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Paul V. Preckel
Timothy G. Baker
Jessica Eide

Presented at Western Agricultural Economics
Association 1997 Annual Meeting
July 13-16, 1997
Reno/Sparks, Nevada

July 1997

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Paul V. Preckel

Timothy G. Baker

and

Jessica Eide¹

February 26, 1997

¹ The authors are professors and graduate research assistant in the Department of Agricultural Economics, Purdue University, 1145 Krannert Building, West Lafayette, IN 47907. The senior author may be contacted at preckel@agecon.purdue.edu. The authors are grateful to Gerald Shively, Otto Doering, Mei-chin Chu, Scott Swinton, Sandra Batie, and Brian Baer for access to data, and helpful comments and suggestions. This material is based on work supported by the Cooperative State Research, Education and Extension Service, U.S. Department of Agriculture under agreement #94-37102-0839. Any opinions, findings, conclusions, or recommendations expressed in this publication are those of the authors and do not necessarily reflect the views of the U.S. Department of Agriculture.

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Abstract

The incentive for excess nitrogen application in seed corn production contracts is analyzed. We find that the lack of contract renewal certainty can encourage greater input use. In a geographic region where contract seed corn production is prevalent, we estimate that nitrogen use is increased by about 15%.

Seed Corn Tournament Contracts and Excess Nitrogen Application

In this paper, a particular type of contract employed in the seed corn industry, the “tournament contract,” is analyzed. In the case of seed corn, there appears to exist a potentially undesirable side-effect to the contracts. Namely, the contract structure encourages excess use of nitrogen fertilizer and as a result, leads to increased nitrate loadings in ground water. In an age of increased public scrutiny of the behavior of agribusinesses, this type of contract might be perceived as not “green” (environmentally friendly). In this paper, the side-effect is specifically identified, the magnitude of the excess use is measured empirically for a seed corn producing region in southern Michigan, and strategies for reducing or eliminating the excess nitrogen use are suggested.

The goal of a tournament contract is to foster competition between the contractees by basing the rewards from the contractor on some measure of performance (Nalebuff and Stiglitz, 1983). Typically this goal is achieved by designing a system of payoffs which rewards contractees who perform better and penalizes those who perform less well.

In agriculture, tournament contracts are common in poultry and in seed corn production. While there has been substantial work done in the poultry area (Knoeber, 1989; Knoeber and Thurman, 1994; Knoeber and Thurman, 1995), there has been little analysis done for seed corn contracts. (An exception is the work by Chu, Swinton, and Batie (1996) that focuses on a static, one year analysis of the effects of contract structure on producer behavior.) There is quite a bit of variation in the details of broiler chicken production contracts, and several of these arrangements have been studied (Knoeber,

1989). However, there are very basic differences between broiler and seed corn contracts which warrant separate analysis in this paper.

One important difference is length of contract. Broiler contracts are long-term, while seed corn contracts are renewed annually. Seed corn producers provide land, machinery, and management skills which for the most part apply to production of other crops as well as seed corn. Because of this asset versatility, the contracting relationship between the seed corn company and producer will not necessarily develop as a long-term agreement. In contract seed corn production, producers are paid for use of the land and for providing a number of services such as land preparation, planting and tending the crop. The seed corn company takes over many of the post-planting field operations such as detassleing and harvesting. Payments to producers are comprised of a fixed payment plus a bonus if their yield is greater than the average of producers in the tournament or less a penalty if their yield is less than average. The seed company's contract allocation (renewal) rules are typically not public. However, there is a perception by farmers that the company allocates on the basis of high yields. Thus, producers have two incentives to apply effort to obtain a high yield: the yield bonus and the increased likelihood of future contract allocations.

This paper addresses: whether the features of seed corn production contracts encourage greater application of fertilizers than would be the case under an allocation of contract by lottery, what is the magnitude of the increase in input use (if any), and how the

contract might be modified to obtain a Pareto improvement for farmers, the company and society.

A Stylized Model for Seed Corn Producers

Due to space limitations, we limit the model description to a brief verbal one in order to focus on our results. (A more complete mathematical description is available from the authors.) The yield model is of the linear (in fertilizer level) and plateau type with a stochastic plateau level (due to weather) plus a random disturbance accounting for other (non-weather) stochastic factors. The producer is assumed to be a maximizer of expected discounted profit. The payoff scheme under the contract is linear with a constant payment plus a bonus (penalty) for yield in excess (short of) the regional average.

Using this framework, we show the unsurprising result that if the bonus rate is equal to the free market price for seed corn (assuming there is a market), then the structure of the payment in the contract does not distort fertilizer use.

However, it may be shown analytically that the presence of contract insecurity has an ambiguous effect on fertilizer use. To analyze this aspect, we assume that producers perceive that he/she will lose their access to the contract in subsequent years if they end up in the bottom z percent of the lower tail of the yield distribution. It is also assumed that all producers with the contract in the tournament region have access to the same information and technology, and have the same level of management ability. Thus, we assume that all producers act the same in a Nash game where they choose their fertilizer application rate.

The ambiguity of the effect of contract insecurity is resolved by analyzing a specific case for a region in southern Michigan where contract seed corn production is prevalent.

Empirical Evaluation of Input Use Distortion

Our empirical evaluation of the magnitude of nitrogen application rate distortions due to specific features of seed corn contracts is performed for a region in southern Michigan. Seed corn is produced in this region under irrigated conditions. A cost budget for continuous, irrigated seed corn production in this region may be found in Eide (1997). The total variable operating costs excluding nitrogen are 133.22 dollars per acre. The design of the tournament contract is taken from Eide (1997).

The contract payment is of the form: $1.1(P_{cbot} - 0.08)[2(\bar{y}(n,w) - \bar{y}(N,w)) + 185]$, where P_{cbot} denotes an agreed upon price (typically a Chicago Board of Trade futures price for commercial corn with a delivery date near harvest for the current year), $\bar{y}(n,w)$ denotes the farmer's yield given nitrogen application rate n and realized weather w , and $\bar{y}(N,w)$ denotes the regional average yield given regional nitrogen application rate N . A value of $P_{cbot} = 3.25$ is used for illustration. This price is adjusted downward by \$0.08 to reflect a typical basis, and is scaled up by 10% (the factor 1.1) to reflect the bonus that the seed corn company gives to producers to make the contract desirable. This adjusted price is applied to adjusted yield. The base, commercial corn yield is set to 185 bushels per acre, and a yield bonus of twice the difference between farm level yields and average yield across other tournament participants is used to provide farmer incentives. These figures

do not represent a particular contract, but are representative of the form and magnitude of the parameters for existing contracts (Eide, 1997).

To reflect the relationship between nitrogen and seed corn yield, the biophysical simulation model DSSAT (Tsuji, Uehara and Balas, 1994) as calibrated to reflect the growth of hybrid seed corn (Ritchie, et al., 1993) in St. Josephs County, Michigan is employed. To reflect the variability due to weather, actual weather data for forty years (1953-1992) were employed as model input. Yields were generated for each of the forty years at each of 21 nitrogen application rates ranging from zero pounds per acre to 440 pounds per acre in 22 pound increments. This data set is smoothed and interpolated by least squares estimation of a model of yield in the form $\min[\alpha(n+n_0(w)),\beta w]$ where $n_0(w)$ denotes the amount of nitrogen available from natural sources.

As part of the process of calibration of the DSSAT model used to simulate seed corn production in southern Michigan, Ritchie et al. (1993) employed experimental plot data and published the actual yields versus the yields predicted by DSSAT. This information serves as the basis for developing the distribution of the variability in yields that is not explained by weather (hereafter referred to as the distribution of “unexplained variability”). This data set includes four alternative nitrogen application programs and replications across three years. While one of these programs does not employ a constant rate across years, the others do. These three fall within the range of nitrogen rates relevant to this study. The rate of nitrogen application and sample variance pairs for these programs are (37,20.726), (90,23.272), and (180,13.748). This data suggests that the

variance of the distribution of unexplained variability is not constant with respect to the nitrogen application rates.

For simplicity, the distribution of the unexplained variation is assumed to be uniform with mean equal to the sample mean of the residuals from the calibration and variance depending upon the level of nitrogen application as described as follows. The sample variances above were transformed into supports (smallest and largest values) for an assumed uniform distribution of yield variation unexplained by weather (and the DSSAT model) by finding the supports giving that variance. Then a linear regression of the support of the distribution of unexplained variability on nitrogen application rate was performed to obtain the following relationship: $d+en=24.838-0.055n$, where n is applied nitrogen in pounds and $[-d-en, d+en]$ is the support for the non-weather uniform random disturbance of yield conditional on the nitrogen application rate. This relationship implies that the *unexplained variation* declines as nitrogen application increases. This does not necessarily imply that nitrogen is a variance decreasing input in the sense of Just and Pope (1978). The reason is that the variation which is explained by the model is *increasing* in nitrogen application. The total variation in output is a combination of variation from these two sources.

Based on the fitted model of yield response and applying the nitrogen rate specified in the budget from Eide (107 pounds of nitrogen per acre), the average yield is 76.9 bushels per acre. Based on the payoff function and the budget, this yields a net return of \$504 per acre. The net return (accounting for the same cost categories as were

used for the seed corn net return) to the next best alternative to seed corn production is assumed to be \$150 based on average cash rent for the county for 1995.

Results of the Empirical Analysis

Based on the economic conditions assumed for this analysis, the optimum level of nitrogen use is 124 pounds of applied nitrogen per acre in the cases where the producer is certain that he/she will retain the contract next period. This result is computed by evaluating expected profits for a grid of nitrogen values from 107 to 147 pounds per acre with a grid size of 2 pounds per acre.

Now consider the case where some of the producers are not permitted to renew their contract in the next period. These scenarios are defined in terms of the percentage in the lower tail of the regional distribution which loses the contract in the next period. If this percentage is small -- even one percent -- then our results show that the optimal producer strategy is to apply nitrogen at the maximum productive rate of 143 pounds per acre. The reason is that the individual can effectively eliminate the probability of falling in the bottom one percent (or other small percentage) of the tail of the regional nitrogen distribution by applying a bit more nitrogen than his neighbors. However, all of his neighbors have identical incentives, and in the absence of collusion, they all increase nitrogen to the point where they no longer can have an effect on the probability of contract loss in the next period.

This phenomenon persists up through the point where the percentage of the lower tail that loses the contract rises to 40%. (See Table 1.) Thus until the percentage of the

lower tail that loses the contract becomes quite substantial, the distortion in input use is significant -- an increase of over 16%. As the “cutoff percentage” rises into the 41-50% range, the optimal nitrogen application rate falls marginally to about 15% above the certain contract situation. At a 51% cutoff percentage, the optimal application rate drops to 132 pounds per acre (about 6.5% above the case with contract certainty), and at 61%, the optimal rate falls to 128 pounds per acre (about 3.2% above the contract certainty level). When the cutoff rises to 73% or above, the optimal nitrogen application drops to the contract certainty level.

In addition to predicting yields, the DSSAT model predicts nitrate loading in ground water. The change in the rate of nitrate loading in the ground water as predicted by interpolation of the DSSAT values is less severe. The worst situation is when the cutoff percentage is in the 1-40% range, where the increase in nitrate loadings is about 7.6%. In the 41-50% range, the increase in nitrate loadings drops to 6.7%. At cutoff levels above 50%, the increase in nitrate loadings is minor, ranging from zero up to 2.7%.

While it is difficult to precisely assess farmers’ perceived level of the cutoff percentage, private communications suggest that somewhere in the range of 1-50% is in the ballpark. This is the region for the cutoff percentage that causes the greatest distortions to input use and that causes the greatest increase in nitrate loadings in the ground water. Thus, the answer to our second question -- what is the magnitude of the increase in input use? -- is around 15% in the study region. Modifications to the contract payment plan that reduce or eliminate the distortions to input use may be warranted.

Implications for Contract Design

The theoretical model underlying these results suggests that, under plausible stylized circumstances, the nature of tournament contracts in the seed corn industry may cause excessive applications of nitrogen (and conceivably other inputs such as pesticides). One of the causes of this increase in input use is the lack of security in the contracts combined with the perception by farmers that if their yield falls too low relative to the regional average they may lose access to the contracts.

One alternative which would mitigate the increased input use would be to decouple the linkage between the probability of contract loss and yield. Anecdotal evidence (Dobbins, 1996) suggests that farmers are skeptical regarding the seed corn company's statements that yield is not the criterion on which they base contract allocations. The only obvious way to break the linkage is by awarding the contracts on the basis of truly random lotteries that are run in such a way that farmers believe they are truly random.

Unfortunately, unlike the modeling framework presented here, there may be real differences in farmers' skills and resources such that their mean yields are indeed different. This approach to mitigating the increased input use would eliminate the seed corn company's ability to select producers for good management skills and resources.

Another alternative which may be preferable to the seed corn companies is to adjust the "bonus rates" for better than average performance to a level which eliminates the incentive to use inputs beyond the desired level. This would allow them to continue to select producers according to their own criteria. The bonus rate could be adjusted

downward to reduce the incentive to over apply nitrogen, thereby compensating for the long term incentives associated with improving the probability of contract renewal. In our example, changing the contract payment to $1.1(P_{cbot} - 0.10)[0.56(y_i - \bar{y}) + 185]$ by reducing the yield adjustment factor from 2 to 0.56 results in an optimal nitrogen application rate of 124 pounds per acre which equals the contract certainty application rate in the case of the original contract payment function. With the modified payment function, the 124 pound per acre rate remains optimal over the range 24-45% for the perceived cutoff percentage. Further, if one is willing to tolerate a range of optimal application rates from 120-128 ($\pm 3.3\%$ from the base of 124), then perceived cutoffs 17-65% produce acceptable optimal farmer behavior. While it may seem at first that farmers or the company are made less well off by this payment scheme in contrast to the original one, note that on average farmers receive, and the company pays, the same amount. In addition, the variability in farmers' payments is reduced (holding the yield distribution fixed). Thus, the answer to the third question -- how can contract allocation and payment schemes be modified to reduce incentives for increased fertilizer applications -- is that either the allocation scheme can be replaced by a truly random assignment of contracts, or the yield bonus in the payment scheme can be adjusted downward.

Concluding Remarks

As the industrialization of agriculture proceeds down its apparently inevitable path, relationships between suppliers and demanders of agricultural products will increasingly operate under contractual agreements. Applied research into the incentives implicit in

these contracts is needed to identify not only the qualitative changes they will induce in producer behavior, but also the quantitative effects. In performing the analysis, it is critical to reflect the details of the contract accurately as it is likely to often be the case that “the devil is in the details.”

This paper presents an analysis of a stylized tournament contract for seed corn production that is similar to tournament contracts offered in southern Michigan. The analysis shows that the nature of the contracts cause significant input use distortions resulting in increased nitrogen applications and nitrate loadings in the 5-15% range. It also shows that distortions may be eliminated by either awarding contracts by lottery, or by modifying the contract payment function appropriately. With increased interest in maintaining a good corporate image, agribusinesses will want to design contracts which are benign to the environment, good for producers, and good for themselves.

Table 1. Optimal Application Rates by Contract Cutoff Probability

Perceived Percentage of the Lower Tail of the Regional Yield Distribution That Loses the Contract	Optimal Nitrogen Application Rate (Pounds/Acre)	Nitrate Loading Rate
0%	124	327
1-40%	144	352
41-50%	142	349
51-60%	132	336
61-72%	128	331
73-100%	124	327

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