different insurance contract designs and the impacts of different subsidy rules on optimal contract choice and risk management. Numerical techniques are used to evaluate the behavior and well-being of an individual farmer using combinations of revenue insurance, yield insurance, and pre-harvest pricing. The model is calibrated using parameters reflecting those faced by farmers in southwest Iowa in the mid-1990s. The robustness of the results is evaluated by altering the base parameters and examining changes in the farmer's behavior. This analysis extends earlier work in this area by allowing the farmer to select optimal hedge ratios for both futures and insurance contracts, by evaluating alternative insurance design features such as area-index indemnification, and by exploring the effects of an actuarially unfair pre-subsidy premium. However, the primary contribution is the evaluation of the impact of different subsidy rules on optimal contract design and risk management.

Without replacement pricing and under current restrictions, the findings indicate a combination of futures and individual-yield insurance outperforms revenue insurance in managing risk. Further, when replacement pricing is used, portfolios of individual-revenue insurance and futures are better able to manage risk than yield insurance and futures. Area-index contracts can provide better risk management than individual-index contracts when "ad hoc" coverage restrictions are relaxed or the farmer faces actuarially unfair premiums for individual-index insurance. Replacement pricing is shown to improve the risk management ability of individual insurance but may reduce the risk management effectiveness of some area contracts.

The new regressive proportional subsidy provides historically high subsidy levels which differ across contract designs. The current subsidy may alter the optimal choice, causing farmers to prefer contracts and hedge ratios that are not the most efficient, in a risk management sense, in order to capture additional subsidy income. Under the current subsidy, the representative farmer evaluated in this study has strong incentives to choose area-revenue contracts with replacement pricing in order to capture the largest subsidy level. The farmer could be equally well off under a flat subsidy of up to 25% less than the current regressive proportional subsidy because of more efficient risk management.

It is important to note these results are based on the behavior of a representative farmer in southwest Iowa who faces a specific risk structure. We have attempted to generalize some of the results by varying a number of parameters in the analysis, such as the level of correlation between prices and yields. However, many other assumptions are made that may affect the study results, such as: (*a*) the level of farmer risk aversion, (*b*) production of a single crop, (*c*) exogenous farm size, (*d*) no capital markets for borrowing or lending, and (*e*) decisions are made in a static framework. Relaxing these and other assumptions may affect the results, and so care must be taken when generalizing beyond the specific cases considered here.

[*Received December 2001; final revision received February 2003.*]

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