Staff Paper

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Staff Paper 00-48 December 2000

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(26 pages total)

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The 1996 Federal Agricultural Improvement Act (FAIR) increased farmer's exposure to downside risk and raised farmer, lender, and congressional interest in the use of alternative instruments to manage income risk. One response has been a proliferation of federally facilitated insurance products. The development of new insurance products is likely to continue because the Agricultural Risk Protection Act of 2000 provides financial incentives for new private sector insurance product development 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 instruments 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.

Farmers can combine pricing instruments with yield insurance to manage income risk. However, this involves selecting multiple risk management instruments and determining the appropriate level of use for each instrument, and may still leave the farmer facing significant income risk exposure. 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 offer better risk protection than existing price and yield management instruments. Revenue insurance, like yield insurance, can potentially feature a variety of designs including indemnification based on an individual-farm or area index, and/or alternative methods to value shortfalls.

Our objective is to investigate the relative performance of alternative insurance contract designs and the ability of revenue insurance to substitute for existing price and yield risk management instruments. Performance is measured by a willingness-to-pay measure in an expected utility framework for an individual corn farmer. The farmer is allowed to use various portfolios of risk management instruments that include combinations of pre-harvest-pricing instruments and yield or revenue insurance. The insurance instruments are included in portfolios under a variety of design specifications to investigate the impact of each design feature on performance. Modeling is conducted with both actuarially fair and unfair farmer premiums; in high and low relative price risk environments; and with zero and negative price-yield correlation. Numerical simulation and optimization methods are used because of the complex nature of the decision problem.

The results show that, without replacement pricing, a combination of futures and yield insurance outperforms revenue insurance. However, when replacement pricing is used, portfolios of revenue insurance and futures are preferred to yield insurance and futures. Under current restrictions, the farmer finds portfolios of revenue insurance with replacement pricing and futures more effective than portfolios without replacement pricing. It is also shown that relaxing the “ad hoc” coverage restrictions on area-insurance may impact relative portfolio performance and increase farmer welfare. Insurance companies and policy makers will find the study results useful in modifying current insurance products and developing future products. Farmers, agribusiness providers, and extension agents can use the results to gain insights about the ability of different insurance products to accomplish farmers' risk management objectives.

Background

Programs currently administered by the USDA Risk Management Agency (RMA) have provided some form of MP crop yield insurance to U.S. farmers since 1938. The Federal Crop Insurance Act of 1980 expanded the scope of MP programs in terms of crops covered, counties covered, and insurance contract design; and also facilitated privatization of the delivery system. Recently, the Federal Crop Insurance Reform and Reorganization Act of 1994 enabled pilot testing of revenue insurance products.

The performance of MP insurance has been challenged on many fronts. Congress has been concerned that participation is low and the size of insurance delivery costs are high; while farmers have argued premium rates often exceed underlying risk and that risk group classification is inadequate. Thus, some changes in MP programs have been directed toward mitigation of moral hazard, adverse selection, and administrative cost problems associated with implementing an insurance program based on individual farm yields. Other changes have focused on altering features of existing products such as improving methods to calculate expected yields, increasing coverage percentages (reducing deductibles), introducing disappearing deductible coverage, and extending protection to include revenue products.

One of the approaches to ameliorating moral hazard, adverse selection, and administrative cost problems was to offer a yield insurance that triggers on county yield rather than individual-farm yield (Halcrow). In 1988, the Commission for the Improvement of Crop Insurance suggested development of a pilot program that would indemnify based on shortfalls below an area-yield index. In 1994, RMA began offering the Group Risk Plan (GRP) where yield losses are indemnified based upon county yield shortfalls (Baquet and Skees; Skees, Black and Barnett). Indemnification is calculated by multiplying the shortfall below the trigger yield times the dollar value of protection selected by the farmer. A drawback of an area-yield insurance program is that the indemnity payout is no longer perfectly correlated with the farmer's actual yield loss. This yield “basis risk” reduces the ability of the insurance instrument to manage individual farm revenue risk. In addition, GRP does not contain the prevented-planting and yield-quality adjustment features contained in MP insurance policies.

RMA initiated an Income Protection contract (IP) in 1997 for pilot testing in selected counties for a variety of crops. The index for IP coverage is the farm’s historical average yield times the average harvest futures price for a pre-planting period. Similar to the MP individual-yield contract, the IP revenue guarantee is a percentage of index value. If a farmer’s realized revenue index falls below the guarantee, the farmer receives an indemnity payment equal to the shortfall.

Three additional revenue insurance contracts have been developed by private insurance companies and offered on a pilot basis. RMA provides reinsurance and subsidies on these products equivalent to what is provided for MP and IP. Revenue assurance (RA), developed by the Iowa Farm Bureau Insurance, is similar to IP. However, RA permits insuring crops individually or as the combined revenue from multiple crops. RA also features premium discounts for spatial diversification and uses a different rating methodology than IP to determine premiums.

Crop Revenue Coverage (CRC), developed by Redland's Insurance Company differs from the IP policy in that the revenue index guarantee is based upon *replacement price coverage*, which is the greater of the realized harvest futures price and the pre-plant harvest futures price. The designer's objective was to increase the use of pre-harvest pricing by reducing the delivery "risk." That is, if the output forward contracted exceeds realized yield, the farmer must buy back a portion of the contracted output at the realized local harvest price. Yield insurance can reduce this risk but the farmer still faces the risk that the replacement price will exceed the pre-planting forward contract price. CRC can be viewed as a contract with two alternative trigger indexes. If the futures price at harvest is less than the pre-planting futures price, the contract operates as a pure revenue-index contract, like the IP contract. However, if the harvest futures price exceeds the pre-plant futures price, the contract is equivalent to a yield contract with yield shortfalls indemnified at the harvest futures price. Redland also offers a replacement pricing product called Market Value Protection (MVP) which can be added as a supplement to MP individual-yield insurance.

Group Risk Income Protection (GRIP) was developed by the IGF insurance company. GRIP is similar to IP except that indemnification is based on an area-revenue index as opposed to the farmer's individual-revenue index. As in area-yield GRP insurance, the area-revenue GRIP contract eliminates many of the moral hazard, adverse selection, and administrative costs associated with individual-index revenue insurance, but subjects the farmer to additional index-basis risk. Beginning in 2001, supplemental replacement price coverage will be available for GRIP contracts.

These insurance instruments permit insuring yields or revenues where indemnification is based on individual- or area-indices either with or without replacement price coverage. Each of the instruments can also be combined with available pre-harvest pricing instruments, offering farmers a flexible, but complex, set of risk management instruments.

Previous Studies

Miranda explores insurance indemnification based on area-yield indices and finds the lower transaction costs associated with area-yield insurance, along with potentially higher coverage levels, could allow better risk protection than individual-yield insurance to many farmers. Mahul examines the optimal design of area-yield insurance contracts and finds the optimal contract design depends on the sensitivity of farm yield to area yield. The implications of combining insurance instruments with other risk management instruments in a farmer's portfolio are not addressed in these studies.

Myers explores the simultaneous use of yield insurance and futures contracts while Poitras examines the use of futures with yield and revenue insurance. These studies provide useful insights into the use of insurance contracts in a portfolio setting but are limited by restrictive assumptions on price and yield distributions, farmer preferences, and/or contract designs.

Wang, et al. use numerical techniques to investigate the impacts of alternative yield insurance designs on portfolio choice and welfare for an individual corn farmer. The effects of alternative yield indices (individual versus area), coverage restrictions, number of contracts purchased per acre, indemnification pricing schemes, and premium wedges are examined. Futures, options, and yield insurance were considered separately and in various combinations in the farmer's risk management portfolio. Performance was explored in a two period model solving for optimal futures and options hedge ratios and for optimal insurance coverage. The results indicate area-yield insurance can perform nearly as well or better than individual-yield insurance for many farmers. 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 instruments in the portfolio. The study also finds optimal coverage levels for area-yield insurance are significantly higher than currently permitted by RMA. Revenue insurance and replacement price coverage were not addressed in the study.

Heifner and Coble use numerical methods to evaluate the performance of alternative insurance contract designs for representative corn, soybean, and wheat farms at four locations across the US. Individual-index insurance contracts, including a form of individual-revenue insurance, are evaluated in portfolios with and without replacement price coverage. Revenue insurance is found to outperform yield insurance when no pre-harvest pricing is used. However, when pre-harvest pricing is included in the portfolio yield insurance becomes competitive with revenue insurance. This study assumes fixed coverage levels and that all farmers pay an actuarially fair premium and receive a subsidy. In addition, area-index insurance designs are not considered.

The remainder of this paper extends previous work by comparing the performance of futures and yield insurance portfolios to portfolios of revenue insurance with and without futures. Here we allow the farmer to select optimal hedge ratios for each risk management instrument in the portfolio and then evaluate the performance of alternative index types (individual versus area), the impacts of coverage restrictions and premium wedges, and the role of replacement price coverage.

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, **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.[1] The random price vector **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 **y** contains the farmer's individual yield at harvest and the yield indices used to indemnify the alternative insurance instruments. The utility function is assumed to have constant relative risk aversion (CRRA) where $u(w) = (1 - \theta)^{-1} w^{(1-\theta)}$ and the constant relative risk aversion parameter is set at $\theta = 2$.[2]

The profit function consists of up to four components:

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

where
$$NP = py - c(y);$$
$$PHP = h(f_o - f);$$
$$YI = s_c\; p_c \max[0,\; x_c E(y_c) - y_c] - \lambda_c a_c(s_c,\; x_c, p_c, E(y_c));\text{ and}$$
$$RI = s_r \max[0, x_r p_r E(y_r) - f y_r] - \lambda_r a_r(s_r, x_r, p_r, E(y_r), f_0).$$

The NP component is the 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.[3] 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_o is the initial futures price when h is selected, f is the futures price at harvest.[4]

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 so the acreage scaling factors s_c and s_r are restricted to equal one. If the farmer elects to use area-index insurance the effective amount of insurance per acre can be adjusted by selecting acreage scaling factors that differ from one. In the YI component the term p_c is the price used to indemnify the yield shortfalls for the chosen insurance instrument, y_c is the yield index 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 constant λ_c (wedge) is used to adjust the insurance premium if premiums paid exceed the underlying risk. 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 MP contract) or some area-yield index (as in the GRP contract).

The RI component is the net return from using revenue insurance. Here p_r is the price index used 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 (similar to the IP contract), while using an area-yield index produces area-revenue insurance (similar to the GRIP contract). As in the yield insurance case, for replacement price coverage $p_r = \max(f, f_0)$. The actuarially fair revenue insurance premium is $a_r(\cdot)$ and the constant λ_r (wedge) is used to adjust the insurance premium if premium paid exceeds the underlying risk.

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 coverage level and/or acreage scaling for the alternative insurance instruments. It is assumed decisions are made simultaneously in a portfolio setting given the known parameters and probability distributions. The profit function in (2) contains a stylized version of the major types of risk management instruments now available to U.S. farmers.

Designs and Model Parameterization

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 as a starting point.[5] 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 are then used as an estimate of the joint distribution of prices and yields at harvest, conditional on information available at planting.

There is evidence the simulated conditional distribution is reflective of a historically low price risk environment. The coefficient variation for futures prices in the simulated distribution was about 15% while Coble and Heifner find coefficient of futures price variations for corn is typically in the range of 18% to 20%. To explore the impacts of the relative level of price to yield risk, we generate a second scenario that reflects a relatively higher price risk environment. The second joint price-yield distribution is generated using the Wang et al. approach, but proportionally increasing the ARCH parameters by 140%, shifting the scale of the distribution, but retaining the original mean levels. This produces a coefficient of variation for futures prices of around 20%. Thus the second base scenario represents a situation where the farmer faces "higher price risk" relative to a given level of yield risk. Two other corresponding joint distributions were simulated with zero price-yield correlation. This results in four simulated distributions: low price risk with zero correlation, low price risk with negative correlation, high price risk with zero correlation, and high price risk with negative correlation. The sample moments and correlations for the simulated distributions at harvest conditional on information available at planting are shown in Table 1. Analyzing the performance of the alternative insurance instruments using each simulated distribution allows results to be generalized across the different risk environments.

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 which is consistent with Jolly and Olson. Production cost, adapted from Jolly and Olson, is specified as $\$2.18(E[y|\Omega]) + \$0.17y$ where $E[y|\Omega]$ 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; while the second term reflects uncertain variable costs that depend on 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.

In practice, coverage levels are restricted. To reflect these restrictions, coverage for individual-index instruments is allowed to be no more than 75% of expected index value which approximates the level used by RMA to reduce exposure to potential moral hazard problems.[6] Coverage for area-index instruments in the restricted cases is set at no more than 90% of the expected index value which also reflects RMA policy. However, the 90% area trigger restriction is "arbitrary" and could be set higher because area-based instruments eliminate moral hazard and adverse selection problems associated with individual-index insurance.

Despite federal subsidies, farmers using individual-index products often pay premiums above the actuarially fair level because the current risk classification approach is imperfect (Skees). RMA reinsurance policies require all farmers in a given location and risk class be charged the same premium which results in a "wedge" between the premium paid by the farmer and the farmer's actuarially fair premium. RMA allows insurance providers to further classify farmers, for reinsurance purposes only, indicating that both RMA and the insurance providers recognize these wedges exist and can vary significantly across farmers. To gain insights into the impacts of the premium wedge faced by farmers we analyze individual-index products as actuarially fair (λ = 1.0) and with a 30% wedge (λ = 1.3). Area-index insurance is characterized by low transaction costs and all farmers face the same area-index distribution. Therefore, if adequate data is available to estimate the area-index distribution, premiums should always be near actuarially fair so λ = 1.

We evaluate the ability of revenue insurance to substitute for existing price and yield management instruments by examining the performance of six portfolios: individual-yield insurance with futures; area-yield insurance with futures; individual revenue insurance; area-revenue insurance; individual-revenue insurance with futures; and area-revenue insurance with futures. These portfolios are evaluated in different economic environments including low price risk, high price risk, no price-yield correlation, and negative price-yield correlation. In addition, the impact of using replacement price coverage in each portfolio is examined.

Results

In the absence of production cost uncertainty and basis risk, unrestricted actuarially-fair revenue insurance based on individual-farm revenue is the “ideal” risk management instrument because, by choosing a coverage level equal to the maximum possible revenue (zero deductible), the farmer can eliminate all risk without impacting expected income. In practice delivering actuarially-fair revenue insurance to individual farmers with no coverage restrictions is not feasible because of moral hazard, adverse selection, and administration cost problems. Restricting coverage levels and acreage scaling can help reduce these transaction costs. However, these changes affect the ability of revenue contracts to manage income risk. In addition, the existence of uncertain production costs and/or basis risk further reduces the ability of revenue insurance to manage income risk. Therefore, in practice, individual-index revenue insurance can no longer completely eliminate income risk and other insurance designs may be more valuable to the farmer.

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/or acreage scaling, using the OPTMUM module of Gauss. The performance of the alternative risk management portfolios is evaluated in terms of how much certain income must be added to the farmer's revenue 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 performance of the different portfolios in terms of the willingness-to-pay measure. For completeness, the optimal futures, insurance coverage, and insured acreage hedge ratios are also shown for each portfolio.

Insurance Contracts Designed without Replacement Price Coverage

We begin by examining the ability of revenue insurance to substitute for futures and yield insurance when insurance contracts are designed without replacement price coverage. Table 2 shows the optimal hedge ratios and willingness-to-pay values for the six alternative risk management portfolios under various conditions the farmer might face. An obvious result is that the risk environment faced by the farmer impacts 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 impacts of the risk environment on the 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 and/or increasing the premium wedge reduces the value of each portfolio.

If we compare the value of a portfolio of yield insurance and futures to revenue insurance we see that combining yield insurance and futures always outperforms revenue insurance by itself under current contract restrictions. This result holds for both individual- and area-index insurance regardless of the risk environment and/or premium wedge. The flexible use of futures in portfolios with yield insurance allows the farmer to better manage risk than using direct revenue insurance. If the farmer uses both revenue insurance and futures in a portfolio the difference in performance, relative to a portfolio of yield insurance and futures, narrows. However, yield insurance and futures still outperform revenue insurance and futures. The results show that under current insurance contract restrictions and without replacement pricing, revenue insurance (with or without futures) is not able to completely substitute for a portfolio of yield insurance and futures.

Under current contract restrictions, the preferred indemnification index (individual versus area) depends on the size of the premium wedge faced by the farmer when using individual-index insurance. When the coverage restrictions are in place, portfolios with area-index insurance outperform portfolios with individual-index insurance when the farmer faces the premium wedge on individual-index insurance. Here the less restrictive, lower-cost, area-index design more than offsets the associated index basis risk. However, when the farmer faces no premium wedge, portfolios with individual-index insurance outperform portfolios with area-index insurance. In other words, the less restrictive area-index restrictions by themselves 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-index insurance eliminates the majority of moral hazard, adverse selection, and transaction costs problems that hinder individual-index insurance. Because of its advantages, area-index insurance can potentially be offered to farmers with fewer restrictions and at a relatively lower cost than individual-index insurance. If the “ad-hoc” area-index coverage restriction is removed, the additional flexibility improves the performance of portfolios with area-index insurance and changes the relative performance of portfolios that include revenue and yield insurance. When the coverage restrictions are removed, area-revenue insurance portfolios (with or without futures) are now preferred to portfolios with area-yield insurance and futures. The results show unrestricted area-revenue insurance can completely substitute for unrestricted area-yield insurance and futures. However, portfolios of individual-index insurance and futures may still outperform unrestricted area insurance and futures, as is the case when the farmer faces negative price-yield correlation and no premium wedge.

The results show that without replacement pricing, the preferred portfolio under current coverage restrictions is individual-yield insurance and futures whenever the farmer pays an actuarially fair premium. When the farmer faces a premium wedge, the farmer prefers a portfolio of area-yield insurance and futures. Relaxing the area-insurance coverage restrictions improves the performance of the area-revenue and futures portfolio enough so that it becomes the preferred portfolio in some cases.

Insurance Contracts Designed with Replacement Price Coverage

The use of replacement price coverage can significantly change the way each insurance instrument performs in a given portfolio. We first discuss the impacts replacement pricing has on the performance of each portfolio and then examine the ability of revenue insurance with replacement pricing to substitute for futures and yield insurance. Table 3 shows the hedge ratios and willingness-to-pay values for the six alternative portfolios when the insurance instruments are designed with replacement price coverage. When the farmer faces an actuarially fair premium, replacement price coverage increases the value of portfolios containing individual-index insurance. Here replacement pricing helps reduce unprotected income risk that results from restrictions. However, replacement pricing provides little or no additional risk protection to farmers using area-yield insurance and futures.

Replacement pricing lowers the value of portfolios consisting of only area-revenue insurance regardless of whether or not coverage restrictions are in place. This is because in the absence of coverage restrictions and replacement pricing, the farmer is able to choose high area-revenue coverage in an effort to reduce income risk. At high coverage levels, replacement pricing adds 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 maintain “high coverage” by increasing scaled acreage to substitute for restricted coverage. Likewise portfolios with revenue insurance and futures lose value when replacement pricing is used without current coverage restrictions because the up-side price risk once again increases exposure to income risk. In contrast, portfolios with restricted area-revenue insurance and futures show significant gains from using replacement pricing because the combination of replacement pricing and futures can be used to reduce unwanted income risk that results from the coverage restriction.

Using replacement pricing when the farmer faces the premium wedge results in a larger decline in expected income because replacement pricing increases the size of the actuarially fair premium from which the proportional wedge is calculated. When the farmer faces the premium wedge, 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 and futures benefit from replacement pricing even when the farmer faces the premium wedge, while individual-revenue insurance by itself is, again, hurt by replacement pricing. Portfolios of individual-yield insurance and futures benefit from replacement pricing when there is a premium wedge and no price-yield correlation but receive little or no benefit when there is negative price-yield correlation.

The relative performance of the risk management portfolios changes significantly when insurance contracts are designed with replacement price coverage because of the differences in the pricing and payoff structure of the insurance contracts. When replacement pricing is used, portfolios of yield insurance and futures again outperform portfolios consisting of only revenue insurance. However, with no premium wedge, using insurance with replacement pricing and futures reverses the performance rankings compared to portfolios without replacement pricing. When replacement pricing is used under current restrictions and actuarially fair premiums, revenue insurance and futures now outperform yield insurance and futures. And when coverage restrictions are relaxed, area-yield insurance and futures now outperform area-revenue insurance and futures.

The results show that under current restrictions individual-revenue insurance and futures is the farmer's preferred portfolio when the premium is actuarially fair. When the farmer faces a premium wedge, area-revenue insurance and futures becomes the preferred portfolio. These portfolios are also preferred to the portfolios without replacement pricing, indicating that, under current restrictions, a form of revenue insurance with replacement pricing is always preferred by the farmer.

If the coverage restrictions are lifted, and the farmer faces a premium wedge or no price-yield correlation, the preferred portfolio includes unrestricted area-revenue insurance without replacement pricing. However, when the farmer pays an actuarially fair premium and faces negative price-yield correlation, individual-revenue insurance and futures is still preferred to unrestricted area-yield insurance without replacement and futures, indicating the farmer will prefer replacement pricing in the portfolio he selects in this setting. These results show that if current coverage restrictions are removed and replacement pricing is available, the farmer always prefers a portfolio that includes a form of revenue insurance to portfolios that contain yield insurance.

Summary and Conclusions

Changes in federal commodity programs have increased revenue-risk exposure for many farmers and spurred interest in alternative risk management instruments. Farmers have long been able to use pricing instruments, such as futures contracts, in conjunction with yield insurance to manage revenue risk. In recent years the design features of the yield insurance have been modified in an effort to increase its use and effectiveness; while the latest innovation in risk management is to provide farmers with direct protection against revenue shortfalls through the use of revenue insurance.

In this study, we examine whether revenue insurance can substitute for a portfolio of yield insurance and futures under alternative design features and risk environments. Numerical optimization and simulation 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 that reflect those faced by farmers in Southwest Iowa in the mid-1990s. The robustness of the results across time and space are evaluated by altering the base parameters and examining changes in the farmer's behavior. The results extend 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 impacts of premium wedges.

The results show revenue insurance alone can not completely substitute for a portfolio of yield insurance and futures contracts. In addition yield insurance and futures are shown to perform as well or better than revenue insurance (with or without futures) when the contracts are designed without replacement price coverage. However, when replacement price coverage is used, revenue insurance and future outperform yield insurance with futures. Under current contract restrictions, futures and either individual-revenue or area-revenue insurance with replacement pricing are shown to be the best performing portfolios. Relaxing area-insurance coverage restrictions can alter these results and improve the risk management ability of some farmers. Although sensitivity analysis is conducted by altering the risk structure faced by the farmer and the design of the insurance instruments, care must be taken in generalizing the results beyond the cases presented here.

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ENDNOTES

1. 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.

2. The relative risk aversion parameter of 2.0 falls with the range estimated in studies by Antle, Arrow, Binswanger, Hamal and Anderson, and Myers.

3. The farmers yield is exogenous in the sense that all production decisions assumed to be fixed at planting.

4. 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 resulted in complex hedging positions but generally added little value in terms of risk management. In the interest of space we only report the results for pre-harvest pricing with futures.

5. Wang et al. calibrate their model by using a bi-variate ARCH model to estimate the price generating process for harvest prices. An inverse hyperbolic sine function is then used to estimate the yield generating process at the county level. Farm-level yields are generated by re-scaling the county-level yields. The estimated models are used to simulate harvest price and yield distributions. Correlation between harvest prices and yields are imposed using the normal transformation procedure proposed by Taylor.

6. Eighty-five percent coverage has recently been authorized, and is being tested on a pilot basis.

Table 1. Sample Moments and Correlations for Simulated Distributions

Variable	Sample Moments				Sample Correlation			
	Mean	Standard Deviation	Skewness	Kurtosis	Futures Price	Cash Price	County Yield	Farm Yield
Low Price Risk Environment								
				Negative Price-Yield Correlation				
Futures Price	$2.56	$0.39	0.41	3.57	1.00	0.84	-0.37	-0.31
Cash Price	$2.48	$0.38	0.43	3.55		1.00	-0.46	-0.38
County Yield	117.51bu/ac	30.40bu/ac	-1.20	4.07			1.00	0.83
Farm Yield	117.52bu/ac	36.48bu/ac	-0.97	3.28				1.00
Revenue	$284.63	$89.20	-0.62	3.32				
				Zero-Price Yield Correlation				
Futures Price	$2.56	$0.39	0.41	3.57	1.00	0.84	0.03	0.05
Cash Price	$2.48	$0.38	0.43	3.55		1.00	0.01	0.03
County Yield	117.51bu/ac	30.40bu/ac	-1.20	4.07			1.00	0.83
Farm Yield	117.52bu/ac	36.48bu/ac	-0.97	3.28				1.00
Revenue	$292.24	$101.98	-0.41	2.93				
High Price Risk Environment								
				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	117.51bu/ac	30.40bu/ac	-1.20	4.07			1.00	0.83
Farm Yield	117.51bu/ac	36.48bu/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	117.51bu/ac	30.40bu/ac	-1.20	4.07			1.00	0.83
Farm Yield	117.51bu/ac	36.48bu/ac	-0.97	3.28				1.00
Revenue	$292.43	$109.38	-0.15	2.84				

Table 2. Hedge Ratios and Willingness to Pay Without Replacement Price Coverage

	Zero Price-Yield Correlation								Negative Price-Yield Correlation							
	Unrestricted Coverage				Restricted Coverage				Unrestricted Coverage				Restricted Coverage			
	Fut.	**Cov.**	**Scaled Acres**	**WTP**	**Fut.**	**Cov.**	**Scaled Acres**	**WTP**	**Fut.**	**Cov.**	**Scaled Acres**	**WTP**	**Fut.**	**Cov.**	**Scaled Acres**	**WTP**
Actuarially Fair																
								Low Price Risk								
IY with Futures					0.75	0.75	1.0	$12.63					0.37	0.75	1.0	$9.52
IR						0.75	1.0	11.04						0.75	1.0	9.20
IR with Futures					0.58	0.75	1.0	12.43					0.20	0.75	1.0	9.37
AY with Futures	0.81	Max	0.91	$14.20	0.81	0.90	1.26	11.11	0.64	Max	0.89	$9.20	0.44	0.90	1.22	7.12
AR		1.79	0.89	14.34		0.90	1.34	10.21		1.73	0.82	9.42		0.90	1.18	6.81
AR with Futures	-0.08	1.81	0.91	14.36	0.45	0.90	1.24	11.04	0.16	Max	0.84	9.50	0.16	0.90	1.20	6.92
								High Price Risk								
IY with Futures					0.79	0.75	1.0	$14.08					0.45	0.75	1.0	$9.70
IR						0.75	1.0	11.20						0.75	1.0	8.72
IR with Futures					0.63	0.75	1.0	13.67					0.28	0.75	1.0	9.33
AY with Futures	0.89	Max	0.92	$16.04	0.88	0.90	1.27	13.00	0.69	1.30	0.87	$9.04	0.51	0.90	1.22	7.18
AR		Max	0.91	16.22		0.90	1.35	10.86		1.61	0.80	9.60		0.90	1.17	6.54
AR with Futures	0.01	Max	0.91	16.23	0.53	0.90	1.20	12.54	0.11	1.63	0.82	9.44	0.21	0.90	1.19	6.87
Actuarially Unfair																
								Low Price Risk								
IY with Futures					0.74	0.75	1.0	$8.09					0.36	0.75	1.0	$4.94
IR						0.75	1.0	6.05						0.73	1.0	4.67
IR with Futures					0.59	0.73	1.0	7.48					0.19	0.74	1.0	4.85
								High Price Risk								
IY with Futures					0.79	0.75	1.0	9.57					0.45	0.75	1.0	$5.14
IR						0.75	1.0	6.13						0.71	1.0	4.37
IR with Futures					0.64	0.71	1.0	8.65					0.28	0.73	1.0	4.91

Notes: IY designates individual-yield insurance, IR designates individual-revenue insurance, AY designates area-yield insurance and AR designates area-revenue insurance. Max indicates 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.

Table 3. Hedge Ratios and Willingness to Pay with Replacement Price Coverage

	Zero Price-Yield Correlation								Negative Price-Yield Correlation							
	Unrestricted Coverage				Restricted Coverage				Unrestricted Coverage				Restricted Coverage			
	Fut.	Cov.	Scaled Acres	WTP	Fut.	Cov.	Scaled Acres	WTP	Fut.	Cov.	Scaled Acres	WTP	Fut.	Cov.	Scaled Acres	WTP
Actuarially Fair																
								Low Price Risk								
IY with Futures					0.79	0.75	1.0	$12.97					048	0.75	1.0	$10.01
IR						0.75	1.0	11.51						0.75	1.0	9.80
IR with Futures					0.69	0.75	1.0	13.45					0.41	0.75	1.0	10.49
AY with Futures	0.98	1.33	0.86	$14.28	0.87	0.90	1.19	11.21	0.89	1.43	0.81	9.48	0.51	0.90	1.06	7.08
AR		1.26	0.94	12.89		0.90	1.24	10.16		1.22	0.76	8.69		0.90	0.96	6.88
AR with Futures	0.57	1.30	0.87	14.00	0.66	0.90	1.17	11.80	0.40	1.26	0.79	9.27	0.39	0.90	1.04	7.47
								High Price Risk								
IY with Futures					0.84	0.75	1.0	$14.51					0.56	0.75	1.0	$10.38
IR						0.75	1.0	11.59						0.75	1.0	9.29
IR with Futures					0.75	0.75	1.0	14.96					0.50	0.75	1.0	10.87
AY with Futures	1.06	1.32	0.85	16.12	0.94	0.90	1.18	13.11	0.93	1.45	0.78	$9.40	0.57	0.90	1.02	7.13
AR		1.23	0.95	13.25		0.90	1.21	10.33		1.19	0.73	7.97		0.90	0.89	6.31
AR with Futures	0.67	1.27	0.84	15.48	0.73	0.90	1.12	13.46	0.44	1.22	0.77	9.11	0.43	0.90	0.99	7.49
Actuarially Unfair																
								Low Price Risk								
IY with Futures					0.79	0.75	1.0	8.19					0.44	0.71	1.0	$4.89
IR						0.72	1.0	5.96					0.36	0.66	1.0	4.44
IR with Futures					0.69	0.71	1.0	7.91						0.69	1.0	4.96
								High Price Risk								
IY with Futures					0.84	0.75	1.0	$9.72					0.52	0.71	1.0	$5.15
IR						0.71	1.0	5.85						0.63	1.0	3.92
IR with Futures					0.75	0.69	1.0	9.32					0.45	0.68	1.0	5.15

Notes: IY designates individual-yield insurance, IR designates individual-revenue insurance, AY designates area-yield insurance and AR designates area-revenue insurance. Max indicates 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.