Reinsuring Group Revenue Insurance with

Exchange-Provided Revenue Contracts

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CARD Working Paper 99-WP 212

Center for Agricultural and Rural Development

Iowa State University

Contents

Tables

Figures

Abstract

Building on recent work by Mirand and Glauber (1997), this report shows that it is feasible to use exchange-based contracts as a substitute for the Standard Reinsurance Agreement (SRA). The contract we analyze here is a Group Revenue Contract, which would allow producers to guarantee against reductions in county-level revenues. The insurance company would then purchase put options on an exchange-based revenue contract to protect against statewide revenue shortfalls. The analysis suggests that this reinsurance tool would eliminate most though not all of the systemic risk associated with this product. The insurance company would have to purchase supplemental reinsurance to complement the exchange-based product, but the level of reinsurance needed would not be greater than under the current SRA. The use of this procedure would greatly reduce federal exposure to losses associated with the current SRA. Also, by allowing informed speculators to impute a fair level of price-yield correlation into the revenue contract and the options based on that contract, the ultimate cost of the product to farmers would be lower.

Key Words: exchange-based revenue, agricultural insurance, reinsurance, risk management.

REINSURING GROUP REVENUE INSURANCE WITH EXCHANGE-PROVIDED REVENUE CONTRACTS

In a recent paper, Miranda and Glauber (1997) showed that the presence of systemic risk in crop yields makes it financially unviable for private sector insurance companies to offer crop insurance without some form of reinsurance. Miranda and Glauber compare the commercial fund of the Federal Crop Insurance Commission (FCIC) Standard Reinsurance Agreement (SRA) with an exchange-traded state yield contract and show that the state yield contract performed substantially better as a potential reinsurance tool. This work is important because it shows that, at least potentially, a private sector alternative to federally provided reinsurance exists. Furthermore, any improvement in the effectiveness of the current reinsurance mechanism (the SRA coupled with exchange-based reinsurance) would presumably be passed on to producers in the form of lower premiums or improved retail products.

There are at least two barriers to the implementation of this idea. First, state insurance regulators effectively prohibit insurance companies from owning “speculative instruments” such as futures or options contracts. Second, the Risk Management Agency (RMA) currently subsidizes the premiums of RMA-approved crop and revenue products as well as the cost of selling the products. In order for an exchange-based reinsurance scheme to work, state regulatory agencies and/or federal regulatory agencies must be convinced that the idea can be implemented in a way that is prudent and financially sound.

The Miranda and Glauber research measures the effectiveness of alternative reinsurance tools using the coefficient of variation of total indemnities paid out net of any reinsurance payments received. Their study, however, does not provide much detail on exchange-based reinsurance. Regulators need more to convince them that the idea is prudent.

How Exchange-traded Reinsurance Works

Our study provides a detailed analysis of the way in which an exchange-traded reinsurance scheme would work. We also provide an analysis of the financial performance aspect from the perspective of the regulator, the insurance company, and the customer. The example we have chosen is to reinsure Group Revenue Income Protection (GRIP) through the purchase of put options on an exchange-offered state revenue contract. The insurance company sells a guarantee against lower than expected county-level revenues to Illinois corn farmers, and then reinsures the systemic component of revenue risk on a state-level revenue contract. The only difference between the example used here and that used in Miranda and Glauber is that our example focuses on revenue whereas their example focuses on yields. The key to understanding what follows is to understand how we differentiate between systemic and nonsystemic risk. Therefore, the following section provides an intuitive explanation as to how the final price of the product is allocated between these two components.

Procedures Used to Price the Product

We consider two separate pricing components. The first component is an estimate of the cost of protecting against declines in *state* revenue. This component is also the fair market value of a put option on an exchange-based revenue contract. The cost of this option will depend heavily on the degree to which county revenues move together. *The more highly correlated these county revenues, the more likely it is that state revenues will be lower than the strike, or the trigger, revenue when indemnities are to be paid.* On the other extreme, if county revenues were independent, the insurance company could effectively pool its risk and, theoretically at least, would not need any reinsurance. When county yields show some, but not perfect, correlation then the county correlation structure tells us how much of the total risk can be pooled and how much must be passed on to the exchange. The structure of cross-county correlations is therefore used to determine how much of the risk is systemic.

The second pricing component is the risk that can be pooled across *counties*, and is a measure of the degree to which county revenues move independently of each other. Payments will occasionally be made to customers in counties where revenues are low even though state revenues are high. In this situation, the premiums from the other counties are used to pay indemnities and no outside reinsurance is needed. This feature of the payment structure is called the *county wrap*.

In an ideal world these two pricing components would be fixed from year to year and the problem would be very simple. This is not the case. The parameters that determine the allocation of the final price of the two components are themselves uncertain. In particular, we do not know in advance how closely county revenues will move together in a certain year. To see why this is important consider a situation where all buyers purchase 90 percent coverage and where state revenues end up at 90 percent of expected revenues. Under this scenario, there will be no payments from the state revenue contract, but claims will be made on the county wrap. Now suppose that in all of those counties where claims are made, yields and revenues are equal to zero, while in the other half of the counties revenues equal 180 percent of expected revenues. This means that the insurance company will be faced with very large indemnities without any offsetting income from the options contract. Dealing with this problem proves to be both interesting and challenging.

The Data

U.S. corn and soybean yields have increased over time, as has the volatility of both yields and prices. Much as we need to incorporate yield increases into measures of expected revenues, we also need to adjust the historical data for changes in yield variability, price levels, and price volatility. For corn, we can obtain good estimates of expected price levels and price volatility from the Chicago Board of Trade (CBOT) futures and options markets, and these parameters are built into the product. Data on future yield and yield variability are not available and must be computed.

We used county data for Illinois corn yields from 1956-96 to implement the simulation model. The advantage of using actual county data is that county yield correlation structure occurring in each of the last 41 weather years is maintained. The disadvantage is that yields in the 1990s are not comparable to yields in the 1950s. Both expected yields and the standard deviation of yields have grown during this period.

To account for higher expected yields, we multiplied each county yield by the ratio of expected yield for that county in 1997 to expected yield in the year under consideration. Linear trends by crop reporting district were used in combination with county-specific intercepts to estimate expected yields. Multiplying by this factor "inflated" all yields to 1997 levels. Adjusting yields in this manner also inflated the standard deviation of yields. If the coefficient of variation of yields is constant—an implicit assumption that we make for each county—then this multiplication inflates the standard deviation by the exact amount to maintain a constant coefficient of variation.

Figure 1 shows the resulting state average yields for the 41 weather years, holding planted acreage constant at observed 1996 levels. The lowest weather years in this adjusted data set are 1970, 1975, 1980, 1983, and 1988, with 1991 and 1995 not too far behind. Figure 2 shows the resulting total production levels in each of the weather years.

The relationship between deviations from trend yields and deviations from expected price is critical to estimating how revenue insurance products will perform. Figure 3 shows how the futures market changed over each of the weather years from 1975 to 1996. The data show that futures markets declined over the growing season in 15 years and increased in 7 years of the 22-year period.

In major production regions one would anticipate that higher than expected yields would be associated with lower than expected prices and vice versa. This inverse relationship shows up quite clearly in Figure 4. Here, we compare the within-year change in the CBOT new crop corn contract (December of the current year) with the deviation from trend yield. Most observations appear in the upper left or lower right quandrants of Figure 4. However, the data for seven years show a positive price-yield relationship, and four appear in the lower left quandrant. These are years when prices and yields are below expectations, and large payouts on revenue products would result.

As we have mentioned earlier, the performance of the exchange-based reinsurance depends crucially on the variability of yields across counties in a given year. If all counties move together—that is, there is little county yield-basis relative to the state yield—then reinsurance is accomplished easily. Figures 5 and 6 show the degree to which county yields deviated from their expected level in each of the 41 weather years. Figure 5 expresses deviations in bushels per acre; Figure 6 expresses the deviations as a percentage of 1997 expected county yields.

There was only one year, 1983, when all Illinois counties had yields that were less than expected. And 1979 and 1982 were the only years when all Illinois counties had yields that were greater than expected. In all other years, some counties did better than expected and others did worse. Notice also how the distance from the top to bottom changes from year-to-year in Figure 6. That is, the within-year variability of deviations from expected yields caries dramatically across years. This instability makes exchange-based reinsurance more complicated than would be the case if the within-year, cross-county yield variability were constant form year to year. Figures 7 and 8 make this point in a more direct way, showing the standard deviation of yield deviations for each weather year. Figure 7 expresses the standard deviation in bushels whereas Figure 8 expresses it as a percentage of expected yield.

Reinsuring the Product

To stimulate the accuracy of the reinsurance tool, we assumed that the product was sold (a) in proportion to actual production and (b) in proportion to the IGF Insurance book of business. Then, for each weather year and associated set of county yields, we drew 399 price observations that were correlated with the state average yield in each weather year.[1] The degree of correlation was fixed at –0.58, as determined by the data shown in Figure 4. The unconditional expected price was held fixed at $2.90/bu., and the unconditional price volatility was held fixed at 20 percent. Conditional expected price deviated from $2.90 as state yields deviated from their 1997 value of 134.2 bu/ac according to the measured degree of correlation.[2]

This procedure gave us a distribution of county revenues where the cross-county correlations in actual revenues that occurred in a particular weather year were maintained. Given a set of county yields in a particular year and a particular draw from the price distribution, we can calculate (a) the indemnities (if any) paid in each county and (b) the offsetting profits made on the state revenue contract at the exchange. By repeating this step for all 399 price draws, we can compute the average indemnity for that year across all prices and the average profit from the exchange option. These data are shown in Table 1, assuming that 5 percent of each county's planted acreage was insured (National Agricultural Statistics Service [NASS] book of business).

Each panel in Table 1 shows the results for a particular weather year. The last three rows show (a) the average price over all weather years ($2.90), (b) the average indemnity paid out under the county Group Revenue Program (GRP) ($15.46), and (c) the average payment from the CBOT option ($11.50), which is taken to be the price that the insurance company would have to pay for such a put option. The average cost to the insurance company offering the county wrap (i.e., the excess of expected indemnities paid over profits made) is therefore $3.96.

Given that enough random deviates were used in the analysis that generated Table 1, the data shown in the last three rows are actuarially fair values of GRIP assuming that everyone chooses the 90 percent coverage level. The CBOT option would cost $11.50, to which the insurance company would add $3.96 to pay for the county wrap, bringing the average actuarially fair cost of GRIP at the 90 percent coverage level product to $15.46.

Notice that $3.96 is the average cost of the county wrap. If the insurance company charged only this value, there would be years when the insurance company would lose substantial money. The exchange-traded option protects against statewide revenue movements, leaving the company responsible for payments made under the county wrap. On average over a long enough period of time, these county wrap payments will equal $3.96, and they can be pooled.

In any one year, however, there is a possibility that the insurance company's exposure will be greater than $3.96. These bad years are caused by two factors. First, it may happen that state revenues are exactly 90 percent of expected revenues, meaning that no profits are made on the option but that payments must be made to some counties. Obviously, there are offsetting years when state revenues exceed the historic value (i.e., the extreme scenario discussed previously of having half the counties get 180 percent of expected revenues and the other half get zero).

Figures 9 through 13 demonstrate the effectiveness of the exchange-based reinsurance tool. Each figure represents a particular weather year: 1956, 1957, or 1988. For each weather year, we have a set of actual county yields. Given these yields and a draw from the price distribution, we can calculate indemnities and "profits" from the exchange-based put options. This allows us to calculate the loss-cost ratio for all possible outcomes.[3] Price is on the horizontal axis and loss-cost ratio is on the vertical axis. Figure 9 shows the loss-cost ratios for the NASS book of business in the 1956 weather year without any reinsurance. Yields in that year were such that as long as prices were above $2.50/bu. the company would have a loss-cost ratio less than one.

However, if prices fell below $2.50, the ratio would be greater than one, as more counties fell below the 90 percent trigger.

Figure 10 shows how the exchange-based option changes things. Now when price fall below $2.50/bu., profits are made on the put option position. These profits offset the losses associated with the additional claims and the insurance company is profitable at prices below $2.50/bu. However, there is a range of prices for the 1956 weather year that would have caused losses for the company. These prices were in the range from $2.50/bu. to $2.75/bu. In this price range the insurance company has purchased the options but is getting no payout because state revenues are above the strike price. In this range of prices, there are a number of counties where indemnities are paid in excess of the premium charges for the county wrap, so the loss-cost ratio is greater than one. For prices above $2.75, fewer and fewer county-level claims are made and the position becomes profitable again.

Figures 11 and 12 show the same situation as Figure 9 and 10 but for the 1957 weather year, which was a particularly bad one for Illinois corn yields. Therefore, prices would have had to be extremely high to avoid losses under the no reinsurance scenario. In the exchange-based reinsurance scenario (Figure 12) the loss-cost ratio gets as high as 1.7 in a narrow price range just above $3.00/bu.

Figure 13 overlays the loss-cost ratios under self-insurance and exchange-based reinsurance for 1988. This was a drought year in Illinois and throughout the Corn Belt, and given the extremely low yields, payments would have been triggered as long as prices were below $5.00/bu. The exchange-based reinsurance does a reasonable job in this year and the maximum loss-cost ratio is 2.5. This was the highest loss-cost ratio found for the exchange-based reinsurance scheme in the entire data set. Note how poorly the self-insurance scenario performed in 1988. At prices below $2.50/bu. the loss-cost exceeds 10, a value that very few insurance companies could live with.

The analysis described in this section makes no attempt to describe the likelihood of a particular price and the associated loss-cost ratio. For example, it may be that the prices that maximize losses in a particular year are extremely likely. To incorporate these probabilities we present the cumulative distribution function (CDF) for all possible loss-cost ratios in the entire data set. Figure 14 shows the CDF of loss-cost ratios assuming that sales were made in proportion to production (the NASS book of business) and that no reinsurance was purchased.

The vertical height under the curved line in Figure 14 shows the probability of having a loss-cost ration below the value shown on the horizontal axis. For example, there is about a 70 percent chance that the loss-cost ratio will be below one, the break-even value. Alternatively, there is a 30 percent chance of losing money in this scenario. There is about a 10 percent chance of a loss-cost ratio above three. These data support the conclusions drawn by Miranda and Glauber (1977). The presence of systemic risk in county revenues means that some form of reinsurance is needed in order to avoid catastrophic losses (loss-cost ratios in excess of three).

Figure 15 shows the CDF of loss-cost ratios assuming that the exchange-based option is used for reinsurance. We can see that this reinsurance tool is quite effective. The probability of a loss-cost ratio above two is only about 2 percent. There is no possibility of a loss-cost ratio in excess of three. This scenario, however, assumes that sales are made in proportion to each county's production.

Figure 16 shows how the results in Figure 17 change if we assume that sales are made in proportion to IGF Insurance Company's existing book of business for a similar product (GRP). Figure 16 looks quite different than Figures 14 and 15 because we now have a small probability of a *negative* loss-cost ratio, which can occur when the payout on the put options exceeds the sum of total indemnities paid plus the cost of the options. This could happen if the company sold product in a part of the state that was unaffected by drought. The presence of drought in the rest of the state would result in a payoff from the revenue option even though indemnities paid by the insurance company were small. Figure 16 also shows a small probability of a loss-cost ratio above three. This would occur when sales were made most heavily in a part of the state that was heavily affected by a localized drought. This is the mirror image of the scenario that led to negative loss-costs.

Figure 17 is similar to Figure 18 except that we substitute IGF's MPCI book of business for the GRP book of business. Again, we see a very small though positive probability of a loss-cost in excess of three. These latter two figures indicate that the reinsurance tool is not a perfect one and that some form of secondary reinsurance would be needed. However, note that the probability of a loss-cost ratio is excess of three in Figure 17 is only one-tenth as large as that in the no reinsurance scenario (Figure 14).

And, finally, Figure 18 shows the CDF of loss-cost ratios if the insurance company sold policies in Illinois according to the total FCIC book of business. Because this last book is closer to the NASS book of business, there is a rather low probability of a negative loss-cost ratio.

Table 1. Average price, indemnity, and payoff from put options

Weather Year		Amount
56	Average Price	2.99
	Average Indemnity	8.44
	Average Payoff from Put Option	6.23
57	Average Price	3.20
	Average Indemnity	19.83
	Average Payoff from Put Option	13.01
58	Average Price	3.12
	Average Indemnity	12.68
	Average Payoff from Put Option	9.08
59	Average Price	3.13
	Average Indemnity	15.70
	Average Payoff from Put Option	11.01
60	Average Price	3.18
	Average Indemnity	15.96
	Average Payoff from Put Option	12.49
61	Average Price	2.92
	Average Indemnity	11.00
	Average Payoff from Put Option	8.84
62	Average Price	2.77
	Average Indemnity	8.87
	Average Payoff from Put Option	7.48
63	Average Price	2.75
	Average Indemnity	9.57
64	Average Price	3.03
	Average Indemnity	14.81
	Average Payoff from Put Option	10.08
65	Average Price	2.71
	Average Indemnity	7.69
	Average Payoff from Put Option	6.35
66	Average Price	3.08
	Average Indemnity	15.05
	Average Payoff from Put Option	12.22
67	Average Price	2.37
	Average Indemnity	14.09
	Average Payoff from Put Option	11.51
68	Average Price	2.90
	Average Indemnity	10.27
	Average Payoff from Put Option	7.37
69	Average Price	2.76
	Average Indemnity	8.31
	Average Payoff from Put Option	5.66
70	Average Price	3.44
	Average Indemnity	24.30
	Average Payoff from Put Option	17.41
71	Average Price	2.67
	Average Indemnity	8.93
	Average Payoff from Put Option	6.92

Weather Year		Amount
72	Average Price	2.65
	Average Indemnity	8.69
	Average Payoff from Put Option	7.18
73	Average Price	2.82
	Average Indemnity	9.56
	Average Payoff from Option	6.94
74	Average Price	3.37
	Average Indemnity	22.80
	Average Payoff from Put Option	17.43
75	Average Price	2.56
	Average Indemnity	9.49
	Average Payoff from Put Option	7.64
76	Average Price	2.87
	Average Indemnity	13.52
	Average Payoff from Put Option	7.88
77	Average Price	2.99
	Average Indemnity	11.17
	Average Payoff from Put Option	5.39
78	Average Price	2.84
	Average Indemnity	9.72
	Average Payoff from Put Option	7.71
79	Average Price	2.40
	Average Indemnity	12.37
	Average Payoff from Put Option	11.27
80	Average Price	3.31
	Average Indemnity	26.56
	Average Payoff from Put Option	13.41
81	Average Price	2.58
	Average Indemnity	9.49
	Average Payoff from Put Option	8.50
82	Average Price	2.49
	Average Indemnity	9.93
	Average Payoff from Put Option	9.12
83	Average Price	3.54
	Average Indemnity	52.48
	Average Payoff from Put Option	40.93
84	Average Price	3.02
	Average Indemnity	10.30
	Average Payoff from Put Option	7.06
85	Average Price	2.51
	Average Indemnity	11.10
	Average Payoff from Put Option	9.69
86	Average Price	2.54
	Average Indemnity	10.08
	Average Payoff from Put Option	8.44
87	Average Price	2.70
	Average Indemnity	9.74
	Average Payoff from Put Option	7.57

Weather Year		Amount
88	Average Price	3.64
	Average Indemnity	71.24
	Average Payoff from Put Option	61.49
89	Average Price	2.97
	Average Indemnity	15.82
	Average Payoff from Put Option	7.39
90	Average Price	2.89
	Average Indemnity	9.79
	Average Payoff from Put Option	8.53
91	Average Price	3.28
	Average Indemnity	27.63
	Average Payoff from Put Option	12.18
92	Average Price	2.47
	Average Indemnity	11.00
	Average Payoff from Put Option	9.38
93	Average Price	3.07
	Average Indemnity	11.48
	Average Payoff from Put Option	6.91
94	Average Price	2.30
	Average Indemnity	15.60
	Average Payoff from Put Option	14.04
95	Average Price	3.27
	Average Indemnity	16.88
	Average Payoff from Put Option	14.30
96	Average Price	2.89
	Average Indemnity	11.92
	Average Payoff from Put Option	8.91
Total Average Price		2.90
Total Average Indemnity		15.46
Total Average Payoff from Put Option		11.50

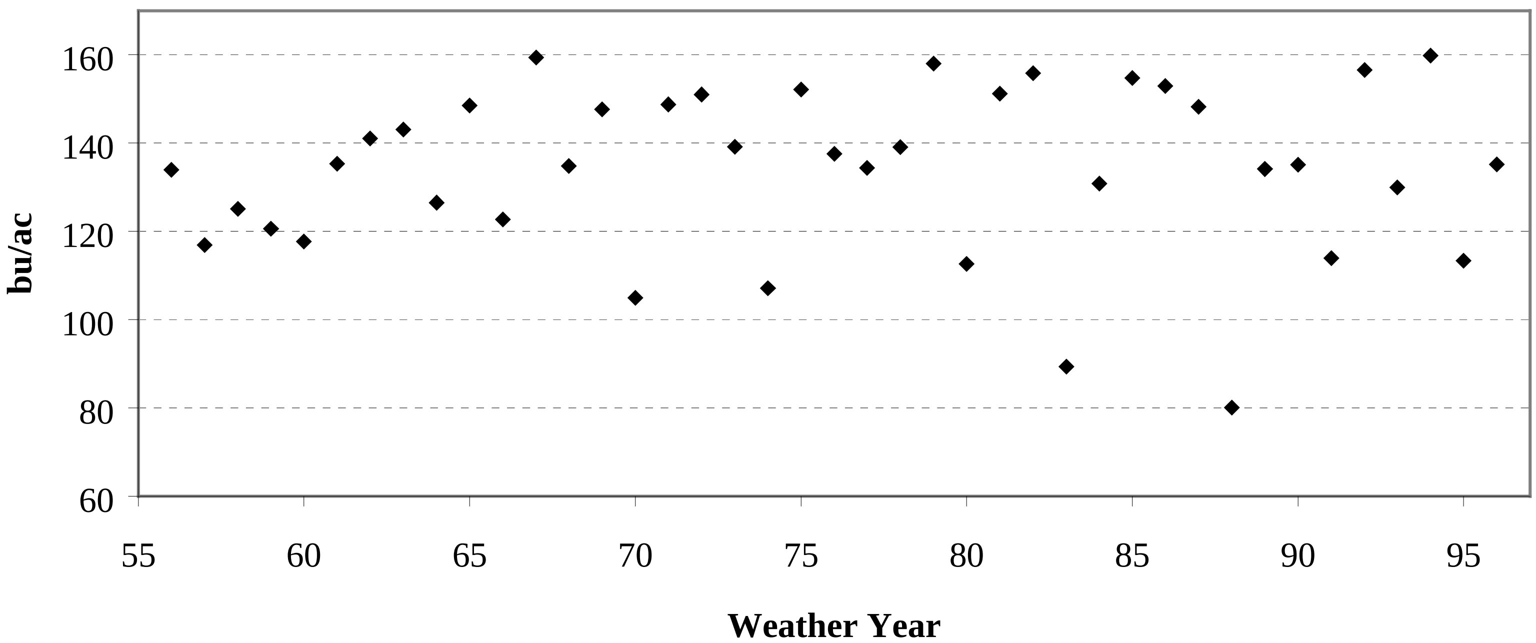

Figure 1. State average yields for Illinois corn at 1997 expected yields and yield volatility.

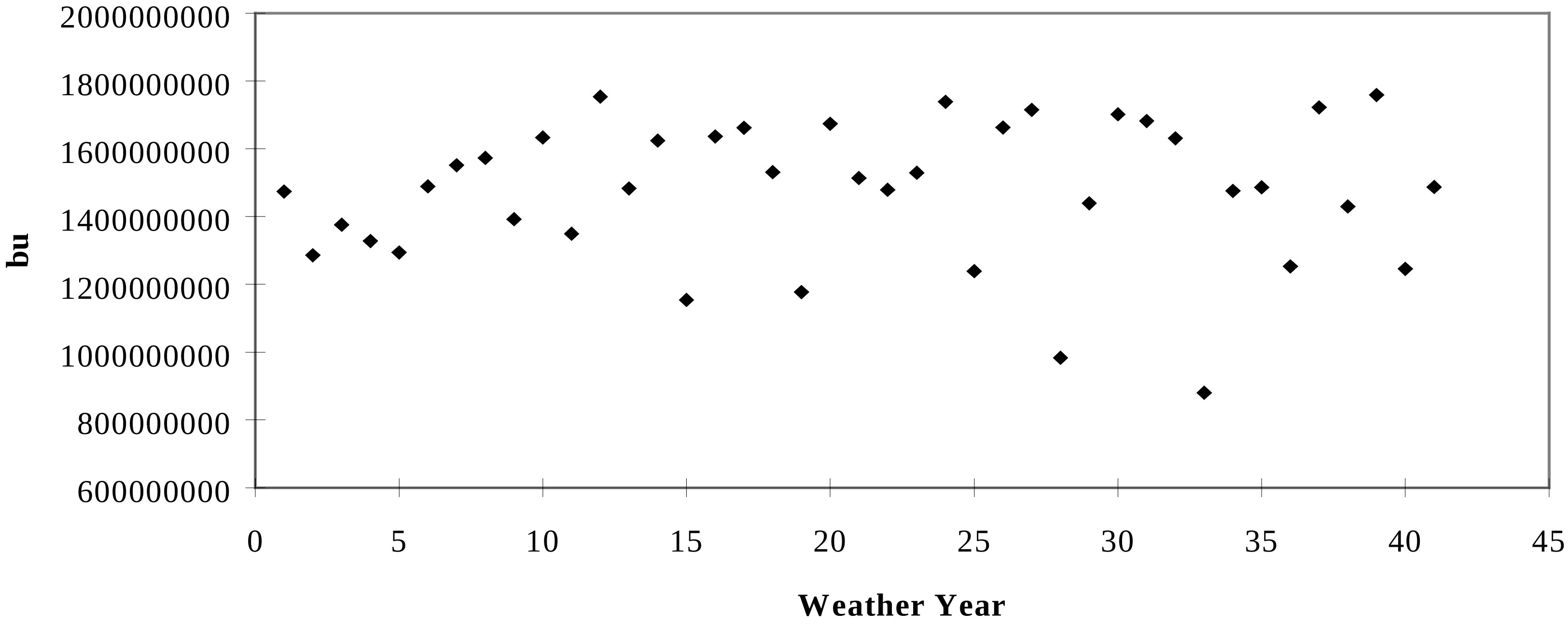

Figure 2. Production of corn in Illinois for the weather years in the data.

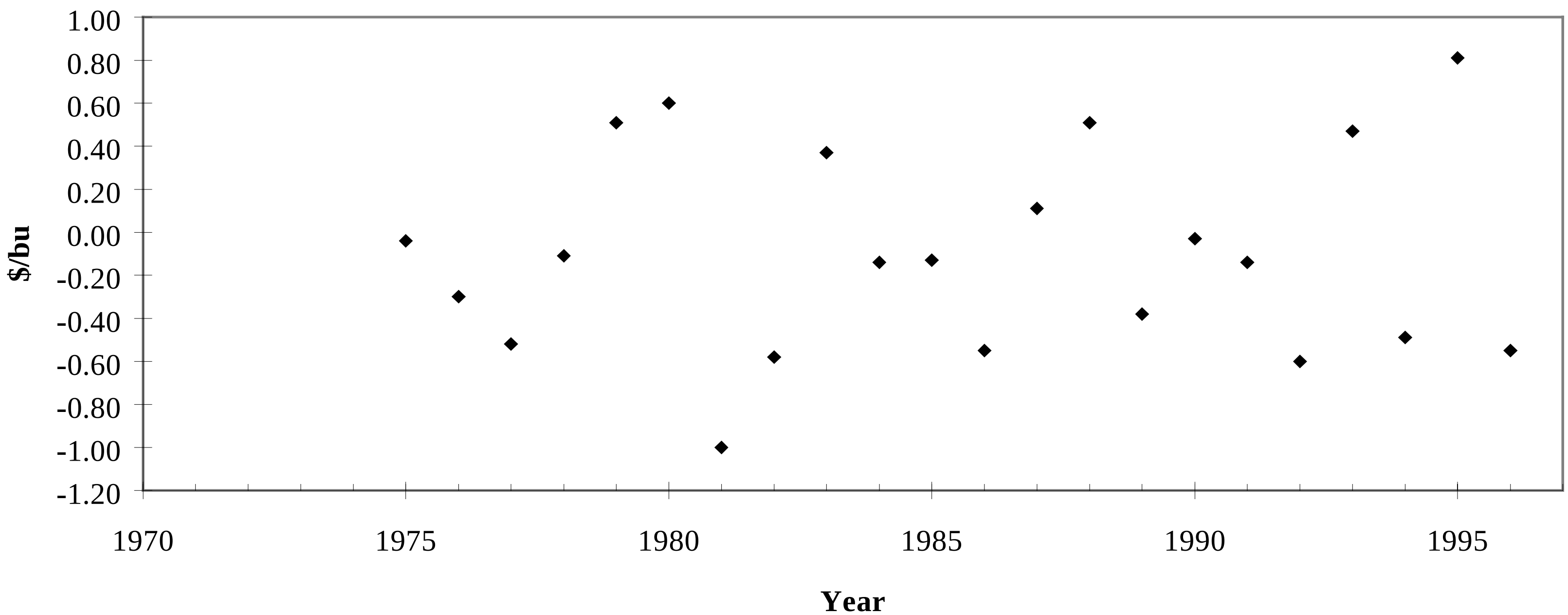

Figure 3. Deviation from expected price of corn: March to December futures.

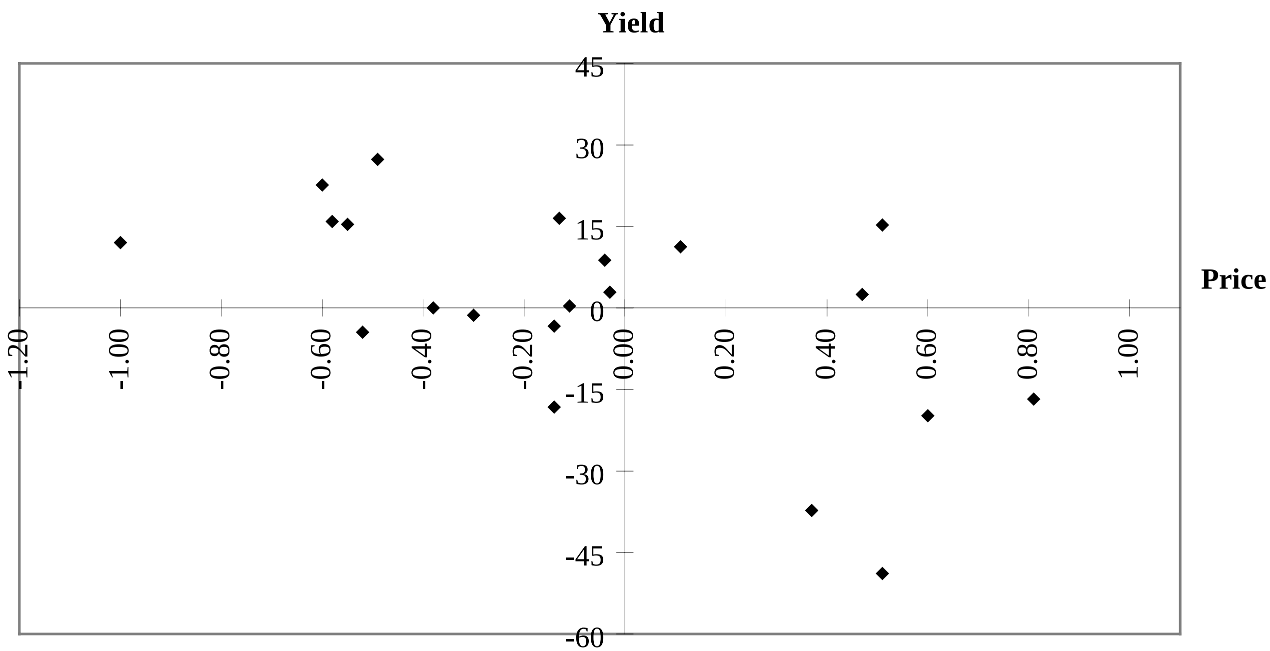

Figure 4. Yield vs. price deviations for Illinois corn yields and CBOT prices (1975-1995) (correlation coefficient = -.58)

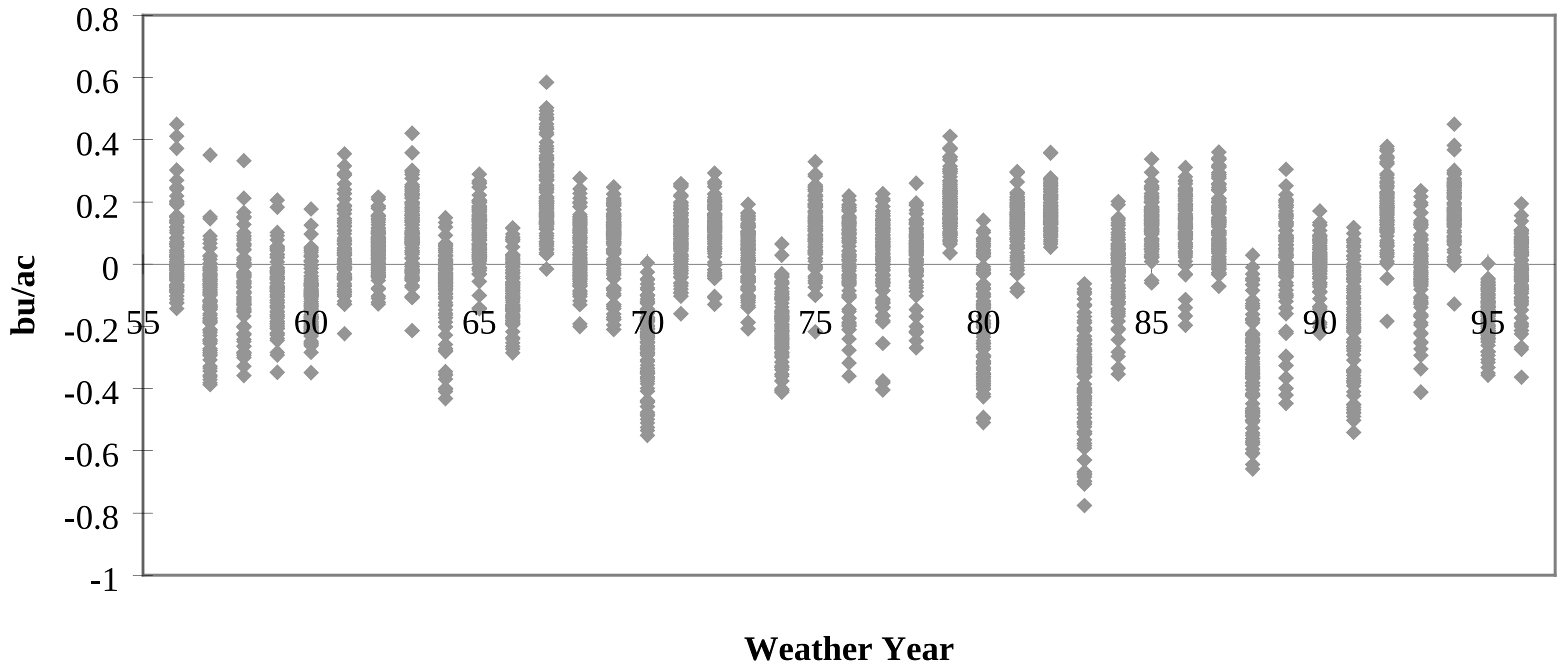

Figure 5. Deviations (bu/ac) from expected county yield for Illinois corn.

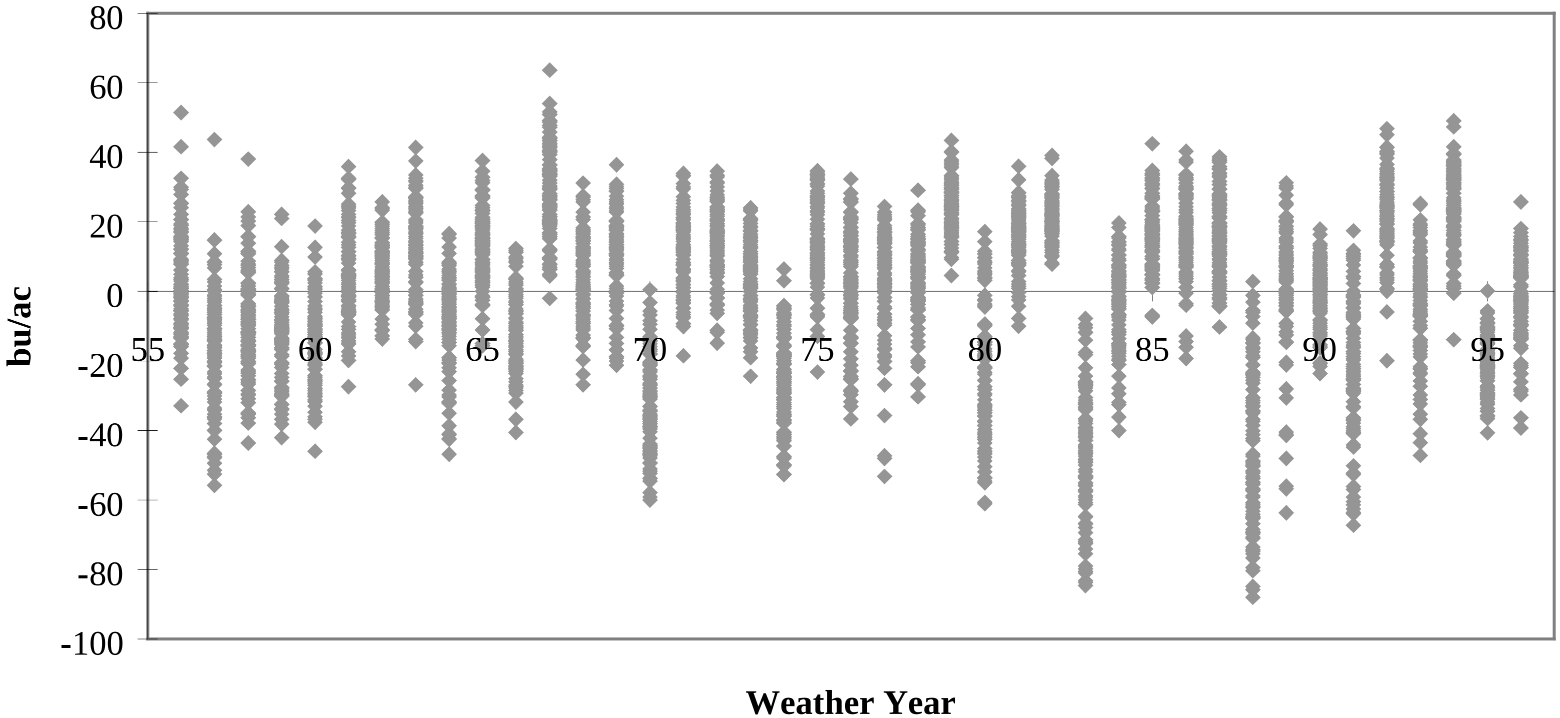

Figure 6. Deviations (% of expected yield) from expected county yield for Illinois corn.

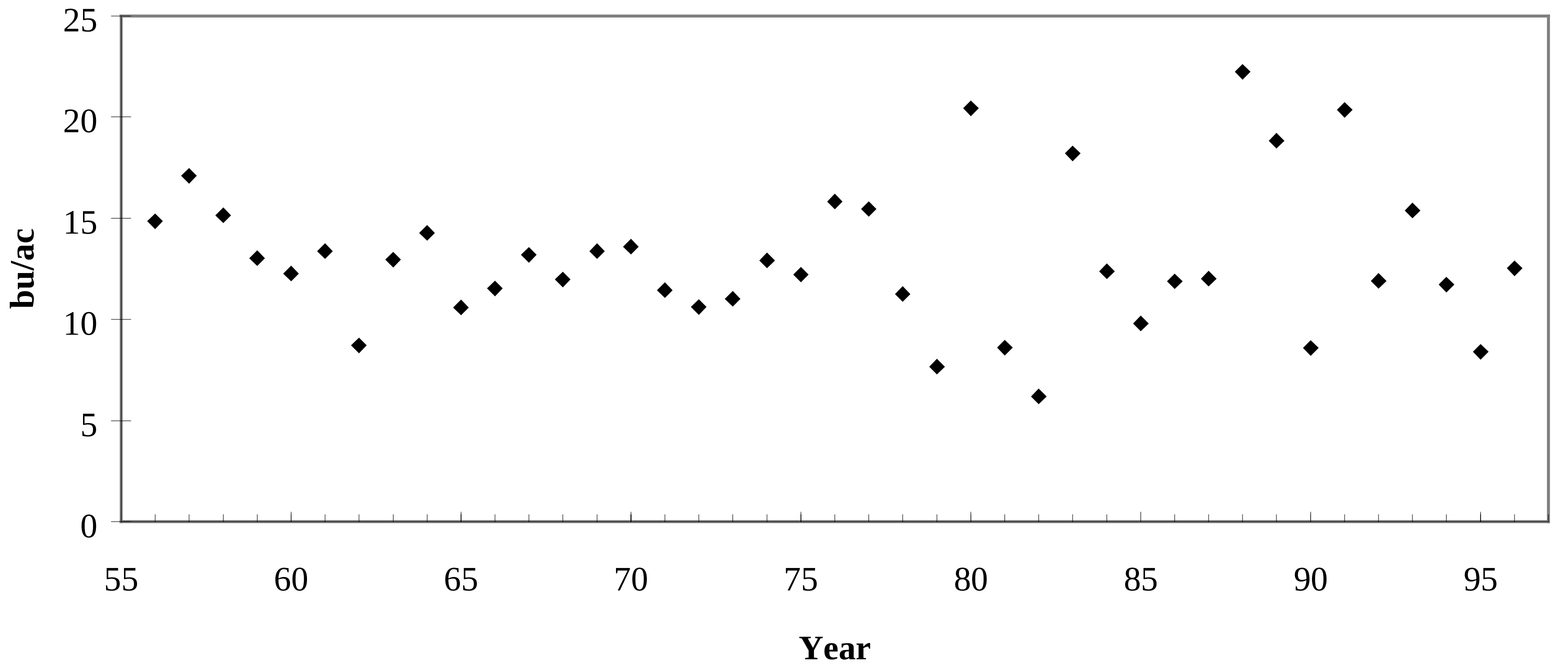

Figure 7. Within year standard deviation of deviations (bu/ac) from expected county yield.

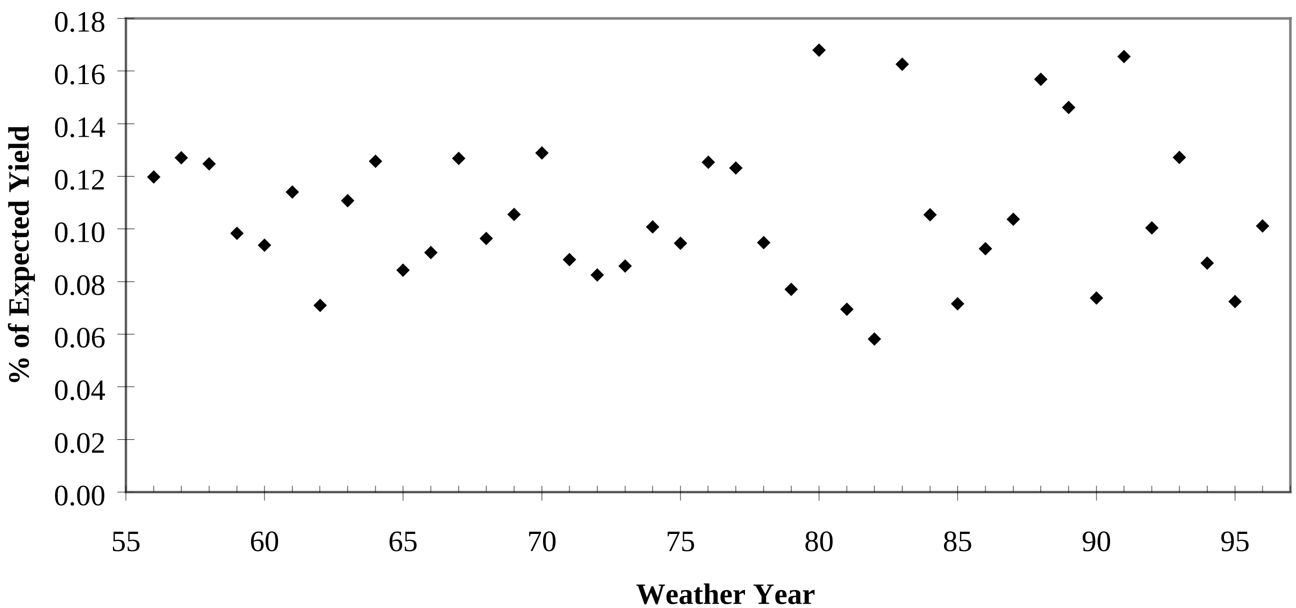

Figure 8. Within year standard deviation (% of expected yield) from expected county yield.

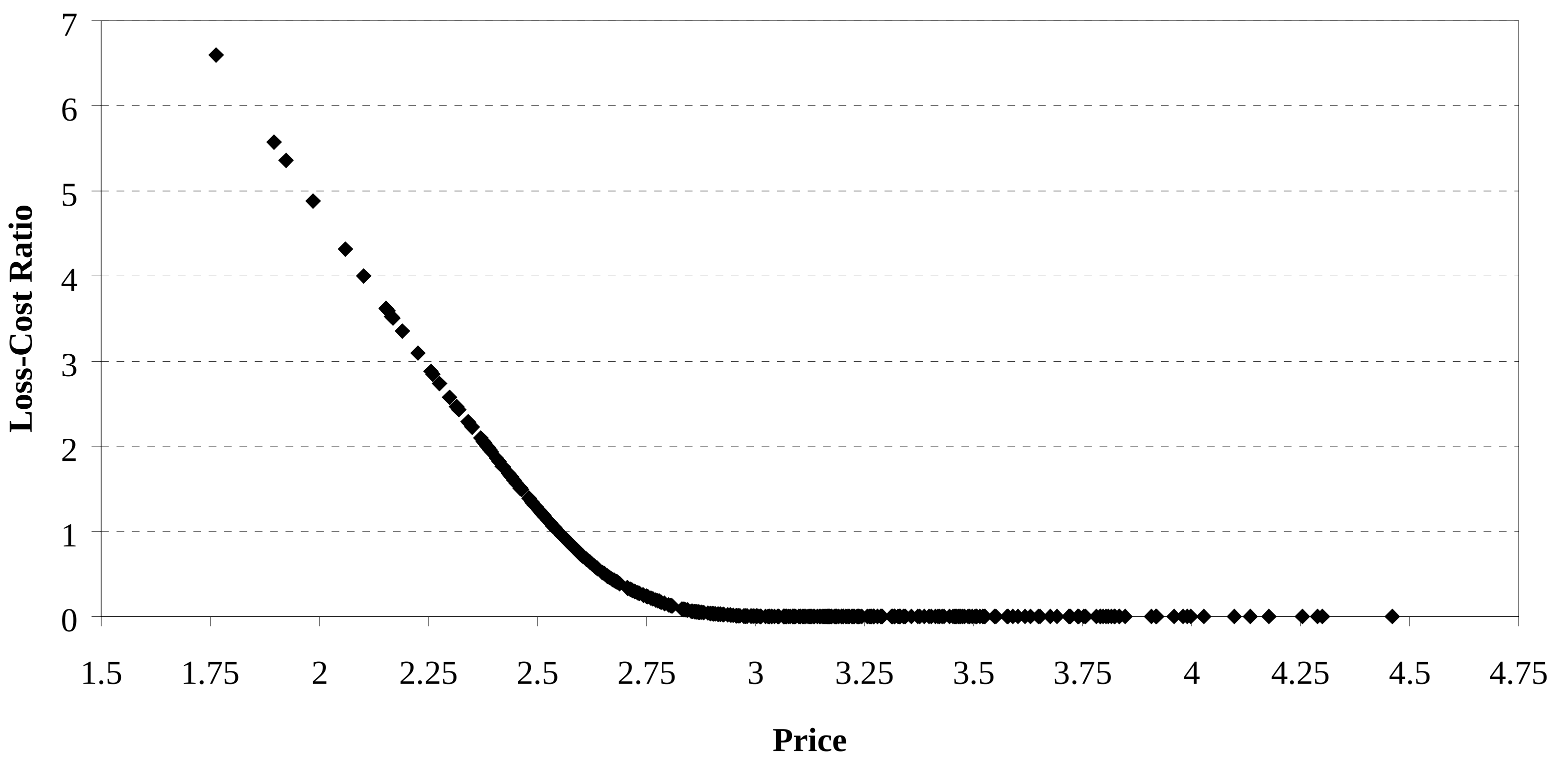

Figure 9. Loss-cost ratios from NASS Book of Business (weather year = 1956).

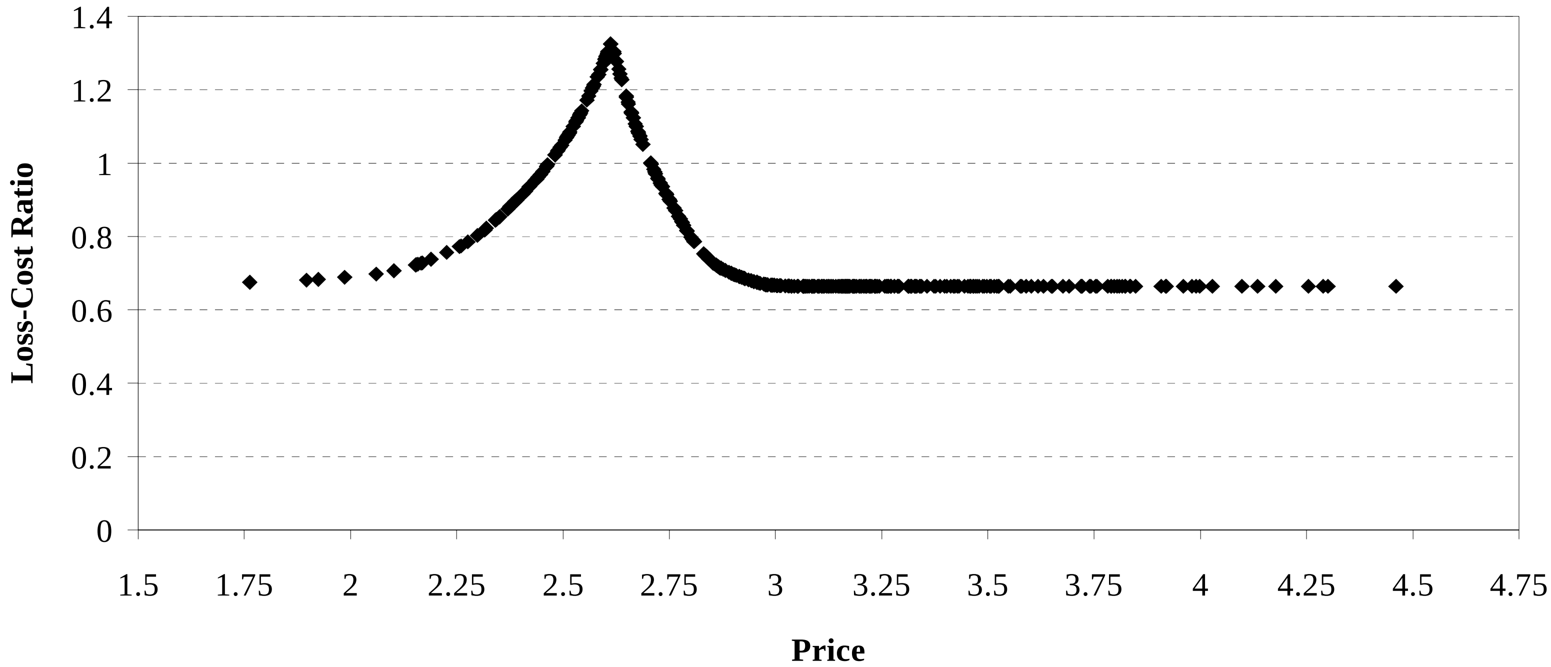

Figure 10. Loss-cost ratios from NASS Book of Business reinsuring with CBOT state revenue put options (weather year = 1956)

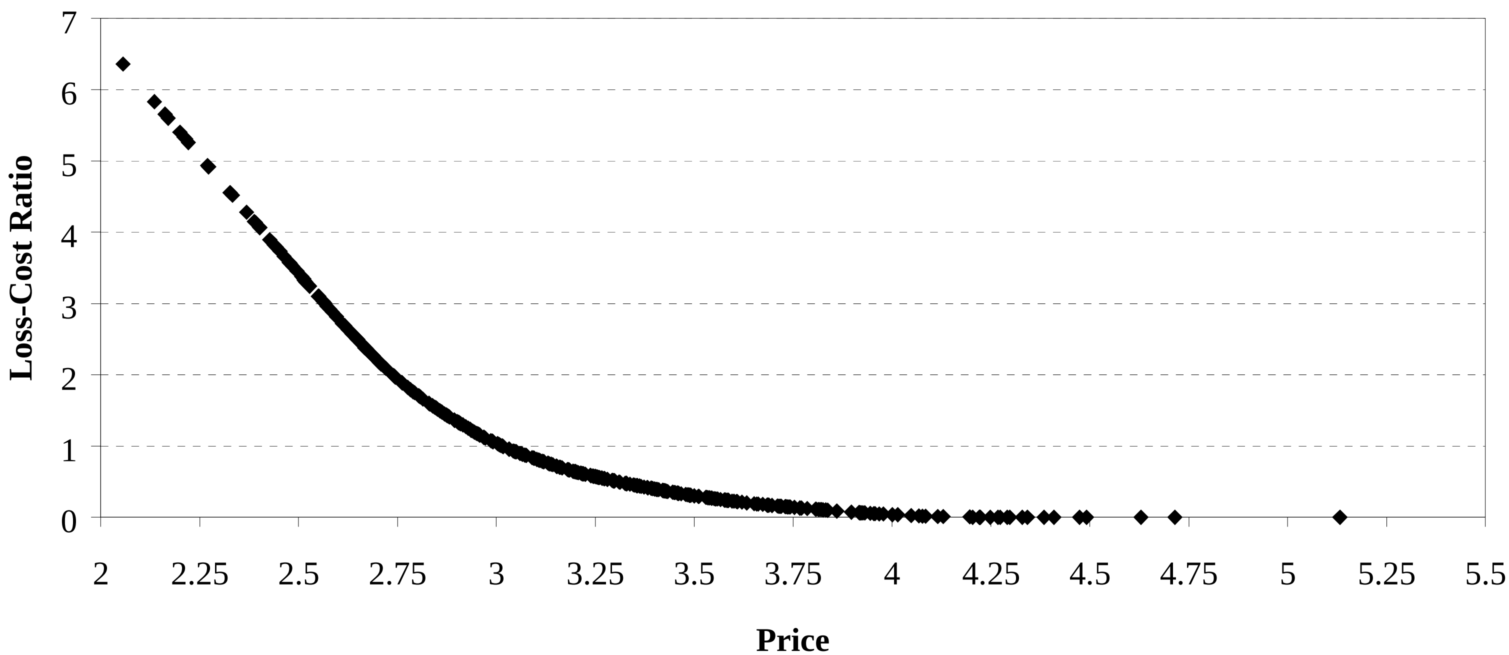

Figure 11. Loss-cost ratios from NASS Book of Business (weather year = 1957).

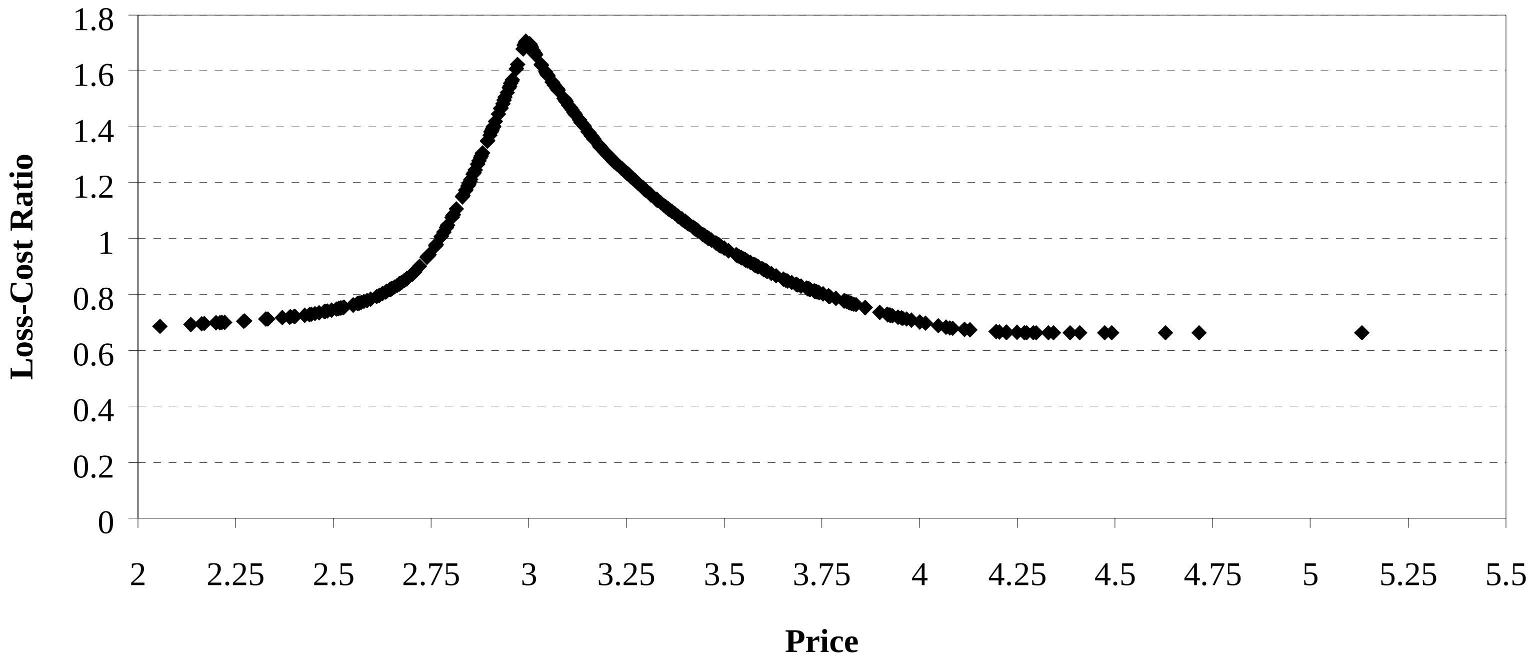

Figure 12. Loss-cost ratios from NASS Book of Business reinsuring with CBOT state revenue put options (weather year = 1957).

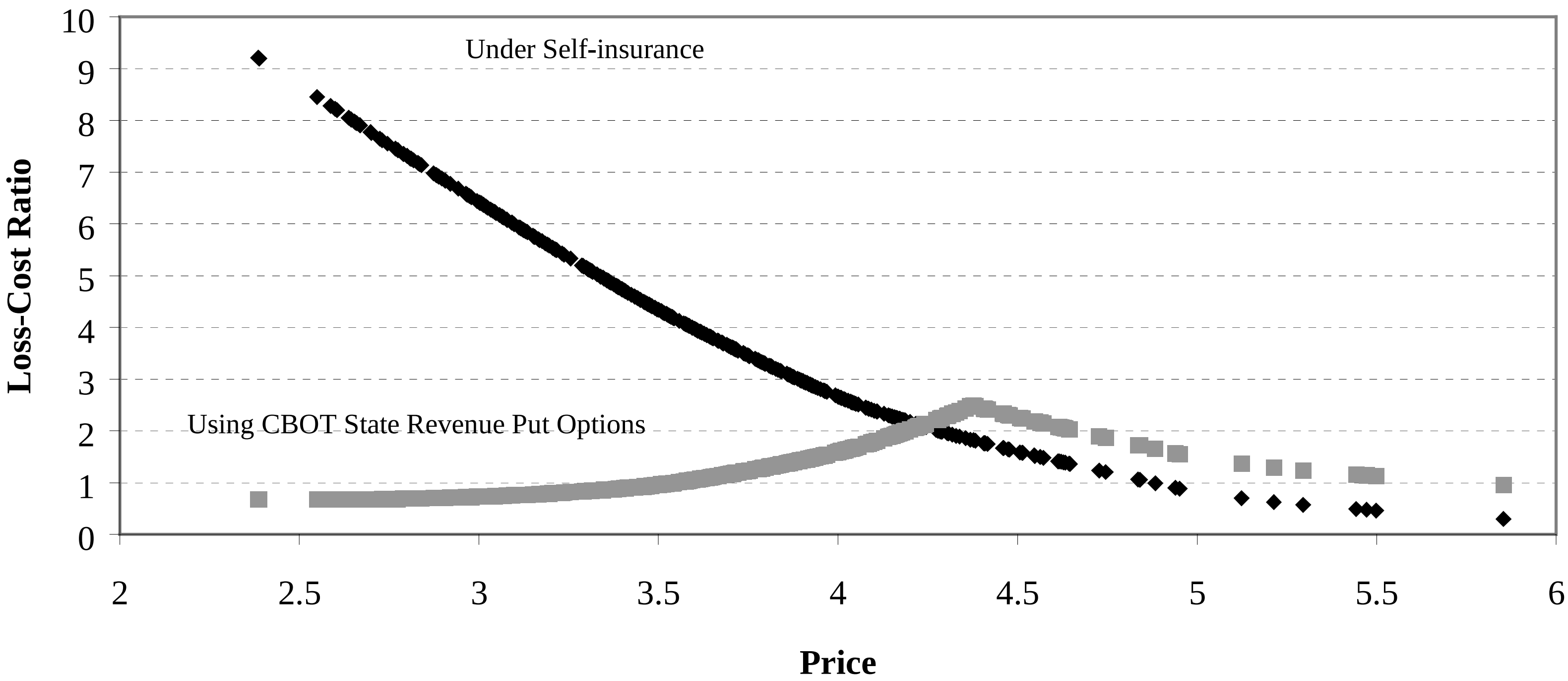

Figure 13. Loss-cost ratios for weather year 1988.

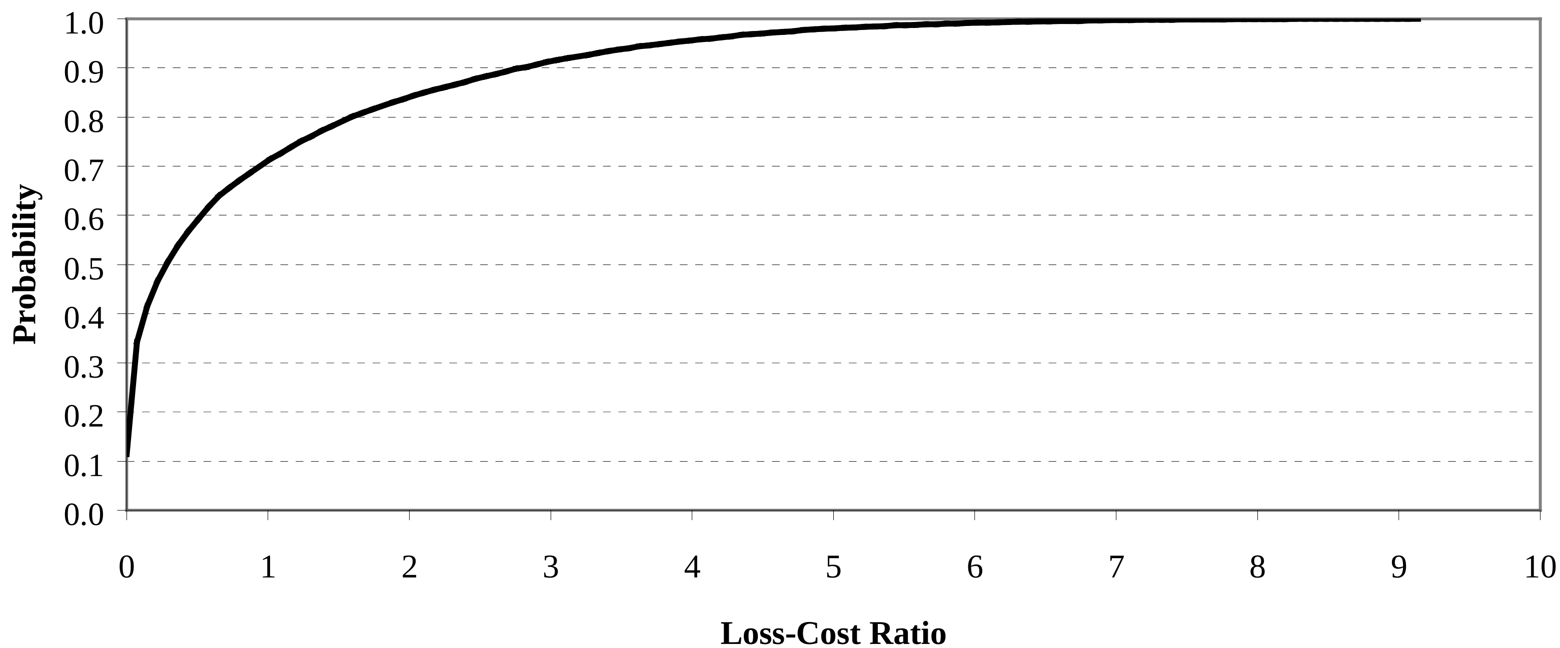

Figure 14. CDF of loss-cost ratios under self-insurance for NASS Book of Business.

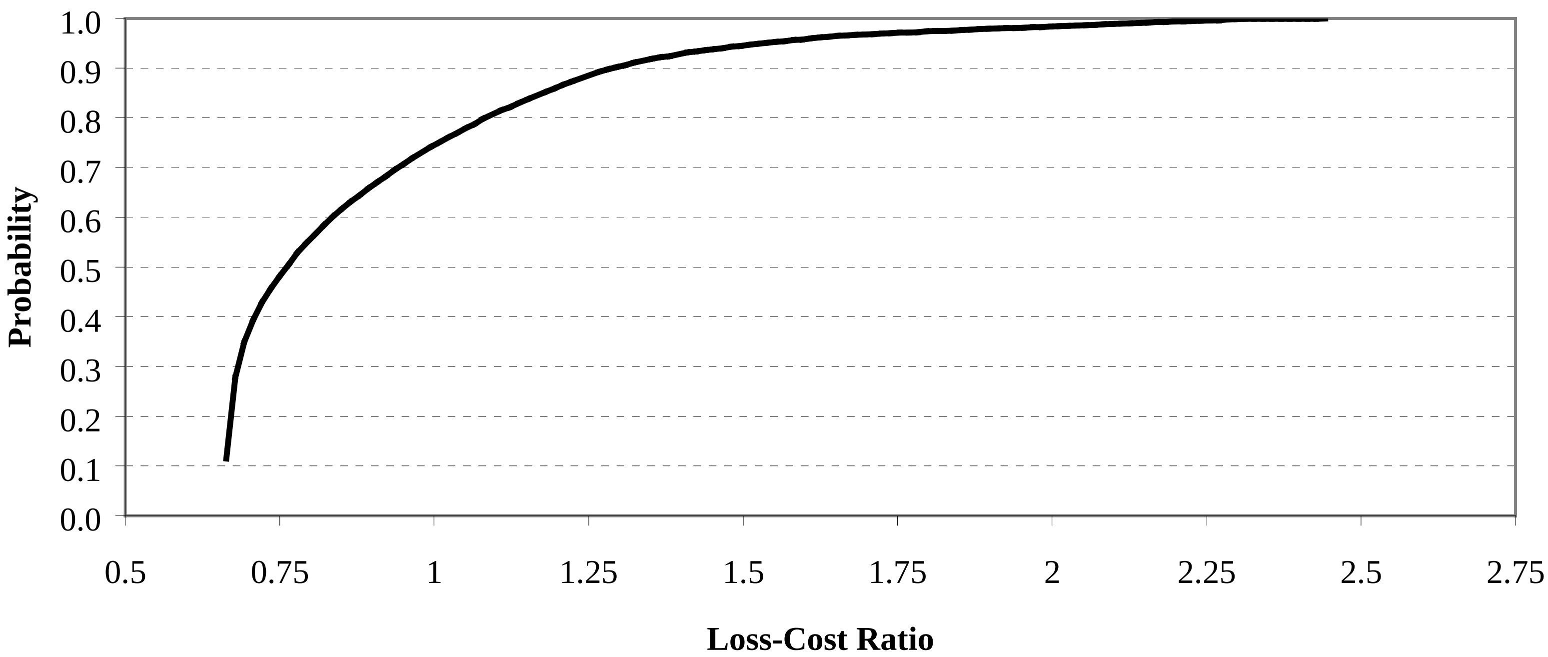

Figure 15. CDF of loss-cost ratios under NASS Book of Business reinsuring with CBOT state revenue put options.

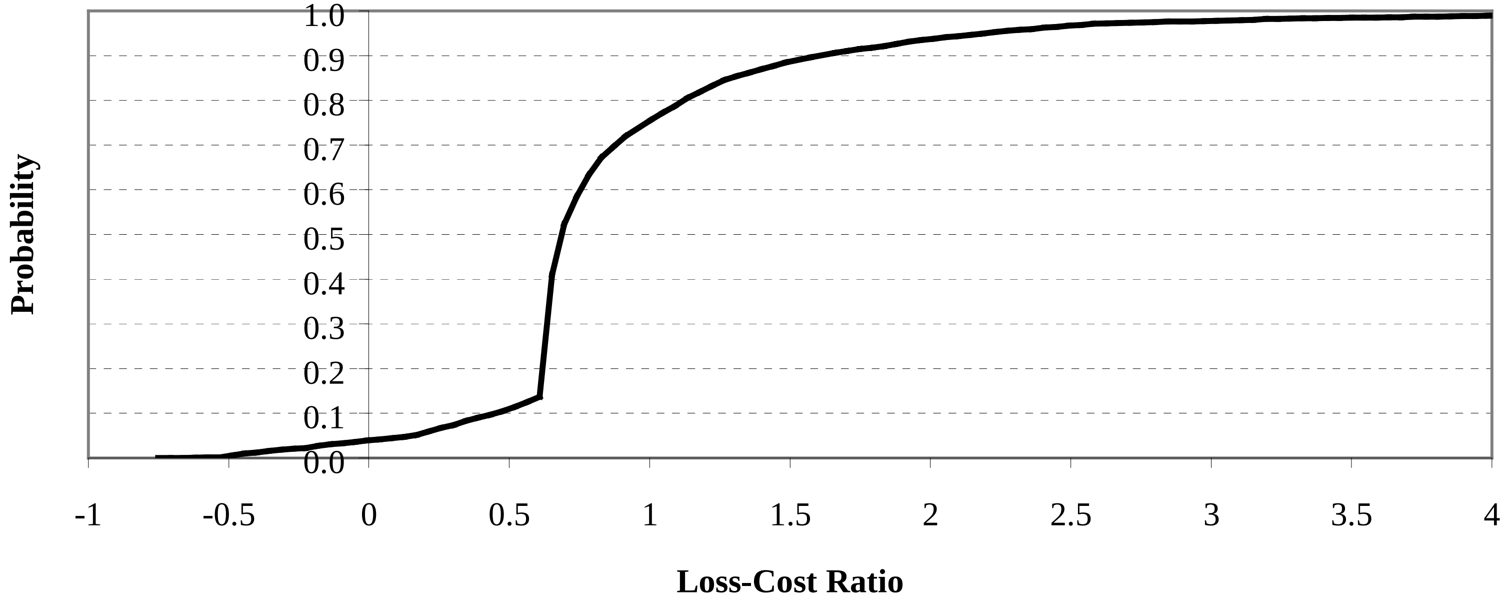

Figure 16. CDF of loss-cost ratios under GRP Book of Business reinsuring with CBOT state revenue put options.

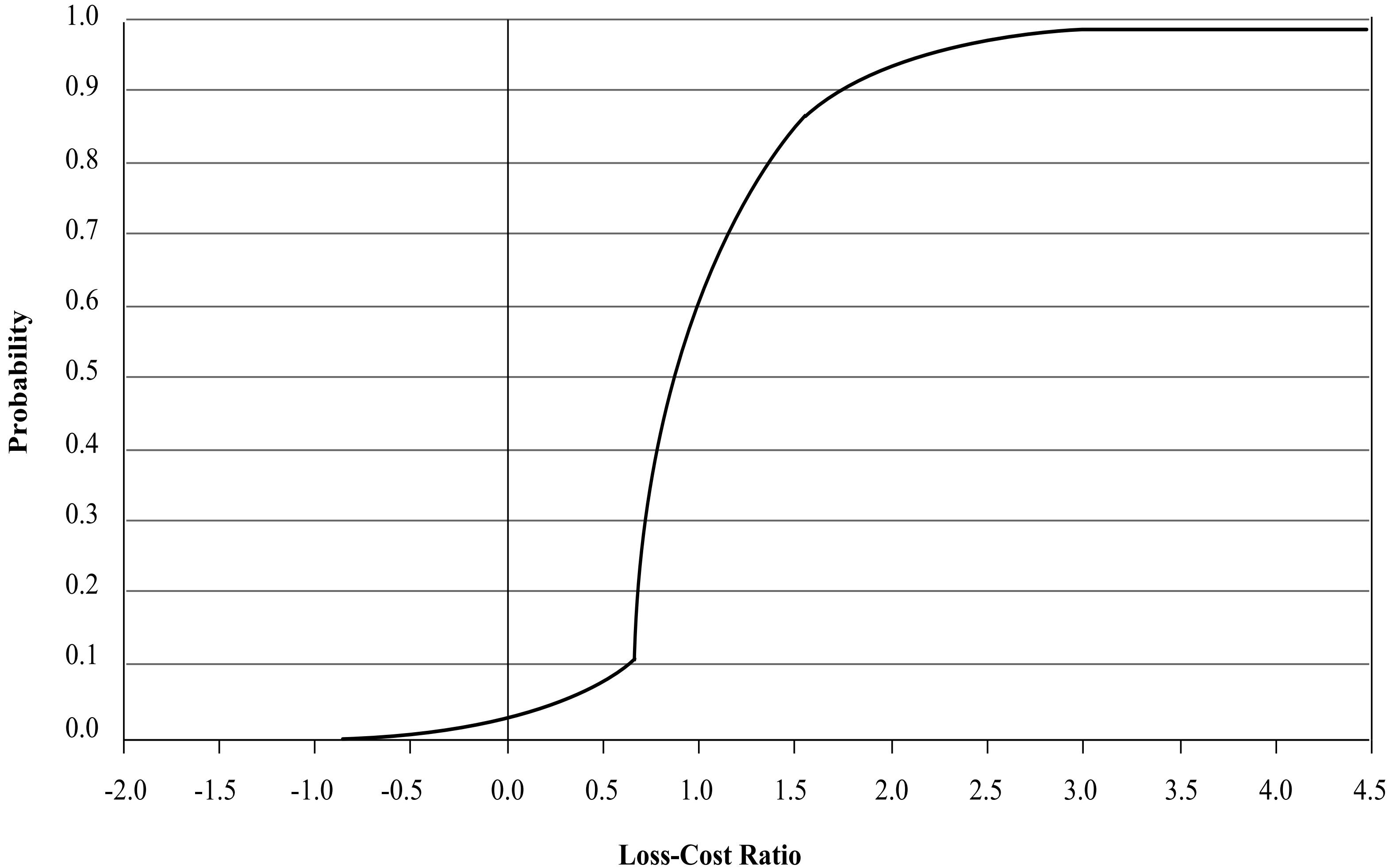

Figure 17. CDF of loss-cost ratios under MPCI Book of Business reinsuring with CBOT state revenue put options.

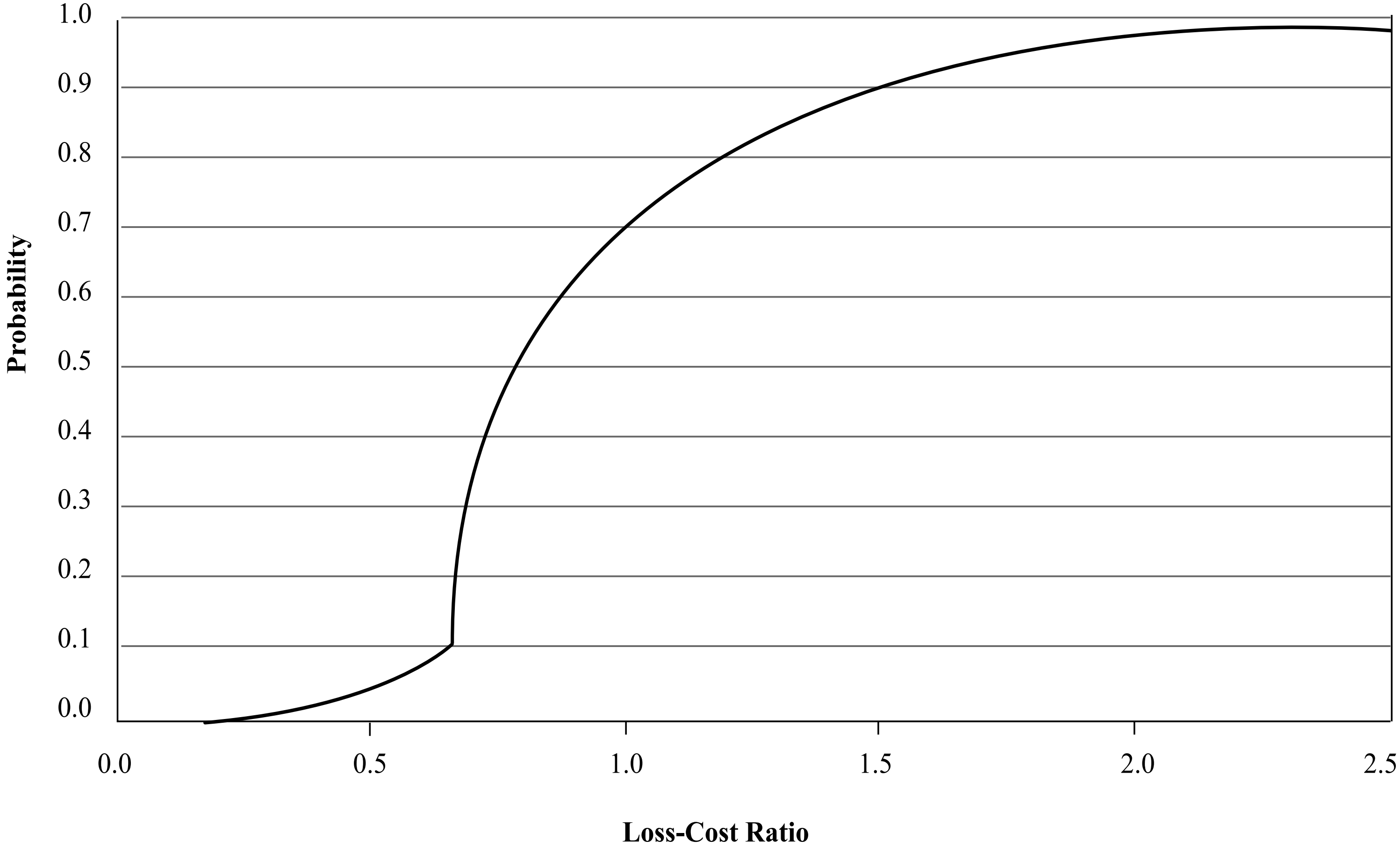

Figure 18. CDF of loss-cost ratios under FCIC Book of Business reinsuring with CBOT state revenue put options.

Endnotes

1. The odd number of price draws per weather year (399) was due to the limitation of the spreadsheet program used to conduct the analysis. This limitation has since been removed so that 1,000 prices per weather year were used in the actual county-level pricing of GRIP.

2. Note that this level of correlation is much greater than that which could prudently be used by a product insured by the SRA. This is true because we assume that speculators would be prepared to accept the risk associated with year-to-year changes in this correlation much as they accept risk due to year-to-year changes in price and price volatility.

3. We define the loss-cost ration as the ratio of indemnities paid to premiums received. We have included profits made on the put option net of the cost of these options in the numerator. The equation reads (Indemnities *minus* option cost *plus* option profits) *divided* by premium received. A value of one is a breakeven position, and a value of two means that losses exceed premiums received by a factor of two.

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