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Efficiency Analysis of Agricultural Market Advisory Services: A Nonlinear Mixed-Integer Programming Approach

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Professional market advisory services provide specific advice (advisory programs) to grain producers on how to market their commodities, and assist them in their efforts to manage price risk. Previous studies analyzed the effectiveness of individual services and could find only weak evidence that these services help farmers improve their returns beyond market prices. The present study applies portfolio theory to determine an efficient combination of advisory programs using a nonlinear integer programming framework. The optimization results provide some evidence that an efficient portfolio provides significantly greater risk and return benefits compared to individual programs and external benchmarks. In a holdout period analysis, efficient portfolios have superior average return performance, but they fail to dominate the relevant benchmarks in terms of mean and variance. However, these out-of-sample results should be considered cautiously, given the small number of observations available.

Key words: agricultural market advisory services; corn; soybeans; efficient portfolios; nonlinear integer programming
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1. Introduction

One of the most important areas in agricultural farm management is the management of risks. Various surveys conducted across the United States in the 1990s found that many farmers indicate price risk as one of their biggest management challenges (e.g., Patrick and Ullerich 1996, Coble et al. 1999, Norvell and Lattz 1999). With the rapid changes in information technology that enable farmers to incorporate up-to-the-minute commodity price information into their marketing decisions, price risk has become more important than ever, although it is difficult to manage for many farmers. Besides having to manage day-to-day farm operations, they also have to monitor a dizzying array of information to make better marketing decisions.

There are many tools to assist grain producers in price risk management. Patrick et al. (1998) and Schroeder et al. (1998) report that farmers view one of these tools, professional market *advisory services* (firms), as an important source of information in their efforts to manage price risk. Professional market advisory services offer advice to farmers on how to market their commodities for a subscription fee. Specifically, they recommend how a farmer should market his or her crops using various instruments, including cash market sales, forward contracts, futures contracts, and options contracts. Such a marketing package is called an *advisory program*. Some firms offer more than one advisory program. Advisory services provide market recommendations at least daily, with some offering multiple daily updates, and most are typically delivered electronically, via satellite networks, e-mail, or web pages. Services using these tools recommend not only the portion of a crop that should be marketed, but also the timing of transactions, such as, "Buy May soybean puts today with a strike price of $5.00 per bushel for 50% of expected production," or, "Sell December corn futures today at $2.50 per bushel for 25% of actual production." It is often thought that advisory services can process market information more rapidly and efficiently than less-skilled farmers to determine the most appropriate marketing decisions. Despite this general view, to date there has been limited economic analysis to test the true effectiveness of these services.

Previous studies on market advisory services have analyzed performance on a stand-alone basis, i.e., individual programs considered one at a time. However, a recent survey by Pennings et al. (2001) shows that farmers often subscribe to several advisory programs concurrently, and that they market grain following the advice of selected programs in an effort to achieve greater risk and return benefits. According to portfolio theory, a combination of advisory programs might have greater risk and return benefits compared with individual programs or benchmarks. Thus, a comprehensive analysis of market advisory services should incorporate possible diversification among advisory programs in a portfolio setting. The purpose of the present study is to address this issue by determining optimal portfolios of advisory programs and by evaluating the risk and return performance of the portfolios against individual programs, as well as external benchmarks. Optimal portfolios will be generated for a representative corn and soybean farm in the Midwestern United States using available data from 1995–2001. In a time when managing price and income risk is of utmost importance to farmers, investigating the benefits of relying on a portfolio of advisory programs can be useful, and might provide valuable insight to producers for determining the best grain-marketing strategies.

2. Commodity Marketing Tools: An Overview

Grain producers have a variety of marketing tools at their disposal. Commonly used tools include cash market sales, forward contracts, futures contracts, and options contracts. Each tool offers producers a unique combination of the four main components of any commodity marketing transaction: pricing, delivery, title transfer, and payment. This section presents a brief overview of the alternative tools mentioned above. A detailed explanation can be found in Chafin and Hoepner (2002).

The simplest way that producers can market their commodities is a cash market sale, where a producer delivers the commodity to a buyer, usually a local elevator merchant, and takes immediate cash payment. The price for the transaction is the prevailing price in the cash *spot* market on the date of the transaction. Cash market sales can be made at harvest, or after harvest if storage facilities are available.

Forward contracts are closely related to cash market sales. The only difference is that the contract price is agreed to in advance of delivery, title transfer, and payment. For example, a producer could sign a forward contract with a local elevator merchant in the spring (when the crop is planted), thereby fixing the price for the product at that time, and then deliver the commodity at harvest and receive payment. Forward contract sales can be made before, at, or after harvest.

Futures contracts are standardized forms of forward contracts traded on organized exchanges. The largest futures exchange for agricultural commodities is the Chicago Board of Trade. This marketing tool provides similar price protection as a forward contract, but the mechanics and pricing effects differ. Selling futures prior to delivery establishes the futures price level at which the commodity will be sold. An offsetting purchase of the same contract is made at delivery, and the physical commodity is sold in the cash market. If the price declines after the futures position was initiated, the contract will be offset for less than the selling price. The profit is added to the lower price received in the cash market. If the price increases, however, losses on the futures contract will offset gains in the cash market. Hence, we use the term *futures hedging*. Futures contract sales can be made before, at, or after harvest.

Put options contracts are closely related to futures contracts. Whereas the seller of a futures contract is obligated to deliver the commodity (or eventually offset the contract), the buyer of a put option buys the right, but not the obligation, to sell futures at a specific price, called the *strike price*. On a given day, options contracts are traded with different strike prices. The cost of the option, known as the premium, is determined by the market in open trading on a futures and options exchange, such as the Chicago Board of Trade. The premium is payable at the time of the purchase of the option. The seller of the option is paid the premium, and in return the seller agrees to provide a futures contract at the specified (strike) price should the buyer of the option decide to sell futures. The producer who purchases a put option faces two basic scenarios. If the futures price drops below the strike price the producer can exercise the option and sell futures at the strike price. Then the producer simultaneously purchases a futures contract at the lower current contract price, earning the difference between the strike price and the current market price, and sells in the cash market. In this way, the put option provides a price floor for the commodity. If the futures price rises above the strike price, the producer simply sells in the cash market and absorbs the loss of the initial premium. Put options contract sales can also be made before, at, or after harvest.

Advisory services recommend a diverse set of cash, forward, futures, and options contract positions during the marketing year (Martines-Filho et al. 2003a, b). The differences across individual advisory services arise from consideration of different marketing behaviors of the clients (farmers). Therefore, there is no single service or program that best serves all farmers. Rather, individual farmers choose the best programs that are consistent with their own marketing and risk preferences.

3. Previous Research on Advisory Services

A few recent studies have investigated the performance of advisory services for grain producers. For example, Gehrt and Good (1993) look at what the returns for corn and soybeans producers would have been if they had followed the recommendations of five advisory services over 1985–1989 and compared those returns against a benchmark price, which was the average cash price received over a 19-month marketing window for each crop year. They conclude that there is some evidence, although it is not very strong, that these services could beat the benchmark prices. Martines-Filho (1996) analyzes six advisory services' preharvest recommendations for corn and soybeans for the 1991–1994 production years. Again, slight evidence was found supporting the ability of the services to generate a higher return than the compared benchmark.

With only a few years and a few advisory services included in the evaluations, the conclusions of the above studies regarding the performance of advisory services could be misleading. For more reliability, the AgMAS Project was initiated at the University of Illinois in 1994 to expand research on market advisory service performance. Since 1995, the AgMAS Project has monitored and evaluated a sample of about 25 advisory programs each year. The empirical findings have been disseminated through various AgMAS research reports. In a recent research report, for instance, Irwin et al. (2003) evaluate several corn and soybean advisory services for the period 1995–2001. Their results show that, on the one hand, when both average price and risk are considered, only a small fraction of services for corn and a moderate fraction for soybeans outperformed market benchmarks. On the other hand, the majority of the programs had better performance compared with the average price received by farmers for both commodities.

The above studies analyze the performance of individual advisory programs without considering possible gains from diversification among them. This issue is addressed here by using a mathematical programming framework, which delineates the present study from the related studies outlined above.

4. Methodology

In a somewhat simplified construct, an advisory program for a given commodity can be represented by a vector $\mathbf{w} = (w_k)$, where w_k stands for the percentage of the commodity that should be marketed using the kth marketing alternative (such as cash sales, forward contracts, futures contracts, and put options contracts). Using these shares and prices received under each alternative, an average price obtained from program $\mathbf{w}^j = (w_k^j)$, denoted by r_j, is generated assuming full compliance with the recommendations of that program (for computational details, see Irwin et al. 2003). A portfolio of market advisory programs is a convex combination of the programs available to the producer, and can be represented by a vector $\mathbf{X} = (x_j)$, where x_j is the weight assigned to $\mathbf{w}^j$ with

$$\sum_j x_j = 1.$$

The price received from a portfolio is given by the weighted sum of the prices received from all programs, namely

$$\sum_j x_j r_j.$$

The application of portfolio theory to the selection of market advisory programs involves the determination of sets of programs that are efficient in return-risk space. Markowitz (1952) introduces this concept using a mathematical programming framework. In this approach, portfolio variance is used as the measure of risk. An *efficient portfolio* is defined as the minimum-variance portfolio that yields a specified level of expected return under relevant constraints characterizing the decision space. The *efficiency frontier* is obtained by solving the problem for a set of exogenously specified expected income levels and joining the optimum solutions in the expected income-variance (E-V) space. This framework, which leads to a convex quadratic programming problem, is a widely used portfolio management approach in the finance literature. Besides its desirable theoretical properties, the findings of some previous empirical studies suggest that the E-V approach better represents farmers' actual risk behavior (Hauser and Eales 1986).

Because most subscribers to market advisory services produce both corn and soybeans, it is most relevant to consider the portfolio selection problem in terms of revenue for the whole farm. A mathematical representation of the advisory portfolio selection problem for a crop farm is as follows.

$$\begin{aligned} \text{Min} \quad & \sum_i \sum_j x_i x_j \sigma_{ij} \\ \text{such that} \quad & \sum_i P_i x_i - \frac{c_i z_i}{S} \geq \bar{p} \\ & \sum_i x_i = 1 \\ & x_i \leq z_i \quad \text{for all } i \\ & x_i \geq 0, \quad z_i = 0, 1 \quad \text{for all } i, \end{aligned}$$

where i and j represent individual advisory programs, $[\sigma_{ij}]$ is the variance-covariance matrix of revenues associated with programs i and j, P_i is the expected revenue for program i (in dollars per acre), $\bar{p}$ is the exogenously specified minimum expected revenue of the portfolio, z_i is a binary variable that indicates whether advisory program i is selected ($z_i = 1$) or not ($z_i = 0$), c_i is the subscription cost associated with program i, and S is the farm size (in acres). Farm size must be defined in this model because subscription costs are paid on a per farm basis. Two farm sizes, 500 and 2,000 acres, will be considered in the present analysis. The range of farm sizes typically found in the Midwestern United States is generally between these two sizes.

The objective function represents the portfolio variance, which is to be minimized. The first constraint restricts the expected revenue (adjusted for the fixed sign-up costs of advisory programs) to be greater than $\bar{p}$. The second constraint represents the convex combination requirement. The last constraint implies that if an advisory program is to have a positive share in the portfolio, then the farmer must sign up for that program (i.e., if $x_i > 0$, then $z_i = 1$), in which case the associated fixed cost (per acre) is subtracted from the expected revenue. The above model is used to obtain the efficiency frontier by varying the value of $\bar{p}$ systematically between the maximum expected revenue and the revenue of the minimum-variance portfolio.

The above model is a quadratic mixed-integer program. Several nonlinear integer programming solvers have recently become available to solve this type of problem. In the present study, we used BARON (Branch and Reduce Optimization Navigator; Sahinidis 2000, Tawarmalani and Sahinidis 2002) interfaced with GAMS (Brooke et al. 1998). BARON is developed to find a global solution to nonconvex programming problems with or without discrete variables. It can solve purely continuous, purely integer, and nonlinear mixed-integer optimization problems. In general, solving nonlinear integer programming problems is difficult and a solution is not always guaranteed, but in this particular application BARON has worked well and has found a solution to the problem within a short processing time (usually within seconds or a few minutes).

The portfolio selection model is also solved for corn and soybeans individually. This case considers the net prices received by the farmer under the recommendations of the advisory services. When finding an optimum portfolio of advisory programs for individual crops, the parameters of the above model need to be altered accordingly. Specifically, the revenue parameter P_i is replaced by the expected price if program i is selected and the expected revenue parameter $\bar{p}$ is replaced by the expected net price. Because subscription costs are paid on a whole-farm basis, subscription costs are ignored in the individual corn and soybean portfolio selection models.

5. Data

When it was first launched in 1995, AgMAS monitored and evaluated a sample of 25 advisory programs. The AgMAS sample included services that were most popular among Midwest farmers. Over time, additions and deletions to this original sample have occurred for a variety of reasons, and, consequently, the sample size varied between 23 and 27 programs over the period 1995–2001. Of the original 25 programs, only 15 were evaluated every year over 1995–2001. Therefore, net prices and revenues were compiled only for these 15 programs in order to maximize the number of time-series observations available for the analysis. Table 1 presents the list of those 15 programs and the services which provided individual programs. Note that only 10 advisory services are listed in the table, because three services (AgriVisor, Brock, and Pro Farmer) offer multiple programs.

To analyze the possibility of survivor bias in the subsample of 15 programs, the average corn and soybean price obtained for the 15 survivors is compared with the average prices for the whole sample. The differences in the average prices were very small, specifically $\$-0.0079$ per bushel for corn and $\$-0.0012$ per bushel for soybeans, with the average price for the entire sample slightly higher than the survivors' average price in both cases. These values support the absence of survivor bias in the sample. This is due to the fact that the programs excluded from the AgMAS sample in the past were dropped, because they have changed their focus and stopped making explicit recommendations for farmers; they were not dropped because of poor performance that made them go out of business. For example, some programs were dropped because they stopped including crop proportions in their recommendations, or they stopped making cash sales recommendations so that they could focus on only futures and options markets.

To simulate a consistent and comparable set of results across different market advisory programs, certain explicit assumptions are made to accurately depict real-world marketing conditions. These assumptions are as follows.

(i) The advice for a given crop is considered to be complete for each advisory program when the cumulative cash sales of the commodity reaches 100%, all futures positions covering the crop are offset, all option positions covering the crop are either offset or expired, and the advisory program discontinues giving advice for that crop.

(ii) With a few exceptions, the marketing window for a crop is 24 months in length and runs from September of the year before harvest through August after harvest.

(iii) Cash prices and yields refer to a central Illinois farm.

(iv) Commercial storage costs and interest opportunity costs are charged to postharvest sales.

(v) Brokerage costs are subtracted for all futures and options transactions.

(vi) Commodity Credit Corporation (CCC) marketing loan recommendations made by the advisory programs are followed wherever feasible.

Based on these, a weighted-average net price is computed for each advisory program included in a particular crop year. This is interpreted as the harvest-equivalent net price received by a farmer who precisely followed the marketing recommendations for a given program (as recorded by the AgMAS Project). The price is stated on a harvest-equivalent basis because postharvest sales are adjusted for physical storage and interest opportunity costs. Full details on the data collection process and computations can be found in Irwin et al. (2003).

As noted earlier, most subscribers to market advisory services produce and market both corn and soybeans. Typically, Midwest farmers grow corn on half of the farm area and soybeans on the other half. It is therefore relevant to examine a combined measure of corn and soybean pricing performance for each market advisory program. The per acre revenue for each commodity is found by multiplying the net advisory price for each program by the corn or soybean yield for each year. A simple average of both per acre revenues is then taken to determine the total revenue obtained from this practice, which is here called *50/50 revenue*.

Table 1 Market Advisory Program Average Net Price or Revenue, Standard Deviation, Correlation with the Other Programs, and Subscription Cost, 1995–2001 Crop Years

		Corn net price			Soybeans net price			50/50 revenue			
Market advisory program	Advisory program ID number	Average ($/bushel)	Standard deviation ($/bushel)	Average correlation	Average ($/bushel)	Standard deviation ($/bushel)	Average correlation	Average ($/acre)	Standard deviation ($/acre)	Average correlation	Annual subscription cost ($)
AgReview	1	2.36	0.29	0.70	5.79	0.97	0.80	308	36	0.73	360
AgLine by Doane (cash only)	2	2.37	0.41	0.83	6.04	0.76	0.86	314	29	0.76	300
AgResource	3	2.60	0.78	0.69	6.65	0.59	0.43	345	57	0.40	600
AgriVisor (aggressive cash)	4	2.45	0.46	0.83	5.98	0.72	0.85	318	33	0.76	299
AgriVisor (aggressive hedge)	5	2.33	0.41	0.80	6.06	0.84	0.82	312	30	0.71	299
AgriVisor (basic cash)	6	2.30	0.29	0.81	5.95	0.67	0.85	308	27	0.77	299
AgriVisor (basic hedge)	7	2.30	0.35	0.81	6.04	0.82	0.84	309	31	0.76	299
Allendale (futures only)	8	2.26	0.22	0.34	6.16	0.63	0.85	310	21	0.40	300
Brock (cash only)	9	2.26	0.35	0.81	5.98	0.67	0.85	306	32	0.77	240
Brock (hedge)	10	2.27	0.28	0.37	6.22	0.69	0.58	313	37	0.42	240
Freese-Notis	11	2.28	0.47	0.82	5.96	0.65	0.86	306	38	0.77	360
Pro Farmer (cash only)	12	2.23	0.51	0.82	6.04	0.75	0.85	303	37	0.70	420
Pro Farmer (hedge)	13	2.23	0.49	0.83	6.16	0.79	0.86	306	38	0.75	420
Stewart-Peterson advisory reports	14	2.17	0.38	0.80	6.18	0.62	0.78	303	27	0.72	150
Top Farmer Intelligence	15	2.37	0.39	0.69	6.10	0.52	0.69	316	18	0.53	180
Average		2.32	0.43	0.73	6.09	0.72	0.78	312	34	0.66	318
Market benchmark		2.32	0.33		5.96	0.63		309	27		
Farmer benchmark		2.23	0.42		5.91	0.76		300	29		

Note. Averages, standard deviations, and correlations for individual advisory programs are estimated via Sharpe's SIM. The average correlation for each program is computed as the average of the 14 correlations values between a given service and each of the other services.

Two benchmarks reported by AgMAS are used in this study. The first is the *market benchmark*. In its strongest form, efficient market theory predicts that market prices always fully reflect available public and private information (Fama 1970). The practical implication is that no trading strategy can consistently beat the return offered by the market. Hence, the return offered by the market becomes the relevant benchmark. In the present context, the market benchmark is simply the average market price for each crop period considered. The average price is computed in order to reflect the returns to a naïve, no-information strategy of marketing equal amounts each day during the crop period. The difference between the advisory prices and the market benchmark measures the value of advisory service information. The theory of efficient markets predicts that this difference, on average, will equal zero.

The second benchmark is the *farmer benchmark*. A farmer benchmark is designed to measure the average price received by farmers for a crop. In practice, the detailed data needed to construct a valid farmer benchmark are not available so an approximation must be used. The only known approximation is the U.S. Department of Agriculture (USDA) *average price received* series. This series has some positive and negative features with respect to measuring the average price received by farmers. On the plus side, the USDA series reflects the actual pattern of cash grain marketing transactions by farmers, and thus incorporates the marketing windows and timing strategies actually used by farmers; it includes forward contract transactions for both the preharvest and postharvest periods, with the transactions recorded as the forward price, not the spot price at time of delivery, and grain sales are adjusted to industry standards for moisture. On the negative side, the USDA series is only available on a statewide basis; it includes cash transactions for different grades and quality of grain sold by farmers; it does not include farmers' futures and options trading profits or losses, and it reflects a mix of farmers' old and new crop sales. Fortunately, none of the problems mentioned are expected to have a large impact on prices, and therefore do not prevent the use of the USDA series as a valid measure of the average price received by farmers. Complete details about computations of both benchmarks can be found in Irwin et al. (2003).

6. Estimation of the Model Parameters

Expected prices or revenues, variances, and covariances are needed as the inputs for the E-V model. Specifically, for the 15 advisory programs, 15 expected prices, or revenues, 15 variances, and 105 covariances must be estimated. The total of 135 parameters exceeds the number of observations available in this study (15 programs times 7 years = 105 observations). The single-index model (SIM) proposed by Sharpe (1963) presents a way to reduce the number of parameters to estimate and, therefore, becomes a preferred alternative to traditional sample estimates when the available data set is small. With the use of Sharpe's SIM we need to estimate only three parameters for each advisory program, and only two more for the index. Thus, we need to estimate a total of 47 parameters, which is sufficiently fewer than the number of available sample observations. Several studies in the finance literature have found that imposing structure on the variance-covariance matrix can improve the estimation of mean-variance efficient portfolios (e.g., Frankfurter et al. 1976, Ledoit 2004).

The SIM makes the simplifying assumption that prices (revenues) associated with individual market advisory programs are related, through a common relationship, to the market benchmark (the *index*) according to the following linear model:

$$P_{it} = \alpha_i + \beta_i P_{Bt} + \varepsilon_{it},$$

where P_{it} and P_{Bt} are the net price or revenue corresponding to service i and the market benchmark price or revenue, respectively, in year t; α_i and β_i are the model parameters to be estimated; and ε_{it} is the error term. The error terms are assumed to be independently distributed with mean zero. Once the α_i and β_i parameters of the above model are estimated, the expected price or revenue and the variances and covariances are computed by

$$P_i = \hat{\alpha}_i + \hat{\beta}_i P_B$$

$$\hat{\sigma}_i^2 = \hat{\beta}_i^2 \hat{\sigma}_B^2 + \hat{\sigma}_{\varepsilon_i}^2$$

$$\hat{\sigma}_{ij} = \hat{\beta}_i \hat{\beta}_j \hat{\sigma}_B^2,$$

where P_i is the expected price or revenue for program i, P_B and $\hat{\sigma}_B^2$ are the sample mean and variance for the benchmark price or revenue, and $\hat{\sigma}_{\varepsilon_i}^2$ is the variance of the error term from the regression of program i against the benchmark. The SIM estimates for average price or revenue, standard deviation, and correlation for the individual advisory programs are presented in Table 1. Note that the SIM estimates for average prices or revenues are the same as the sample mean estimates.

7. Results

The efficient frontiers formed by the optimal portfolios of advisory programs were determined for corn, soybeans, and 50/50 revenue by solving the E-V model for 10 different levels of expected corn and soybean prices and 50/50 revenue. The highest level in each case was obtained by maximizing the expected price (revenue) ignoring the portfolio variance (this portfolio always includes a single program, namely the most aggressive program in each case), whereas the lowest level was specified as the expected price (revenue) that corresponds to the minimum variance portfolio ignoring the expected returns constraint. The remaining eight levels were obtained by dividing the range into nine equal intervals.

Table 2 presents the compositions of 10 optimal portfolios for corn price, soybean price, and 50/50 revenue. Note that the results for individual crops do not consider the program subscription costs, but that the results for 50/50 revenue include the subscription costs; see Table 1 for subscription costs of individual programs. The results of the revenue model for the 500- and 2,000-acre farm sizes were similar. Therefore, for the sake of space, here we present only the results for the 2,000-acre farm; 500-acre farm results are available from the authors upon request. To provide a more meaningful interpretation of the risk levels of different alternatives, the standard deviation values are reported instead of variances.

The efficient portfolios for corn price, denoted by P1–P10, are shown in Panel 2a in Table 2. The portfolios included up to six programs (e.g., P3). The low-risk portfolios included a greater number of programs

Table 2 **Composition of E-V Optimal Portfolios, 1995–2001 Crop Years**

Portfolio number	Expected price ($/bushel)	Standard deviation ($/bushel)	Portfolio proportions for market advisory programs (by ID #) (percent)					
			1	3	4	8	10	15
2a Corn price								
P1	2.28	0.18	15.92			54.67	29.41	
P2	2.31	0.20	42.54	2.79		34.96	17.81	1.90
P3	2.35	0.26	49.47	10.45	2.78	25.59	11.27	0.43
P4	2.38	0.31	51.74	15.94	11.23	16.52	4.57	
P5	2.42	0.38	52.93	21.66	19.45	5.96		
P6	2.46	0.45	40.70	30.22	29.07			
P7	2.49	0.52	19.48	40.68	39.84			
P8	2.53	0.60		52.23	47.77			
P9	2.56	0.68		76.11	23.89			
P10	2.60	0.78		100.00				

Portfolio number	Expected price ($/bushel)	Standard deviation ($/bushel)	Portfolio proportions for market advisory programs (by ID #) (percent)			
			3	10	14	15
2b Soybean price						
P1	6.31	0.44	35.95	13.30	1.72	49.04
P2	6.35	0.45	42.90	13.21	0.66	43.23
P3	6.39	0.45	49.80	13.03		37.16
P4	6.42	0.46	56.65	12.68		30.67
P5	6.46	0.48	63.49	12.34		24.18
P6	6.50	0.49	70.33	11.99		17.68
P7	6.53	0.51	77.17	11.64		11.19
P8	6.57	0.53	84.02	11.29		4.69
P9	6.61	0.56	91.36	8.64		
P10	6.65	0.59	100.00			

Portfolio number	Expected price ($/acre)	Standard deviation ($/acre)	Portfolio propositions for market advisory programs (by ID #) (percent)			
			3	8	10	15
2c 50/50 revenue, 2,000-acre farm (net of subscription costs)						
P1	313.02	15.73		38.93	3.80	57.26
P2	316.50	17.12	9.77	26.16		64.07
P3	319.97	19.95	19.39	13.94		66.66
P4	323.44	23.60	28.16			71.84
P5	326.91	28.11	40.18			59.82
P6	330.39	33.28	52.21			47.79
P7	333.86	38.83	64.23			35.77
P8	337.33	44.64	76.26			23.74
P9	340.81	50.61	88.29			11.71
P10	344.28	56.52	100.00			

that have more stable prices during the sample period and low correlation with others (such as *AgReview*, *Allendale-futures only*, and *Brock-hedge*). In portfolios with higher expected price specifications these programs gradually lose their share and eventually disappear, while competitors with higher expected prices enter the solution. For instance, *AgResource*, which yields the maximum average price for corn (but also has the highest variance among all the programs), increases its share gradually and dominates the portfolio, and in the end remains as the only program in the optimum solution. These results are intuitive and consistent with the theory.

Panel 2b in Table 2 shows the efficient portfolio compositions for soybeans. The optimum soybean portfolios contained fewer programs compared with corn (which contain three programs in most cases). *Top Farmer Intelligence*, which offers a relatively high mean price and the lowest risk, is the dominating program in the first few portfolios, but it gradually loses share to other programs, particularly to *AgResource*, which appears in all 10 portfolios. Given that the latter program was also present in almost all corn portfolios, one would expect this program to have a substantial share in the optimum 50/50 revenue portfolios. These two programs and *Brock-hedge*, which appears in all of the portfolios P1–P9, have high average prices and relatively low variances among all programs (see Table 1).

Panel 2c in Table 2 presents the results for 50/50 (corn and soybeans) revenue. Recall that this case involves the total revenue that would be obtained by growing corn on half of the land and soybeans on the other half, and following the advisory service recommendations for both crops. Thus, one would expect that if a particular program appears with significant shares in the optimum portfolios of both commodities when considered separately the optimum 50/50 revenue portfolios would also include that program. This is the case for *AgResource*. Despite the fact this program has the highest subscription cost, it has a significant share in almost all portfolios and dominates all the other programs in the aggressive 50/50 revenue portfolios. The revenue-efficient portfolios comprise at most three programs (e.g., P1–P3), but in most cases only two programs.

Figure 1 exhibits the E-V efficient frontiers for corn and soybean prices (Panels A and B, respectively) and 50/50 revenue (Panel C), the E-V characteristics of individual programs, and the two benchmarks. In all cases, a comparison of the efficient portfolios vis à vis the individual advisory programs shows that for each program we can always find a strictly dominant efficient portfolio, which demonstrates the merit of relying on a portfolio rather than on an individual program. For corn price (Panel A), it is seen that the efficient frontier is relatively close to the performance of individual programs, indicating that the gains from diversification might be relatively small. Three of the portfolios on the efficient frontier, namely P2–P4, dominate both the market benchmark and the farmer benchmark in the mean-variance sense, because they offer a higher expected price and lower risk than the benchmarks. For soybeans, the efficient frontier lies far more northwest relative to the individual programs as well as to the two benchmarks, which indicates that possible benefits from diversification can be substantial. This result is mainly due to the existence of one program, *AgResource*, which has a very high expected soybean price, a very low standard deviation, and low correlations with the other programs. The soybean efficiency frontier dominates most of the individual programs and the two benchmarks in the mean-variance sense. For the 50/50 revenue case, the four portfolios P1–P4 dominate the market benchmark, and P1–P5 dominate the farmer benchmark.

8. Statistical Analysis of Portfolio Efficiency

A formal statistical analysis was conducted to test dominance of the efficient portfolios vis à vis the two benchmarks. A joint test for the mean and variance of paired data was employed for this purpose (Bradley and Blackwood 1989). To implement the test, a series D_{kt} is generated, which represents the price or revenue difference between portfolio k and a given benchmark in year t (i.e., $D_{kt} = P_{kt} - P_{Bt}$), and a series S_{kt} that represents the sum of portfolio and benchmark's price or revenue values (i.e., $S_{kt} = P_{kt} + P_{Bt}$). Then, assuming a linear relationship between the two series, the following OLS regression can be specified:

$$D_{kt} = \beta_{k1} + \beta_{k2} S_{kt} + e_{kt}.$$

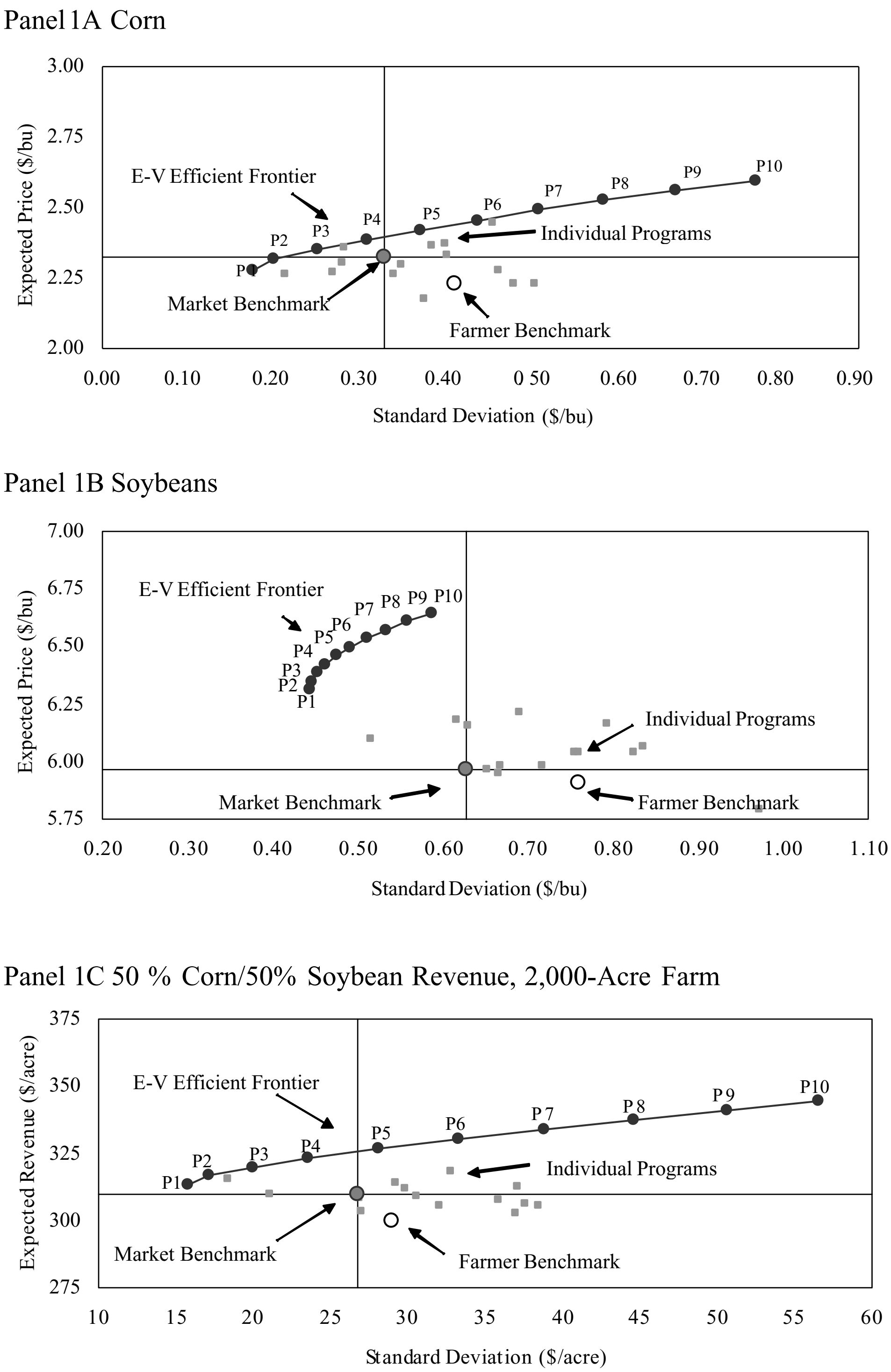
Assuming that the net advisory and benchmark prices or revenues are normally distributed, the regression coefficients above become functions of the means and variances given by

$$\beta_{k1} = (\mu_{P_k} - \mu_{P_B}) - \left[\frac{\sigma^2_{P_k} - \sigma^2_{P_B}}{\sigma^2_{S_k}}\right] \cdot (\mu_{P_k} + \mu_{P_B})$$

$$\beta_{k2} = \frac{\sigma^2_{P_k} - \sigma^2_{P_B}}{\sigma^2_{S_k}},$$

where μ_{P_k} is the mean price or revenue for portfolio k, μ_{P_B} is the mean price or revenue for the benchmark, $\sigma^2_{P_k}$ is the variance of portfolio k, $\sigma^2_{P_B}$ is the variance of the benchmark, and $\sigma^2_{S_k}$ is the variance of the sum

Figure 1 Comparison of the E-V Optimal Portfolios of Market Advisory Programs to Individual Programs and Benchmarks, 1995–2001 Crop Years



of portfolio and benchmark prices or revenues. Note that $\mu_{P_k} = \mu_{P_B}$ and $\sigma^2_{P_k} = \sigma^2_{P_B}$ if and only if $\beta_{k1} = \beta_{k2} = 0$. As a result, the simultaneous test of the equivalence of means and variances can be implemented by calculating the F-statistic for the joint null hypothesis that the intercept and slope parameters equal zero, and by comparing the test statistic with the critical F-values. This procedure is carried out to compare each of the dominant portfolios for corn, soybeans, and 50/50 revenue against the two benchmarks.

The results of the analysis are displayed in Table 3. For each efficient portfolio, a plus sign (+) in the risk dominance relationship column indicates that the portfolio dominates the respective benchmark. That is, the portfolio has a greater mean and lower risk than the benchmark. A question mark (?) indicates that the portfolio neither dominates nor is dominated by the benchmark. That is, either both the mean and variance are greater than the mean and variance of the benchmark, or both are lower than the mean and variance of the benchmark. The value for the F-statistic is computed only for those cases where the point estimates indicate a risk dominance (as indicated by a + sign). A significant F-value (so labeled with an asterisk) indicates that the dominance is statistically significant. As shown in Table 3, for corn price none of the dominant portfolios can be considered statistically different from the market benchmark, but three portfolios, namely P3–P5, significantly dominate the farmer benchmark. For soybeans, the F-values show that most of the efficient portfolios significantly dominate both the market benchmark (P4–P10) and the farmer benchmark (P5–P10). For 50/50 revenue, the only portfolio that significantly dominates the market benchmark is P1, which also significantly dominates the farmer

Table 3 **Joint Test Results for Differences in Mean and Variance Between Points on the Efficient Frontier and the Benchmarks**

Portfolio number	Corn price: Dominance relationship	Corn price: F-statistic	Soybean price: Dominance relationship	Soybean price: F-statistic	50/50 revenue: Dominance relationship	50/50 revenue: F-statistic
Panel 3a Efficient portfolios vs. the market benchmark						
P1	?	N/A	+	3.18	+	4.42*
P2	?	N/A	+	3.47	+	1.58
P3	+	1.42	+	3.72	+	0.71
P4	+	1.14	+	3.98*	+	0.76
P5	?	N/A	+	4.18*	?	N/A
P6	?	N/A	+	4.33*	?	N/A
P7	?	N/A	+	4.45*	?	N/A
P8	?	N/A	+	4.54*	?	N/A
P9	?	N/A	+	4.47*	?	N/A
P10	?	N/A	+	4.07*	?	N/A
Panel 3b Efficient portfolios vs. the farmer benchmark						
P1	+	2.55	+	2.76	+	3.81*
P2	+	3.62	+	3.08	+	2.90
P3	+	3.89*	+	3.39	+	2.03
P4	+	3.89*	+	3.71	+	1.83
P5	+	3.85*	+	4.00*	+	2.01
P6	?	N/A	+	4.25*	?	N/A
P7	?	N/A	+	4.47*	?	N/A
P8	?	N/A	+	4.66*	?	N/A
P9	?	N/A	+	4.71*	?	N/A
P10	?	N/A	+	4.42*	?	N/A

Note. The signs indicate the relationship between the portfolio and the benchmark in terms of risk and return. A plus sign indicates that the portfolio dominates the benchmark, i.e., it has a lower standard deviation and a greater mean than the benchmark. A question mark indicates that the portfolio neither dominates nor is dominated by the benchmark, i.e., the mean and standard deviation are either both greater or both lower than the benchmark's. An asterisk indicates that the null hypothesis is rejected at the 90% significance level. "N/A" means not applicable because the point estimates do not indicate risk dominance.

benchmark. This portfolio has \$4 per acre and \$13 per acre higher expected revenue, and \$11 per acre and \$13 per acre lower standard deviation than the market and farmer benchmarks, respectively.

An interesting finding arises from the comparison of the two benchmarks. The point estimates indicate that the market benchmark dominates the farmer benchmark in each of the three cases: corn and soybeans prices, and 50/50 revenue. The risk dominance is significant at the 90% confidence level for corn but not for soybeans and 50/50 revenue (the respective F-values are 4.90, 0.60, and 1.07). These results reinforce the notion that there is room for improvement in farmers' marketing performance.

9. Holdout Analysis

To investigate the real-time usefulness of advisory services and to examine whether farmers would be better off using these services than following either of the benchmarks, a simple out-of-sample experiment was carried out. Out-of-sample performance measurement is widely used in the finance literature as a way to validate investment decision models (e.g., Jorion 1985). In this study, the period of analysis, 1995–2001, was divided into two subperiods. First, the parameters of the portfolio optimization problem were estimated based on data for the in-sample period 1995–1998, and the optimal composition of the efficient portfolios was determined based on this estimation. Then the performance of the efficient portfolios was evaluated for the out-of-sample period 1999–2001 by comparing the mean return and risk of the efficient portfolio against the market and farmer benchmarks in those years. This type of holdout analysis is especially useful when a sufficiently large database (i.e., a sufficiently long time period) is used, which is unfortunately not the case in the present study. Therefore, the findings of this analysis must be interpreted with caution.

The out-of-sample performance results are presented in Table 4 and Figure 2. Table 4 shows the optimal portfolio compositions for the 1995–1998 period. Interestingly, the portfolios are very similar to the ones obtained by using the full sample. In both cases, *AgResource* offers the highest expected price for both corn and soybeans (therefore the highest 50/50 revenue), and dominates the portfolios as the minimum expected price (revenue) requirement is raised. Some differences are observed between the two sets of portfolios, however. The efficient 50/50 revenue portfolios for 1995–1998 include more advisory programs than the full sample portfolios. (*AgLine* and *AgriVisor-aggressive hedge* are the additional programs that were not included in the full sample solutions.) Figure 2 compares the out-of-sample performance of the portfolios vis à vis the two benchmarks. The dark circles indicate the average price or revenue and standard deviation associated with each portfolio listed in Table 4 for the out-of-sample period 1999–2001. The most striking observation in the figure is that the average price or revenue over 1999–2001 for all the portfolios is greater than that of the two benchmarks' (particularly in the case of soybean prices), but the risk (even that of the minimum variance portfolio) is always higher than the benchmark risk. This indicates that the selected portfolios would outperform the benchmarks in terms of average price or revenue during the holdout period, but not in terms of risk. Hence, the efficient portfolios fail to dominate the benchmarks in a mean-variance sense. Because according to the point estimates, none of the portfolios dominated the benchmarks, the statistical significance test described in the previous section was not applied to the out-of-sample results.

10. Concluding Remarks

This study presents a comprehensive analysis of the efficiency of market advisory services by considering a portfolio of advisory programs, rather than one program at a time, using the well-known mean-variance framework introduced by Markowitz (1952). A mixed-integer quadratic programming framework is used to evaluate the risk and return characteristics of optimum portfolios formed by various grain-marketing alternatives available to corn and soybean producers. The model was solved using recently introduced optimization software, BARON, interfaced with GAMS. The optimization results provide some evidence that an efficient portfolio provides significantly greater risk or return benefits compared with external benchmarks. In a holdout period analysis, efficient portfolios have superior performance in terms of average returns, but fail to dominate the relevant benchmarks in terms of mean and variance. However, these out-of-sample results should be

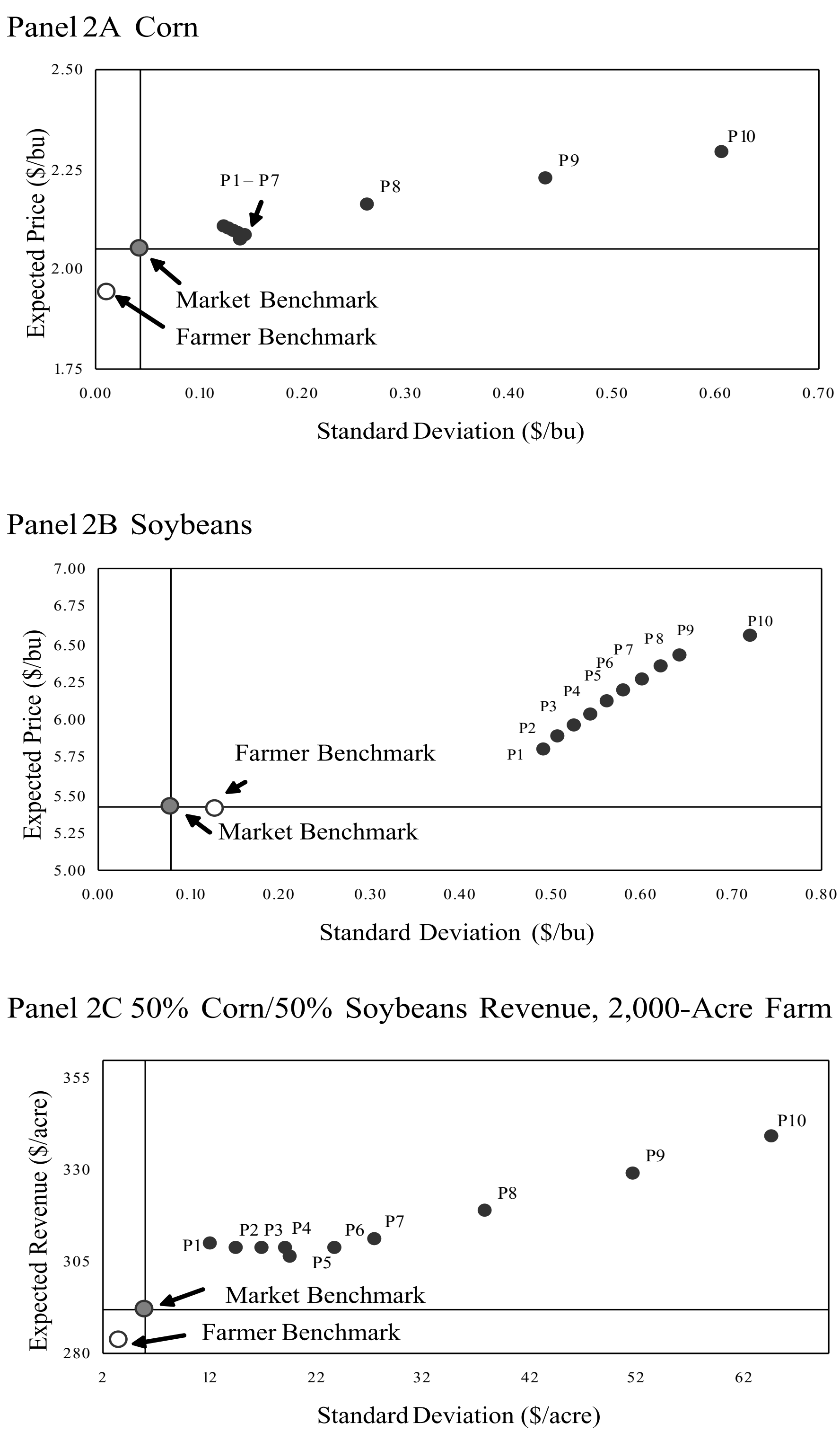
Table 4 Out-of-Sample Performance Results for E-V Optimal Portfolios

Portfolio number	In-sample portfolio proportions for market advisory programs (by ID #) (1995–1998) (percent)							1999–2001 out-of-sample performance ($/bushel)	
	1	3	4	6	8	9	10	Average price	Standard deviation
4a Corn price									
P1	10.19			20.43	13.23	4.84	51.31	2.08	0.14
P2	15.38		16.24	0.01	10.53		57.84	2.08	0.14
P3	14.78		29.36				55.86	2.08	0.14
P4	11.17		46.31				42.52	2.09	0.14
P5	7.56		63.26				29.18	2.09	0.13
P6	3.94		80.21				15.84	2.10	0.13
P7	0.33		97.16				2.50	2.11	0.13
P8		29.22	70.78					2.16	0.26
P9		64.61	35.39					2.23	0.44
P10		100.00						2.29	0.61
Market benchmark								2.05	0.04
Farmer benchmark								1.94	0.01

Portfolio number	In-sample portfolio proportions for market advisory programs (by ID #) (1995–1998) (percent)			1999–2001 out-of-sample performance ($/bushel)	
	3	10	15	Average price	Standard deviation
4b Soybean price					
P1	6.42	12.35	81.23	5.80	0.49
P2	15.90	12.77	71.33	5.88	0.51
P3	25.39	13.19	61.42	5.95	0.53
P4	34.87	13.61	51.51	6.03	0.55
P5	44.36	14.04	41.61	6.11	0.56
P6	53.84	14.46	31.70	6.19	0.58
P7	63.32	14.88	21.80	6.26	0.60
P8	72.81	15.30	11.89	6.34	0.62
P9	82.29	15.72	1.99	6.42	0.64
P10	100.00			6.56	0.72
Market benchmark				5.42	0.08
Farmer benchmark				5.41	0.13

Portfolio number	In-sample portfolio proportions for market advisory programs (by ID #) (1995–1998) (percent)							1999–2001 out-of-sample performance ($/acre)	
	2	3	4	5	8	10	15	Average price	Standard deviation
4c 50/50 revenue, 2,000-acre farm (net of subscription costs)									
P1				1.87	31.62	5.09	61.42	309.23	12.06
P2	9.89	6.60		9.33	25.40	5.11	43.67	307.57	14.58
P3		11.72	17.27	10.20	22.69	4.87	33.25	307.97	16.97
P4	14.54	16.42	25.16		19.42	4.34	20.11	307.60	19.19
P5	23.33	19.61	34.68		22.38			305.63	19.54
P6	17.28	26.87	44.55		11.30			308.03	23.69
P7	12.55	33.54	53.92					310.31	27.52
P8		52.04	47.96					318.43	37.94
P9		76.53	23.47					328.62	51.62
P10		100.00						338.54	64.74
Market benchmark								291.93	5.96
Farmer benchmark								283.46	3.50

Figure 2 Out-of-Sample Performance of E-V Optimal Portfolios Over 1999–2001 Using the Estimates for the 1995–1998 In-Sample Period



Note. The labels P1–P10 correspond to portfolios on the efficient frontier for the 1995–1998 subsample. The figures show the average price or revenue and standard deviation obtained by these portfolios during the 1999–2001 out-of-sample period.

considered with caution, given the small number of observations available.

An alternative to the nonlinear formulation is MOTAD (Hazell 1971), which uses a linear approximation of the portfolio variance and can be solved by using widely available off-the-shelf linear mixed-integer programming solvers. Here, we used MOTAD to test the robustness of solutions obtained from BARON. Our computational results (which are not presented here for the sake of space, but which are available from the authors upon request) showed that both approaches produced similar solutions, which increased our confidence in the results obtained from BARON. Therefore, depending on the solver availability, either the nonlinear formulation or the linear approximation of it can be used conveniently to deal with these types of problems.

In the particular problem studied here, the sets of advisory programs included in efficient portfolios were usually small, including two to four programs in most cases. However, in some cases up to six advisory programs were involved. In practice, farmers might prefer to work with more than one advisory service or program to benefit from risk and return characteristics of those programs. Integrating too many advisory programs in marketing decisions might not be desirable, however, for two reasons. First, a larger portfolio implies an increased cost because each advisory program requires a fixed subscription cost, regardless of its share in the portfolio. Second, and more important, following the recommendations of too many services and incorporating them in day-to-day decisions is complicated. Therefore, whether or not a larger portfolio should be selected is an important empirical issue that needs to be addressed. To address this issue, the model presented in this study was modified slightly by appending a constraint that restricts the number of advisory programs that can be included in the portfolio. This constraint is simply

$$\sum_i z_i \le m,$$

where m is the maximum number of programs allowed in the portfolio. By varying the parameter m systematically, we measured the risk and return contributions of relaxed portfolios (i.e., additional advisory programs). Our results (not presented here due to space limitation, but available from the authors upon request) showed that an optimum portfolio with two advisory programs is always better than working with an individual program both in terms of risks and returns. Also, allowing a larger number of programs always improves the benefits from optimum portfolios. However, the contributions were marginal when more than two programs were allowed in the portfolio. This finding shows that one can do well by working with only two advisory programs, instead of a single program or a highly diversified portfolio, which producers can find useful when marketing their products by selecting the most appropriate sources of information, depending on their risk attitude.

The results presented here show that small portfolios of market advisory services can be valuable alternatives for grain farmers, raising some interesting questions. For instance, what allows some services to provide valuable advice to farmers? What is the process that the services use to generate recommendations? These issues are not fully understood, and are an open area for additional research. Furthermore, when evaluating the performance of advisory services it is important to mention that these services provide other products to their subscribers beyond specific marketing recommendations. These products include analysis of the USDA market reports, general market commentary and analysis, price forecasts, and weather forecasts. According to survey results (Pennings et al. 2001), most farmers that subscribe to advisory services view these products as valuable inputs to their management decisions.

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