Journal of Agricultural and Applied Economics, 31,3(December 1999):519–535

Actuarial Effects of Unit Structure in the U.S. Actual Production History Crop Insurance Program

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ABSTRACT

This paper examines the effects of optional subdivision on APHP losses for wheat, corn, and soybeans. Thirty-seven state/crop programs are analyzed and the implications of the results are discussed in relation to newly developed crop and revenue insurance programs. The results illustrate the importance of incorporating actuarial experience into the premium rate structure and contract provisions of an insurance program.

Key Words: *Actual Production History Program* (APHP), *crop insurance programs*.

Beginning with passage of the Federal Crop Insurance Act of 1980, federally-subsidized and reinsured crop insurance programs have been given increasing prominence in U.S. farm policy. Over the past two decades, a continuing effort has been made to improve and expand these programs and elevate their role as a public policy response to crop producers' need for risk protection. To this end, availability of Actual Production History Program (APHP) coverage has been extended to more crops and regions, catastrophic coverage premiums have been fully subsidized, and a number of new yield and revenue insurance products have been approved for government premium subsidy and reinsurance.[1]

Contributing to an increased public policy emphasis on insurance programs is a widely held belief that several factors have combined

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The authors thank Haiping Luo, Shiva Makki, Agapi Somwaru, and Malini Nair for their assistance in developing datasets used in this research. Several members of the Federal Crop Insurance Corporation's Research Advisory Committee and an anonymous Journal reviewer also provided useful suggestions on the research and manuscript.

This manuscript is based on work supported by the USDA/ERS under Cooperative Agreement No. 43-3AEK-7-80027. Opinions, findings, conclusions or recommendations in this publication are those of the authors and do not necessarily reflect the view of the USDA.

[1] Throughout this paper, APHP is used to refer to the yield insurance coverage that, until recently, was commonly referred to as *multiple peril crop insurance* (MPCI). Over the past decade, the emergence of new 'multiple peril' insurance programs, including the Group Risk Plan (GRP), introduced in 1993; Catastrophic Coverage (CAT), introduced as a distinct derivative of APHP in 1995; Crop Revenue Coverage (CRC), introduced in 1996; Income Protection (IP), introduced in 1996; and Revenue Assurance (RA), introduced in 1997 has led to a shift away from the generic name MPCI. We use the acronym APHP rather than APH to distinguish the insurance program from the actual production history (APH) yield calculation method that is the basis for APHP coverage, but is also used to establish insured yields for CAT, CRC, IP, and RA coverage.

to create a more risky economic environment in U.S. agriculture. Prominent among these factors are recent trade policy initiatives and significant changes in U.S. commodity programs contained in the 1996 Federal Agricultural Improvement and Reform (FAIR) Act. Trade initiatives such as the North American Free Trade Agreement, enacted in 1994, and provisions of the Uruguay round of the General Agreement on Tariffs and Trade, which were also completed in 1994, are perceived to have increased risk through greater exposure of U.S. commodity markets to shocks in international markets (Glickman). The FAIR Act is perceived to have removed an important buffer against price risk through replacement of the longstanding deficiency payments program with transition payments that are not price-risk responsive.

Given a shift toward greater reliance upon insurance programs as instruments of public policy, it is not surprising that considerable attention has focused on the performance of those programs. Much of this attention has been directed toward various aspects of the APHP contract and premium rate structure that are considered problematic in regard to producer acceptance or actuarial soundness. One aspect of the APHP contract structure that has been the subject of significant controversy is how insurable units are defined. Two types of units are insured. For most major commodities, *basic* units consist of all acreage of the crop in a county held by the insured under identical ownership. For example, all of a farmer's interest in wheat on land which he or she owns or cash leases in a county is in one basic unit, while separate basic units are defined for each landlord on share-leased land. *Optional* units are subdivided basic units. The criteria for optional subdivision are based on location and production practices. Specifically, for most commodities optional subdivision is allowed for land in different sections, under rectangular survey,[2] and for irrigated versus dryland production.

Allowing insured farmers to have multiple, separately insured units has been criticized as an important source of excessive losses due to reduced spatial diversity and increased potential for fraudulent reporting of losses. Smaller, subdivided units are by nature less spatially dispersed than large units and, as a result, may be subject to higher losses because yields are more highly correlated within the unit. Losses may be fraudulently reported when a farmer who has several insured units shifts reported production from a unit on which a loss is being reported to another unit, on which there is no loss, in order to increase the insurance indemnity. Optional subdivision is viewed as particularly conducive to both fraudulent reporting and spatial effects because (a) optional units are configured with minimal spatial diversity (all land in the unit is in one section or, where section designations are not applicable, all land in the unit is often in a contiguous tract), (b) optional subdivision greatly increases the total number of insured units on many farms, hence increasing the likelihood that when a loss is experienced on one unit there will be other units, on which there is no loss, to which reported production can be shifted, and (c) shifting of reported production across optional units within the same basic unit on share-leased land is not inhibited by a necessity to defraud a landlord as well as the insurer.

One obvious solution to the potential problems created by insuring multiple units within a farm is to eliminate all subdivision and insure at the enterprise-unit (commodity) level. This solution has been considered and rejected. In 1986, the Federal Crop Insurance Corporation (FCIC) proposed a rule change to define insured units as all interest of a person in production of a commodity in a state. This proposal encountered vigorous opposition from farmers and the crop insurance industry. In 1989, the Commission for the Improvement of the Federal Crop Insurance Program was emphatic in recommending that unit subdivision be retained, stating: "The definition of an insurance unit and the ability to have optional units are two of the major policy provisions that determine whether the policy is useful to a producer." (p. 23)

[2] Where legal descriptions are not based on rectangular survey, alternative criteria such as Farm Services Agency farm serial number and non-contiguity are used to define insurable units.

Given that optional subdivision is allowed, equitable premium rates should reflect any difference in loss experience for optional and basic units. In 1988, the FCIC introduced into its rate structure a 10-percent surcharge for optional subdivision. Following recommendations of the Commission, this surcharge was replaced with a 10-percent discount for insuring at the basic unit level, beginning in the 1990 crop year. However, the 10-percent rate differential was established on the basis of very limited analysis. A more comprehensive analysis of the appropriateness of the differential for different crops and regions has several benefits: (a) it will help ensure an equitable APHP rate structure, (b) it will provide similar support for the rate structure of Crop Revenue Coverage (CRC), the federally subsidized revenue insurance product which has gained widest acceptance and which relies on the APHP unit definition and yield-rate structure, and (c) it will offer guidance in deciding whether new insurance products should incorporate unit definitions similar to those of APHP or whether a more aggregate unit structure should be used.[3]

This paper examines the effects of optional subdivision on APHP losses for the three largest insured crops: wheat, corn, and soybeans. In conducting this analysis, we use records on insured units in states comprising approximately 85 percent of APHP coverage (insured liability) on those crops. Importantly, this is the first time a data set of this magnitude has been constructed for use in examining any aspect of the APHP rate structure. Because of this, and because in specifying the model to analyze unit definition we incorporate other central elements of the rate structure, we also obtain results relating to several other important issues. Specifically, we are able to examine the appropriateness of (a) rates that are lower for insured units with high approved yields relative to the county yield (i.e., the yield-span or risk area structure of APHP rates which has been in effect for most crops since 1986 and has previously been examined by Skees and Reed, and Goodwin, using yield data rather than APHP actuarial data), (b) a penalty structure, adopted in 1994, for insureds who provide less than three years of yield data in establishing their insured yield, and (c) lower premium rates for irrigated versus dryland production.

The remainder of the paper is organized in four sections. First, we outline aspects of the APHP contract and rate structure that are important to our analysis. Next, we describe the data and estimation methods used. We then present results of our analysis of 37 state/crop programs and, in the final section, we offer suggestions on the broader implications of our results for established and newly developed crop and revenue insurance programs.

APHP Contract and Premium Rate Structure

Actual Production History Program coverage is currently available for 64 commodities with 670 state/commodity contract offerings.[4] Due to significant inherent differences in the biological processes involved in production of such a diverse set of plant species, it is not surprising that some aspects of the APHP contract are tailored to conform to these uniquenesses. It is beyond the scope of the present discussion to provide a comprehensive summary of contract provisions for all commodities. However, most essential contract provisions are uniform for major field crops, including those examined in this study. Our objective in this section is to provide a description of contract provisions applicable for the study crops during the 1992–1996 study period. For the purpose of conciseness, we further narrow the focus to defining terms and describing components of the contract and rate structure that have direct bearing on our analysis. For a more complete description of the history of the APHP and evolution of general APHP (and earlier MPCI) contract provisions,

[3] The IP insurance design does not allow separate units. Revenue Assurance does, but with substantially larger premium differentials than those for APHP and CRC.

[4] Information on state/crop programs is based on APHP sales experience for the 1997 crop year.

Table 1. Definition of Terms and Description of Components of the APHP Contract and Rate Structure Applicable for the 1992–96 Study Period

Component of Contract/Rate Structure	Description
Transitional Yield (t-yield)	• Proxi yields, based on county yields, that are used in determining the insured yield for a unit when actual historical yields are not available.
Actual Production History (APH) Yield	• Years 1992–93—average of 10 years of actual unit-level yields or t-yields. • Years 1994–96 — If 4 or more years of actual yields are provided then average of those yields. — If 3 years of actual yields are provided then average of 4 years of yields including the actual yields and a t-yield for the 4th year. — If 2 years of actual yields are provided then average of 4 years of yields including the 2 years of actual yields and 90% of t-yields for two additional years (i.e., t-yields penalized 10%). — If 1 year of actual yield is provided then average of 4 years of yields including the actual yield provided and 80% of t-yields for 3 additional years (i.e., t-yields penalized 20%). — If no actual yields are provided then 65% of average of 4 years of t-yields (i.e., t-yields penalized 35%).
Coverage Level	• Percent of APH yield insured. • Ranges from 35% to 75% during the study period.
Producer Premium Rate	• Tabulated county premium rate (with subsidy) for the coverage level. • Separate rates for specific production practices such as irrigated and dryland production. • Tabulated rates are also broken out by yield spans which are discrete categories based on the ratio of the APH yield to the historical average county yield. Rates decrease as the ratio of the APH to county yield increases. • 10% discount for basic versus optional units.
Price Election	• Price at which any insured yield loss is indemnified. During the study period, prices elections from 50 to 100% of an estimated harvest-period price were available to insureds.
Liability	• APH yield · coverage level · acreage · price election.
Indemnity	• (Max (0, APH Yield · coverage level − realized yield)) · acreage · price election
Loss-Cost Ratio	• Indemnity/Liability

the reader is referred to surveys by Gardner and Kramer, Goodwin and Smith, and Knight and Coble. Specific details of individual commodity programs can be found in various technical manuals available from the FCIC.

Components of the APHP contract and rate structure that have direct bearing on our analysis are described in Table 1. One mandate of the 1980 Act was that the FCIC move away from coverage based on a common yield for all farms in a county and toward individualized yield coverage. The procedure for determining the insured yield for a unit has evolved over time (Goodwin and Smith; Knight and Coble). Since 1986, insured yields for most major crops have been based on approved Actual Production History (APH) yields. In Table 1 we describe how the APH yield was calculated during the 1992–1996 study period. During this time the basic APH yield calculation was modified once, beginning with the 1994 crop year. An important feature of the calculation process adopted in 1994 is a 'penalty' structure for producers who provide less than three years of actual yields. In this penalty structure, t-yields (proxy yields, based on county yields, that are substituted for missing actual yields in the APH calculation) are factored downward, with progressively larger penalties the fewer actual yields provided. The purpose of these penalties is to encourage producers to provide actual yields, which are the intended basis for APHP coverage. The effect of the penalty structure for a producer whose average farm yield is equal to the county yield is a reduction in coverage or, in effect, an increase in the deductible on the policy.

Coverage levels from 35 percent to 75 percent of the APH yield were offered during the study period. Our analysis is restricted to the 65-percent and 75-percent levels because those coverages, in general, represented more than 95 percent of liability insured under the APHP. Producer premium rates are the subsidized premium rates per dollar of liability insured. These rates are conditioned on (a) the coverage level chosen, (b) production practices such as irrigated versus dryland production, (c) yield spans which are based on the relationship between the APH yield for the unit and the historical county average yield, and (d) optionally subdivided versus basic units. A 10-percent discount for basic versus optional units is a primary focus of our analysis.

Four additional terms are defined in Table 1. The *price election* is the price at which any insured yield loss is indemnified. The APHP *liability* is the product of the APH yield and coverage level (i.e., the insured or guaranteed yield) multiplied by acreage and the price election. The APHP *indemnity* is zero if the realized yield is greater than or equal to the insured yield. If the realized yield is less than the insured yield, then the indemnity is equal to the yield shortfall for the unit multiplied by the acreage and price election. The *loss-cost ratio* for an insured unit is the ratio of indemnity to liability. This is the measure of unit-level losses used in our analysis. Importantly, the expected loss-cost ratio is the actuarially fair, pure premium rate.[5] Thus, the estimated effect of a factor such as optional subdivision on the loss-cost ratio is its estimated effect on the actuarially fair premium rate.

Data and Estimation Methods

Here, we describe the data and estimation methods used in our analysis. Somewhat more attention than usual is devoted to examination of attributes of the data because detailed information on unit structure has not to our knowledge been reported elsewhere and is essential to understanding the implications of our results.

Data

Data used in the analysis were obtained from two sources. Actual Production History Program unit-level enrollment records, coverage information, APH yields, and indemnity records for the 1992–1996 crop years were obtained from the FCIC. National Agricultural Statistical Service (NASS) county yields for 1974–1996 were obtained from NASS databases. Variables included in the analysis of unit-level loss-cost ratios for 13 corn states, 14 soybean states, and 10 wheat states are defined in Table 2. Seven of the variables including *optional, 75-percent coverage level, percentage irrigated, risk-area ratio, 35-percent penalty, 20-percent penalty,* and *10-percent penalty* are incorporated into the models because the APHP premium structure, as described in Table 1, implies that expected loss-cost ratios (fair premium rates) differ among these factors.[6] *Yield ratio* is included to account for

[5] It should be noted that since acreage and price election enter multiplicatively into both the liability and indemnity they cancel out of the loss-cost ratio and, hence, do not affect the actuarially fair premium rate per dollar of liability.

[6] The role of *risk area ratio* in the APHP premium structure is important, meriting further elaboration. As indicated in Table 1 under the heading 'Producer Premium Rate,' the APHP rate table for a crop in a county contains rates that vary substantially across yield spans, which are discrete ranges of the ratio of insured unit APH yield to an historical average yield for the county. Risk area ratio is a continuous representation of this relationship, which is descretized by the FCIC for the purpose of presentation in APHP rate tables.

Table 2. Definition of Variables Included in Models of Unit-Level APHP Loss-Cost Ratios

Variable	Definition
Optional	Dummy variable equal to 1 if the unit is insured as an optional unit and 0 if insured as a basic unit.
75% Coverage Level	Dummy variable equal to 1 if the unit is insured at the 75% level and 0 if insured at the 65% level.
Percentage Irrigated	Continuous variable indicating the percent of liability in the insured unit that is on irrigated acreage.
Risk Area Ratio	Continuous variable equal to the ratio of the unit APH yield to the estimated county yield for the year.
35% Penalty	Dummy variable equal to 1 if a 35% penalty on t-yields was applied in the APH calculation due to provision of no actual yields in years 1994–96.
20% Penalty	Dummy variable equal to 1 if a 20% penalty on t-yields was applied in the APH calculation due to provision of only 1 year of actual yields in years 1994–96.
10% Penalty	Dummy variable equal to 1 if a 10% penalty on t-yields was applied in the APH calculation due to provision of only 2 years of actual yields in years 1994–96.
Yield Ratio	Ratio of actual to predicted county yield in the year.*
Ownership Share	Percentage share of crop on the unit owned by the insured.
Acreage	Total acres in the insured unit.
County	Dummy variables for each county in the state.
Year	Dummy variables for years 1992–96.

* Actual county yield is the NASS county yield for the year. Predicted county yield is a trend-adjusted predicted county yield for the year based on 23 years of NASS county yields.

general production conditions in each county and year. *Ownership share* is included to reflect differences in loss-reporting incentives for owners of a large interest in the production from a unit versus those whose ownership interest is small. *Acreage* is included to account for differences in losses that may result from pooling of larger, and perhaps more geographically dispersed, acreages and from differences in incentives to report losses (especially small losses) on small versus large units. County dummy variables are included to reflect differences in riskiness of production across counties, while year dummy variables account for any other year-specific environmental or program factors that might affect loss experience.

Table 3gives number of observations and means of all variables except year and county dummy variables. The number of observations in our state-level models ranges from 7,000 for Louisiana soybeans to more than 500,000 for Kansas wheat. The percentage of insured units that are optional units is similar for corn and soybeans and is somewhat higher in most wheat states. The percent of units insured at the 75-percent coverage level is less than 25 percent for most state/crop programs, but is as high as 84 percent for Washington wheat. Irrigated acreage was eliminated from the analysis in any state in which it accounted for less than 2 percent of insured liability. Among the remaining states, the percent of liability on irrigated acreage is highest for Nebraska corn, at 45 percent. *Risk area ratio* ranges from approximately 0.7 to 1.48, while the mean percent of units in each of the three APH penalty categories (*35% penalty, 20% penalty,* and *10% penalty*) is in the 4-percent to 12-percent range in most states. *Yield ratio* would take a value of 1.00 in a year when the actual yield was equal to the expected yield for that year. Average values of the variable at the state level, across all years, range from 0.84 for Oklahoma wheat to 1.24 for Mississippi soybeans. Average ownership share of insureds is in the 60-percent to 96-percent range for all crops and states. Average acreage in insured

Table 3. Number of Observations and Means of Variables in State-Level Models of Unit-Level APHP Loss-Cost Ratios

	Number of Observations and Means of Variables Included in Models of Corn Loss-Cost Ratios												
Variable/Statistic	IL	IN	IA	KS	MI	MN	MO	NE	ND	OH	SD	TX	WI
Number Obs. (1,000s)	225	95	450	76	11	234	50	278	11	52	130	26	34
Optional	0.35	0.53	0.49	0.47	0.70	0.63	0.35	0.61	0.60	0.49	0.57	0.32	0.55
75% coverage level	0.53	0.42	0.34	0.05	0.06	0.08	0.05	0.07	0.02	0.27	0.02	0.05	0.04
% Irrigated	—	—	—	37.7	2.7	—	—	45.4	10.1	—	2.9	29.0	—
Risk Area Ratio	0.94	0.89	0.91	0.74	0.83	0.87	0.80	0.80	0.71	0.91	0.80	0.96	0.82
35% Penalty	0.05	0.06	0.04	0.13	0.07	0.06	0.10	0.06	0.08	0.06	0.07	0.12	0.09
20% Penalty	0.04	0.05	0.04	0.08	0.08	0.05	0.06	0.06	0.06	0.06	0.05	0.09	0.11
10% Penalty	0.05	0.06	0.04	0.07	0.07	0.04	0.05	0.05	0.05	0.06	0.05	0.07	0.09
Yield Ratio	1.05	1.03	0.99	0.96	0.93	0.95	1.02	0.94	0.86	1.03	1.03	1.22	1.00
Ownership Share	60.5	71.3	71.7	63.9	90.5	81.5	66.3	68.0	80.6	78.1	71.2	62.5	95.9
Acreage	71	62	74	72	48	74	58	77	78	51	71	106	55

	Number of Observations and Means of Variables Included in Models of Soybean Loss-Cost Ratios													
Variable/Statistic	AR	IL	IN	IA	KS	LA	MI	MN	MS	MO	NE	NC	OH	SD
Number Obs. (1,000s)	11	166	75	358	110	7	9	194	8	62	174	9	56	104
Optional	0.45	0.32	0.49	0.45	0.38	0.37	0.85	0.66	0.55	0.37	0.48	0.66	0.48	0.54
75% coverage level	0.09	0.49	0.37	0.34	0.07	0.03	0.05	0.17	0.07	0.09	0.18	0.23	0.24	0.03
% Irrigated	32.7	—	—	—	4.9	9.4	—	—	17.0	—	24.0	—	—	—
Risk Area Ratio	0.74	0.94	0.91	0.92	0.81	0.80	0.83	0.96	0.77	0.90	0.86	0.73	0.93	1.05
35% Penalty	0.12	0.06	0.07	0.05	0.11	0.08	0.09	0.06	0.10	0.08	0.08	0.25	0.05	0.07
20% Penalty	0.07	0.05	0.07	0.05	0.08	0.04	0.08	0.05	0.07	0.06	0.07	0.12	0.06	0.06
10% Penalty	0.06	0.06	0.07	0.04	0.07	0.04	0.07	0.05	0.05	0.06	0.07	0.07	0.06	0.07
Yield Ratio	1.07	1.02	1.02	1.01	1.07	1.11	0.95	0.98	1.24	1.04	1.01	0.96	1.01	1.19
Ownership Share	70.2	59.4	71.3	70.2	63.5	77.4	84.6	80.9	89.7	67.2	64.6	87.6	74.6	69.3
Acreage	130	63	53	65	46	103	47	74	166	65	44	37	55	67

Table 3. (Continued)

Variable/Statistic	Number of Observations and Means of Variables Included in Models of Wheat Loss-Cost Ratios									
	CO	KS	MN	MT	NE	ND	OK	SD	TX	WA
Number Obs. (1,000s)	46	503	77	77	140	461	126	87	69	16
Optional	0.68	0.53	0.77	0.75	0.53	0.82	0.64	0.71	0.49	0.36
75% coverage level	0.01	0.05	0.06	0.39	0.09	0.08	0.06	0.01	0.01	0.84
% Irrigated	9.1	3.0	—	3.8	3.2	—	2.8	—	29.3	4.2
Risk Area Ratio	0.99	1.05	1.10	1.03	1.00	0.93	1.20	0.86	1.48	0.83
35% Penalty	0.06	0.05	0.07	0.08	0.08	0.05	0.09	0.09	0.08	0.07
20% Penalty	0.04	0.04	0.04	0.05	0.06	0.04	0.06	0.06	0.06	0.04
10% Penalty	0.04	0.04	0.04	0.04	0.06	0.04	0.07	0.05	0.06	0.04
Yield Ratio	0.93	0.96	0.98	1.19	0.99	1.04	0.84	1.01	1.00	1.03
Ownership Share	65.2	59.3	81.9	69.3	63.9	73.1	67.5	74.8	63.8	49.6
Acreage	129	82	109	170	69	113	110	101	134	321

Table 4. Summary of Effect of Optional Unit Subdivision on Average Size of Insured Units

State	Mean of Unit Size		
	Basic Units That Will Be Subdivided (Acres)	Subdivided Units (Acres)	Basic Units That Are Not Subdivided (Acres)
Corn States			
Illinois	248	69	72
Indiana	309	63	61
Iowa	260	73	76
Kansas	279	79	66
Michigan	349	49	47
Minnesota	302	73	76
Missouri	239	60	57
Nebraska	314	78	76
N. Dakota	324	81	73
Ohio	364	53	50
S. Dakota	308	74	67
Texas	411	111	103
Wisconsin	267	47	64
Soybean States			
Arkansas	489	121	137
Illinois	209	61	65
Indiana	249	54	51
Iowa	212	64	66
Kansas	173	51	44
Louisiana	458	118	95
Michigan	306	49	45
Minnesota	318	74	75
Mississippi	632	146	191
Missouri	282	67	65
Nebraska	150	44	44
N. Carolina	201	32	46
Ohio	288	55	55
S. Dakota	279	69	65
Wheat States			
Colorado	596	132	121
Kansas	311	84	81
Minnesota	707	118	79
Montana	869	168	175
Nebraska	255	73	64
N. Dakota	632	112	117
Oklahoma	509	110	109
S. Dakota	620	107	86
Texas	584	139	128
Washington	837	266	353

corn units is less than 100 for all corn states except Texas. Size of insured soybean units is also substantially less than 100 acres in Midwestern states but is larger in Mississippi Delta states. Insured wheat units are larger, particularly in Montana and Washington.

The means reported in Table 3 do not provide a sense of the variability of the data across counties and insured units. Because of the number of state programs included in the analysis, economy of presentation does not permit a thorough reporting of all descriptive statistics in this paper. However, we do consider it important to provide a clearer picture of the effect optional subdivision has on the APHP unit structure. Of particular interest is a comparison of the size of basic units that are not subdivided with those that are subdivided and insured as optional units. Tables 4 and 5 provide this information. Table 4 shows the effect of optional subdivision on average insured unit size for all states. In Illinois corn, for example, the mean size of basic units that are optionally subdivided is 248 acres before subdivision. After subdivision, the mean size of the optional units into which these relatively large basic units are split is 69 acres, compared with a mean size of 72 acres for basic units that are not optionally subdivided. This general pattern holds true across all three crops in all states. Through optional subdivision, large basic units are split into optional units that are very similar in average size to smaller basic units that are not subdivided. Thus, state-level means indicate that optional subdivision has a significant equalizing effect on insured unit size.[7]

It is not feasible to provide a detailed analysis of the distribution of unit sizes for all the crops and states. However, such information for a few representative state/crop programs can provide a good sense of the nature of the effects of optional subdivision. Selected percentiles of unit size distributions for Iowa corn, Arkansas soybeans, and Kansas wheat are reported in Table 5. Iowa corn and Kansas wheat are used as examples because these states have the largest number of insured units for those crops, while Arkansas soybeans is chosen to add regional diversity. Two features of the distributional information provided in Table 5 are striking: (a) a large number of insured units, both basic and optional, are quite small (25% of units in all three state/crop programs are less than 40 acres in total size), and (b) the distributions of insured unit size are remarkably similar for basic units that are not subdivided and for optionally subdivided units (after the subdivision has been done). With minor exceptions, both of these relationships hold true for all states and crops included in

Table 5. Percentiles of Insured Unit Size Distributions for Iowa Corn, Arkansas Soybeans, and Kansas Wheat

Percentile	Basic Units That Will Be Subdivided (Acres)	Subdivided Units (Acres)	Basic Units That Are Not Subdivided (Acres)
	Iowa Corn		
10th	80	21	25
25th	122	37	38
50th	195	63	65
75th	320	91	94
90th	504	140	140
	Arkansas Soybeans		
10th	100	21	19
25th	173	39	36
50th	314	77	77
75th	623	150	160
90th	1,100	266	324
	Kansas Wheat		
10th	81	21	23
25th	130	39	39
50th	214	70	67
75th	367	111	102
90th	626	158	154

[7] Our conclusion regarding the similarity of size of units insured as basic and optional units is based on operational (agronomic) considerations rather than statistical criteria. Differences in means for "subdivided units" (i.e., optional units) and "basic units that are not subdivided" (i.e., basic units) are, in fact, statistically significant at the 5-percent level for all but two state/crop programs (based on two-tailed z tests). However, agronomically one would not expect these differences, which are less than 15 acres for all but six state/crop programs, to have important effects on the riskiness of production.

our analysis. Hence, the effect of optional subdivision on the distribution of unit size is the same as its effect on mean size: through optional subdivision the size distributions of units insured as basic and optional units are largely equalized.

Estimation Methods

The basic methodological approach used in the study is regression analysis of actual APHP loss experience (loss-cost ratios). Unlike simulation approaches, which have previously been used in analyzing the effects of unit structure (Shurle), this approach permits us to use the large database available on actual loss experience under the APHP contract provisions and to capture behavioral effects, such as possible actuarial effects of fraudulent shifting of reported production. The latter advantage is particularly important since behavioral aspects of the optional subdivision decision have been a primary focus of concern and criticism.

Actual Production History Program insured-unit loss-cost ratios take values between 0, when there is no loss, and 1, when there is a total loss (i.e., indemnity = liability). Given the mixed discrete/continuous nature of the distribution of the dependent variable, the analysis is conducted using a two-limit tobit estimator, with limits of 0 and 1. Our models are of the form:

$$LC_{it} = \alpha + \mathbf{d}^c_{it}\boldsymbol{\delta}^c + \mathbf{d}^t_{it}\boldsymbol{\delta}^t + \mathbf{d}^p_{it}\boldsymbol{\delta}^p + \mathbf{z}_{it}\boldsymbol{\Psi} + \epsilon_{it} \equiv \mathbf{x}_{it}\boldsymbol{\beta} + \epsilon_{it};$$

$$E[\epsilon_{it}] = E[x_{it}\epsilon_{js}] = 0 \quad \forall\ i, t \quad \text{and} \quad j, s;$$

$$E[\epsilon_{it}\epsilon_{js}] = 0 \quad \forall\ i \neq j \quad \text{or} \quad t \neq s;$$

$$E[\epsilon^2_{it}] = \sigma^2;$$

where LC_{it} is the unit-level loss-cost ratio for insured unit i in time period t; $\mathbf{d}^c_{it}$ is a $1 \times (m - 1)$ vector of dummy variables for $m - 1$ of m total counties included in the state model (data for a county were eliminated from the analysis if fewer than 50 units were insured during the study period); $\mathbf{d}^t_{it}$ is a 1×4 vector of dummy variables for crop years 1993–96; $\mathbf{d}^p_{it}$ is a 1×5 vector of values of the program-related dummy variables *optional, 75-percent coverage level, 35-percent penalty, 20-percent penalty,* and *10-percent penalty*; $\mathbf{z}_{it}$ is a 1×5 vector of values of the continuous variables *percent irrigated, risk area ratio, yield ratio, ownership share,* and *acreage*; α is a scalar parameter; $\boldsymbol{\delta}^c$, $\boldsymbol{\delta}^t$, $\boldsymbol{\delta}^p$, and $\boldsymbol{\Psi}$ are conformably-scaled column vectors of parameters; $\mathbf{x}_{it} = [1\ \mathbf{d}^c_{it}\ \mathbf{d}^t_{it}\ \mathbf{d}^p_{it}\ \mathbf{z}_{it}]$; $\boldsymbol{\beta}' = [\alpha\ \boldsymbol{\delta}^c\ \boldsymbol{\delta}^t\ \boldsymbol{\delta}^p\ \boldsymbol{\Psi}]'$; and ϵ_{it} is a random disturbance.[8]

Computation of Optional Subdivision Effects

A central result reported in the following section is the estimated effect of optional subdivision on APHP loss-cost ratios for each crop in each state. These are percentage differences in expected loss-cost ratios for basic versus optional units and, hence, can be compared directly with the 10-percent discount currently given for units insured at the basic unit level. Expected loss-cost ratios used in these calculations are computed from the two-limit tobit model parameter estimates as:

$$E[LC_{it}|\mathbf{x}_{it}] = L\Phi_L + U(1 - \Phi_U) + (\Phi_U - \Phi_L)\mathbf{x}_{it}\boldsymbol{\beta} + \sigma(\phi_L - \phi_U),$$

where L and U are the lower (zero) and upper (one) limits, respectively;

$$\Phi_j = \Phi[(j - \mathbf{x}_{it}\boldsymbol{\beta})/\sigma],$$

$$\phi_j = \phi[(j - \mathbf{x}_{it}\boldsymbol{\beta})/\sigma], \qquad j = L, U;$$

σ is the maximum likelihood estimate of the

[8] The dummy variables *35-percent penalty, 20-percent penalty,* and *10-percent penalty* are included in the model to account for any effects of reduced yield coverages, during the years 1994–96, for insureds who provided less than three years of actual yields for the APH yield calculation. Values of these variables are all zeros for the years 1992 and 1993. This does not create a potential specification problem, with these variables picking up year effects in addition to the effects they are intended to measure, because year dummy variables are also included in the model. Although only 4 percent to 12 percent of observations fall in each of these categories (Table 3), given the overall sample sizes this should not pose a problem in estimation of these effects.

Table 6. Summary of Tobit Model Results for Models of Unit-Level APHP Loss-Cost Ratios on Corn, Soybeans, and Wheat*

	Corn			Soybeans			Wheat		
Variable	Pos. and Sig.	Neg. and Sig.	Not Sig.	Pos. and Sig.	Neg. and Sig.	Not Sig.	Pos. and Sig.	Neg. and Sig.	Not Sig.
Optional	8	1	4	11	0	3	7	1	2
75% Coverage Level	13	0	0	14	0	0	9	0	1
% Irrigated	3	2	1	0	1	4	3	3	1
Risk Area Ratio	1	12	0	0	13	1	1	8	1
35% Penalty	0	10	3	0	10	4	0	6	4
20% Penalty	0	9	4	0	10	4	0	8	2
10% Penalty	1	6	6	0	8	6	0	5	5
Yield Ratio	0	13	0	0	14	0	0	10	0
Ownership Share	12	1	0	14	0	0	10	0	0
Acreage	7	5	1	13	0	1	7	2	1

* Abbreviations used in the table are 'pos. and sig.' for positive and statistically significant at the 10% level, 'neg. and sig.' for negative and statistically significant at the 10% level, and 'not sig.' for not statistically significant at the 10% level. Entries in the table indicate the number of state models for the crop in which the parameter estimate on the variable was in each of the three sign/significance categories. For example, the results for "optional" in the 13 state corn models indicate that the variable had a positive sign and was statistically significant in 8 state models, had a negative sign and was statistically significant in 1 state model, and was not statistically significant in 4 state models.

standard deviation of the normal distribution and ϕ and Φ are the normal density and cumulative distribution functions, respectively. The effects reported in the following section are means of effects calculated at each data point. Given the nonlinear nature of the estimator, this approach is more appropriate than the common practice of calculating effects at the means of the data. This is especially true in the present application where expected loss-cost ratios are quite different in 'average' years (means of the data) than in good or poor production years.

Results

Tobit model results for the 37 state/crop programs are presented in Table 6. Because of the number of models estimated, these results are presented in a summarized form that lends itself to economical presentation and easy interpretation. A full reporting of parameter estimates is included in Appendix Table A1 for the reader who is interested in detailed information on individual-state models.

Information reported in Table 6 summarizes the algebraic signs and statistical significance of each independent variable in the state level models of five-year APHP loss-cost ratios. The sign on *optional* is positive and the parameter estimate is statistically significant in 26 of 37 state/crop models: eight of 13 corn states, 11 of 14 soybean states, and seven of 10 wheat states. In all but two of the remaining cases there is no statistically significant difference in loss-cost ratios for basic and optional insured units. Thus, our results, in general, support the incorporation of a rate differential between basic and optional units in the APHP and CRC rate structures. An analysis of the appropriateness of the current 10-percent discount for insuring basic units will be presented after the other model results in Table 6 have been examined.

There is almost complete consistency in the model results relating to the 75-percent coverage level. Expected loss-cost ratios for 36 of 37 state/crop insurance programs are higher for 75-percent than for 65-percent coverage. This is an expected result, which is consistent with the APHP premium rate structure.

Results relating to irrigated production are mixed. The preponderance of evidence for soybean states suggests no significant difference in loss-cost ratios for irrigated and dryland production practices. Results for corn and wheat exhibit more statistical significance but vary in sign. Since APHP premium rates for irrigated production are lower than or equal to those for dryland production within a county, the estimated positive and significant effects for some state/crop programs are inconsistent with the rate structure. For some state/crop programs, these results may stem from the fact that the five-year study period did not include a severe drought year, when the loss-mitigating benefits of irrigation would be strongest. However, at least in the case of wheat, it is unlikely that this fully explains our results. As the parameter estimates in Appendix Table A1 show, the wheat states with negative and significant estimated effects of irrigation (i.e., lower loss-cost ratios for irrigated than dryland practices) are Kansas, Oklahoma, and Texas, while estimated effects of irrigated production are positive and significant for Montana, Nebraska, and Washington. Personnel at Risk Management Agency (RMA) regional service offices in Spokane, Washington; Billings, Montana; and Topeka, Kansas have been aware of unexpectedly high loss experience on irrigated wheat production in the northern states since the mid-1980s. Thus, this appears to be a long-term phenomenon that is confirmed by our study results.

Parameter estimates on *risk area ratio* are negative and significant in all but four of 37 models. This result is important, because it is the first time the APHP actuarial data have been used to analyze the relationship between farm (insured unit) yields, expected county yields, and actuarially-fair APHP (or CRC) premium rates. Our results are consistent with the yield-distribution results of Skees and Reed, and Goodwin. These results support the 1985 modification of the APHP rate structure to provide lower premium rates for insured units with high approved yields relative to the historical average county yield.

Results relating to the penalty structure for providing less than three years of actual yields for the APH calculation (parameter estimates on *35-percent penalty, 20-percent penalty,* and *10-percent penalty*) exhibit a pattern that has important implications for the validity of this feature of the APHP and CRC rate structures. Specifically, the preponderance of the models indicate that APHP loss-cost ratios are lower (negative and significant parameter estimates) for insured units on which these coverage penalties are imposed. This suggests that the coverage penalties more than compensate for any difference in riskiness of units on which limited historical yield information is provided.

Yield ratio takes a negative sign and is statistically significant in all of the state/crop models. This is not surprising since the loss-cost ratio would be expected to be high in years when the county yield is lower than normal (generally unfavorable production years) and low in years of higher-than-normal county yields (favorable production years). No direct implications derive from this result, but inclusion of the variable in the models is important because it is the best available measure of production conditions in each year, localized to the county level.

Ownership share has a positive and significant estimated effect on loss-cost ratios in all but one of 37 state/crop models. This suggests that the larger the share an individual holds in an insured unit the more indemnified losses are relative to liability. We believe that transaction costs likely account for this result, as well as the positive and significant estimated effect of *acreage* in the preponderance of our models. Specifically, a larger ownership share or larger insured unit provides greater incentive to incur the cash and opportunity costs of time and effort to report and validate a loss. These costs, which are largely independent of size of loss, would exceed the indemnity in cases of small per-acre losses (small yield shortfalls) on small units and/or on units in which the insured holds a small ownership share.[9] The result for *acreage* may appear

[9] Although average ownership shares presented in Table 3 are relatively high, there are a significant proportion of insured units, especially in the 1995 and 1996 crop years when strong incentives were provided to insure, on which the ownership share is small (i.e., less than 20%). These are likely landlords who are part owners of the land. Clearly, for these persons the incentive to report say a two-bushel-per-acre corn loss

counterintuitive due to an *a priori* expectation that larger units are composed of more heterogeneous soils and will have less highly correlated yields than small units. However, it should be remembered that most insured units, both basic and optional, are small enough so that any expected loss-reducing effect of unit size would be small. Our results suggest that any such effects are outweighed by the reduced incentive to incur the costs of establishing losses on small acreages.

Estimated fair discounts for basic versus optional units are given in Table 7. A zero discount is reported if the parameter estimate on *optional* is not statistically different than zero (see Table 6 and Appendix Table A1). Consistent with the results summarized in Table 6, the estimated effects are positive and significant for eight of 13 corn states, 11 of 14 soybean states, and seven of 10 wheat states. Two aspects of the general pattern of these results are central to the ongoing debate about unit structure. The first aspect was identified in the discussion of Table 6. To reiterate, it is that the preponderance of our results suggests that loss-cost ratios are higher for optional than for basic units. Given that basic and optional units are essentially identically distributed in size, a reasonable null hypothesis might have been that there would be no statistically significant difference between losses for the two types of units. However, in 70 percent (26 of 37) of the state/crop programs analyzed, estimated loss-cost ratios are significantly higher for optional than for basic units (i.e., parameter estimates on *optional* are positive and statistically significant). Thus, a premium rate discount for basic units (or surcharge for optional units as was originally implemented in 1988) is generally appropriate.

The second aspect of our results that has direct implications for the unit structure debate is that we do not find evidence of a general insufficiency of the penalty (loss of a discount) associated with optional subdivision. Our median estimated discounts for basic units are approximately 9 percent for soybeans, 4 percent for corn, and 5 percent for wheat. Although these discounts vary substantially among states, they exceed the current 10-percent lev-

Table 7. Estimated Actuarially-Fair Percentage Discounts for Basic Versus Optional Units

State	Estimated Fair Discount (%)
Corn States	
Indiana	13.8
Kansas	12.8
Illinois	11.2
Texas	10.1
Wisconsin	8.2
Missouri	4.8
Iowa	4.2
Minnesota	2.1
Michigan	0.0
Nebraska	0.0
N. Dakota	0.0
Ohio	0.0
S. Dakota	−4.8
Soybean States	
Illinois	16.0
Indiana	14.7
N. Carolina	14.7
Kansas	11.1
Ohio	10.6
Louisiana	9.4
Missouri	9.3
Iowa	8.8
S. Dakota	8.4
Minnesota	7.3
Arkansas	5.3
Michigan	0.0
Mississippi	0.0
Nebraska	0.0
Wheat States	
Washington	13.8
Texas	10.3
Kansas	6.2
Colorado	5.6
Oklahoma	5.1
Nebraska	1.9
S. Dakota	1.1
Montana	0.0
N. Dakota	0.0
Minnesota	−3.0

on a 40-acre unit is small (indemnity of $32 for a price election of $2 and an ownership share of 20%), while the opportunity cost of the time and effort required is nontrivial.

el—in most cases only modestly—in only nine of the 37 state/crop programs analyzed. Thus, our results indicate that the current 10-percent discount is, in general, more than adequate to correct for increased losses due to optional subdivision. This finding is counter to claims that abuses associated with the proliferation of units through optional subdivision are a major source of actuarial insufficiency in the insurance program.

Apart from these general implications, our results raise the additional issue of whether a uniform rate differential is appropriate across all APHP state/crop programs. Our estimated fair discounts vary across commodities and among states for each of the three commodities studied. The median estimated discount for soybeans is very close to the current 10-percent level. For corn and wheat, however, it appears that a discount of approximately half the current level is justified. Tailoring of discounts to conform with commodity-level actuarial experience would appear appropriate. Further, such refinement of the APHP and CRC rate structures should be operationally feasible, with the primary cost being the development of appropriate discounts for other commodities, using methods similar to those employed in the present study.

Our results also show substantial variation in fair discounts among states for each of the three commodities. Tailoring of rates to reflect such differences should be operationally feasible, but political implications are a serious concern. Significant variation in APHP rates between contiguous counties has been a politically sensitive issue throughout the life of the program. This sensitivity has led to the modification of rate-setting procedures to smooth rates at the crop reporting district level. A similar controversy would appear inevitable if the discount for basic units were substantially different for a given commodity across state lines, which, like counties, would be viewed by producers as arbitrary political boundaries. Thus, we believe the benefits of state-specific discounts are likely outweighed by direct costs and substantial difficulties that would be posed in program administration.

Concluding Comments

A substantial base of actuarial experience provides a basis for refinements to the APHP contract design. The analysis presented in this article makes the most extensive use to date of those data in examining the validity of several revisions introduced into the rate structure since 1985. Our results illustrate the importance of incorporating actuarial experience into the premium rate structure and contract provisions of an insurance program. Purely theoretical rate setting has significant shortcomings. In particular, theoretical rates cannot capture behavioral effects of the insurance contract design.

Two issues examined in this article are considered to be at least partly behavioral. Higher losses for optional than for basic units are believed to arise, at least in part, from shifting of production between units when losses are reported.[10] The penalty structure for insuring on the basis of limited yield experience was incorporated into APHP rates to account for a selection process in which farms with yields lower than the county average elect to use county yields, in order to obtain artificially-inflated coverage, while farms with yields higher than the county average provide actual yields for the APH calculation. The magnitude of such behavioral effects can be examined only through use of actuarial experience.

The need to incorporate actuarial experience into insurance contract designs has two important implications in the present policy context in which greater importance has been placed on existing and newly-designed insurance programs. First, for an established insurance program like APHP, it is important to maintain a consistent database on actuarial experience and to use that database in refining the contract provisions. Second, behavioral ef-

[10] It should be noted that fraudulent reporting of losses is not the only behavioral factor that might contribute to higher losses for optional than for basic units. It is also possible that an adverse selection process in the decision to subdivide contributes to this difference. Clearly, our methods, which rely upon a dummy variable to capture the total optional subdivision effect, do not identify the sources of that effect.

fects pose a challenge for new insurance designs. One approach to meet this challenge is to rely upon established designs, to the extent possible, as has been done in the yield coverage component of CRC. A second approach is to supplement theoretical rates with adjustment factors based on experience for other programs and then to incorporate actuarial experience for the contract as soon as sufficient data have accumulated to support reliable analysis. Unfortunately, during the time period when purely theoretical rates or theoretical rates with arbitrary adjustments are used, the performance of new programs is likely to be affected by a poorly calibrated rate structure.

References

Commission for the Improvement of the Federal Crop Insurance Program. *Recommendations and Findings to Improve the Federal Crop Insurance Program.* Washington, DC, July 1989.

Gardner, B.L., and R.A. Kramer. "Experience with Crop Insurance Programs in the United States." *Crop Insurance for Agricultural Development, Issues, and Experience.* Peter Hazell, Carlos Pomareda, and Alberto Valdes (eds), pp.195–222. Baltimore: Johns Hopkins University Press, 1986.

Glickman, D. "Remarks of Secretary Dan Glickman: 1998 Agricultural Outlook." USDA Agricultural Outlook Forum, February 23, 1998.

Goodwin, B.K. "Premium Rate Determination in the Federal Crop Insurance Program: What Do Averages Have to Say About Risk?" *Journal of Agricultural and Resource Economics* 19(December 1994):382–395.

Goodwin, B.K., and V.H. Smith. *The Economics of Crop Insurance and Disaster Aid.* Washington, DC: AEI Press, 1995.

Knight, T.O., and K.H. Coble. "Survey of Multiple Peril Crop Insurance Literature Since 1980." *Review of Agricultural Economics* 19(Spring/Summer 1997):128–156.

Shurle, B. "The Impact of Size on Yield Variability and Crop Insurance Premiums." *Review of Agricultural Economics* 18(September 1996):415–422.

Skees, J.R., and M.R. Reed. "Rate Making for Farm-Level Crop Insurance: Implications for Adverse Selection." *American Journal of Agricultural Economics* 68(August 1986):653–659.

Appendix

Table A1. Parameter Estimates for Tobit Models of Unit-Level APHP Loss-Cost Ratios on Corn, Soybeans, and Wheat

	Parameter Estimates for Corn Models					
Variable/Statistic	IL	IN	IA	KS	MI	MN
INTERCEPT	1.3856*	2.3247*	1.1783*	1.3537*	2.4265*	1.0436*
Optional	0.0260*	0.0449*	0.0146*	0.0628*	−0.0063	0.0120*
75% coverage level	0.0905*	0.1688*	0.1382*	0.1667*	0.3009*	0.1141*
% Irrigated	—	—	—	−0.0848*	−0.1109	—
Risk Area Ratio	−0.2727*	−0.4173*	−0.2615*	0.0918*	−0.7296*	−0.3929*
35% Penalty	−0.1101*	−0.1807*	−0.0286*	−0.0357*	−0.2518*	−0.0665*
20% Penalty	−0.1085*	−0.1779*	−0.0239*	−0.0289	−0.2028*	−0.0111
10% Penalty	−0.0471*	−0.0478*	−0.0349*	0.0662*	−0.0673	−0.0140
Yield Ratio	−1.3999*	−2.4437*	−1.5259*	−1.9845*	−2.3232*	−1.2155*
Ownership Share	0.1187*	0.1236*	0.0988*	0.0994*	0.2895*	0.0830*
Acreage	0.0003*	0.0004*	0.0001*	0.0008	−0.0005*	−0.0001*
	Parameter Estimates for Soybean Models					
Variable/Statistic	AR	IL	IN	IA	KS	LA
INTERCEPT	0.3203*	1.1293*	1.4666*	1.0509*	0.2392*	0.3446*
Optional	0.0265*	0.0421*	0.0481*	0.0282*	0.0481*	0.0496*
75% coverage level	0.2625*	0.1032*	0.1884*	0.1315*	0.1737*	0.2685*
% Irrigated	−0.0809*	—	—	—	−0.0181	−0.0109
Risk Area Ratio	−0.1851*	−0.4085*	−0.3596*	−0.4173*	−0.1226*	−0.1176*
35% Penalty	−0.0935*	−0.1130*	−0.1504*	−0.0954*	−0.1587*	0.0561
20% Penalty	−0.0834*	−0.0975*	−0.1360*	−0.0795*	−0.1444*	−0.0118
10% Penalty	0.0040	−0.0279*	−0.0437*	−0.0520*	−0.0448*	−0.0429
Yield Ratio	−0.9174*	−1.4682*	−1.8622*	−1.5591*	−1.0555*	−0.7128*
Ownership Share	0.4382*	0.1472*	0.1694*	0.0564*	0.1738*	0.2351*
Acreage	0.0002*	0.0039*	0.0004*	0.0003*	0.0009*	0.0004*
	Parameter Estimates for Wheat Models					
Variable/Statistic	CO	KS	MN	MT	NE	ND
INTERCEPT	1.1238*	1.1105*	0.5036*	0.8875*	1.0225*	1.9865*
Optional	0.0370*	0.0383*	−0.0151*	0.0070	0.0109*	0.0051
75% coverage level	0.1935*	0.1824*	0.0978*	0.1891*	0.1586*	0.2190*
% Irrigated	−0.0114	−0.1070*	—	0.3151*	0.1853*	—
Risk Area Ratio	−0.2005*	−0.1988*	0.0269*	−0.1185*	−0.1551*	−0.2173*
35% Penalty	−0.0354	−0.1387*	−0.0103	0.0236	−0.1032*	−0.0831
20% Penalty	−0.0932*	−0.1083*	−0.0174	0.0148	−0.0851*	−0.0814*
10% Penalty	−0.0386*	−0.0487*	−0.0048	−0.0126	−0.0402*	−0.0234*
Yield Ratio	−1.8116*	−1.7667*	−0.9813*	−1.3081*	−1.8250*	−2.2114*
Ownership Share	0.0816*	0.0832*	0.0389*	0.0841*	0.0877*	0.1242*
Acreage	0.0002*	−0.0001*	0.0002*	0.0004*	0.0000	0.0001*

* An asterisk indicates the parameter estimate is statistically significant at the 10% level.

Appendix

Table A1. (Extended)

Parameter Estimates for Corn Models

MO	NE	ND	OH	SD	TX	WI
0.8885*	1.9624*	1.4883*	2.1029*	2.0581*	0.7743*	2.1812*
0.0175*	−0.0059	−0.0010	0.0034	−0.0267*	0.0707*	0.0511*
0.0966*	0.2202*	0.3393*	0.2012*	0.1502*	0.2187*	0.2059*
—	0.1173*	0.0781*	—	0.2713*	−0.5906*	—
−0.0895*	−0.1935*	−0.3746*	−0.4580*	−0.2892*	−0.2090*	−0.3010*
−0.0228	−0.1719*	0.0369	−0.0911*	−0.2177*	−0.0346	−0.0950*
0.0003	−0.1136*	−0.1008*	−0.0756*	−0.1350*	−0.0116	−0.0882*
−0.0067	−0.0593*	−0.0142	−0.0142	−0.0613*	0.0436	−0.0329*
−1.4400*	−3.0814*	−1.4002*	−2.0738*	−2.1883*	−1.4707*	−1.5615*
0.1154*	0.1709*	0.2313*	0.2004*	0.1637*	0.1609*	−0.1539*
0.0006*	0.0003*	−0.0003*	0.0002*	−0.0002*	0.0003*	−0.0003*

Parameter Estimates for Soybean Models

MI	MN	MS	MO	NE	NC	OH	SD
1.0612*	1.1753*	0.8294*	0.9137*	1.5009*	0.6433*	1.4182*	0.1845*
0.0118	0.0289*	−0.0222	0.0423*	0.0046	0.0929*	0.0325*	0.0354*
0.4119*	0.1370*	0.2164*	0.1567*	0.1329*	0.1609*	0.1825*	0.1391*
—	—	−0.0313	—	−0.0042	—	—	—
−0.4578*	−0.3302*	−0.1284*	−0.3337*	−0.1841*	−0.4379*	−0.4775*	−0.0233
−0.2172*	−0.0538*	−0.0094	−0.0578*	−0.1082*	0.0216	−0.0221	−0.0135
−0.1773*	−0.0601	−0.0190	−0.0579*	−0.0826*	−0.0205	−0.0464*	−0.0202
−0.1008*	−0.0520*	−0.0220	0.0066	−0.0366*	−0.0960*	−0.0149	0.0021
−1.1920*	−1.2628*	−0.8559*	−1.4496*	−2.3253*	−1.0597*	−1.7624*	−1.1049*
0.1548*	0.0812*	0.3133*	0.1707*	0.1286*	0.3254*	0.1829*	0.1190*
0.0002	0.0001*	0.0001*	0.0008*	0.0004*	0.0003*	0.0003*	0.0003*

Parameter Estimates for Wheat Models

OK	SD	TX	WA
0.9144*	1.5952*	0.2627*	0.7835*
0.0304*	0.0465*	0.0655*	0.0391*
0.2116*	0.0652	0.1157*	0.1236*
−0.1509*	—	−0.3951*	0.1118*
−0.2446*	0.0019	−0.1073*	−0.2119*
0.0070	−0.1739*	−0.0731*	−0.0490*
−0.0395*	−0.1317*	−0.0399*	−0.0743*
−0.0039	−0.0690*	−0.0046	−0.0228
−1.2203*	−1.8843*	−0.8587*	−1.0281*
0.1189*	0.0966*	0.1487*	0.0623*
−0.0001*	0.0001*	0.0003*	0.0001