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Eric Allen DeVuyst

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J. Roy Black
Major professor

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**AN ECONOMIC COMPARISON OF NARROW ROW CROPPING SYSTEMS AND
CONVENTIONAL ROW CROPPING SYSTEMS IN MICHIGAN'S THUMB AND
SAGINAW VALLEY**

By

Eric Allen DeVuyst

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ABSTRACT

AN ECONOMIC COMPARISON OF NARROW ROW CROPPING SYSTEMS AND CONVENTIONAL ROW CROPPING SYSTEMS IN MICHIGAN'S THUMB AND SAGINAW VALLEY

By

Eric Allen DeVuyst

Farmers in Michigan's Thumb and Saginaw Valley are losing their comparative advantage in dry bean production. To regain or maintain their advantage Michigan farmers are evaluating alternative production methods. One production method that appears to have the potential to increase profitability is narrow row cropping. An approximate decision analysis framework utilizing subjective probability distributions is developed to compare narrow row cropping systems and conventional row cropping systems. This analysis generates a distribution of break even returns to conversion costs of switching from conventional row widths to narrow (22" inch) rows. The results indicate that narrow row cropping systems have a high probability of increasing profitability for dry bean and sugar beet producers in Michigan's Thumb and Saginaw Valley.

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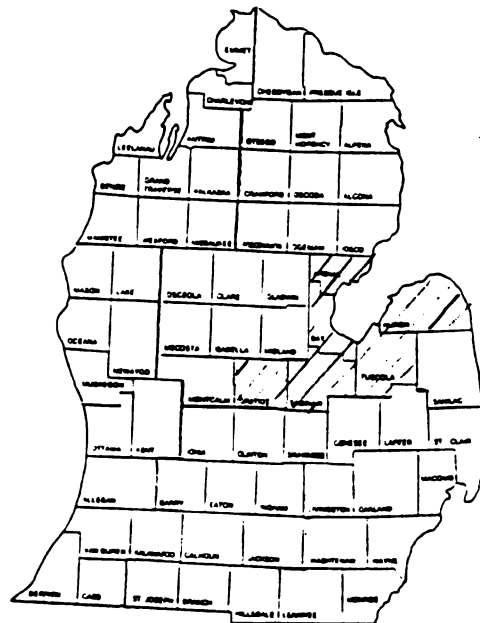
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CHAPTER 1. INTRODUCTION

1.1 Background

The fine textured soils in Michigan's Thumb and Saginaw Valley (Figure 1.1) are very productive. In 1987, Arenac, Bay, Huron, Gratiot, Saginaw, Sanilac, and Tuscola counties accounted for 22% of corn grain, 28% of wheat, 25% of soybean, 73% of dry bean, and 92% of sugar beet production in Michigan.

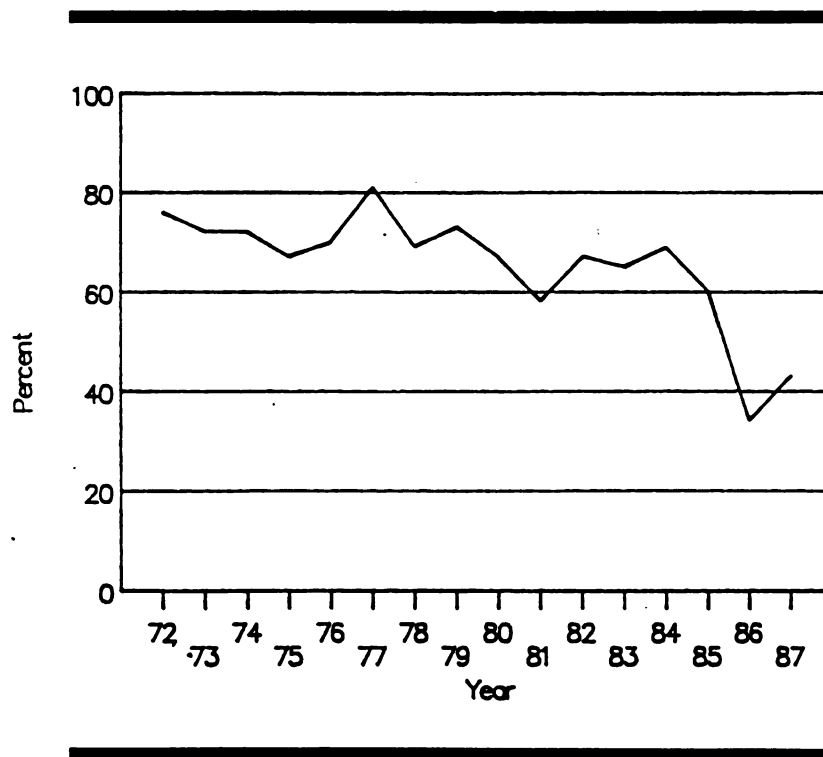
Figure 1.1 Michigan's "Thumb and Saginaw Valley"



Historically, Michigan has had a major share of North American navy bean production. However, Michigan's production dry beans has fallen from 5412 cwt. in 1985 to 2220 cwt. in 1988 (see Figure 1.2). Minnesota, North Dakota, and Ontario increased

total dry bean production 170 percent between 1972 and 1987, while Michigan's production fell 35 percent (NASS, 1988). This is an indication that Michigan farmers' comparative economic advantage in growing dry beans has diminished. In contrast to dry bean acreage, Michigan's sugar beet acreage increased by 46.4% between 1980 and 1987. In this same time period United States sugar beet acreage increased only 5.3%. This suggests Michigan has a comparative advantage in sugar beet production over other producers in the United States.

Figure 1.2 Michigan's Share of North American Navy Bean Production



In order to regain or maintain their economic advantages, Michigan farmers are re-evaluating alternative production practices — particularly practices followed by

competing farmers in the Red River Valley of Minnesota and North Dakota. One promising practice is narrow row cropping systems. The yield and economic advantages of growing soybeans in narrower rows in the eastern corn belt are well known to researchers and farmers. The recent development in Michigan of upright dry bean varieties that can be direct harvested has increased farmers' interest in producing dry beans in narrow rows. Narrow row¹ sugar beets may offer an opportunity to increase Michigan's comparative advantage in sugar beet production.

Many farmers in the Red River Valley raise dry beans and sugar beets in 22 inch rows in contrast to the 28 and 30 inch rows used in Michigan². Western European sugar beet growers, on soils similar to the fine textured soils in Michigan's thumb, use a 19-inch row spacing. Agronomic researchers believe Michigan farmers would have higher dry bean and sugar beet yields if they were to switch to narrower rows.

A conference, "The Resource Efficiency in Agricultural Production," was held at Michigan State University in December, 1987 (Christenson, et. al., 1987) to address the engineering, agronomic, and economics issues of narrow row cropping. Participants included agronomists, plant pathologists, agricultural engineers, and agricultural economists from Indiana, Minnesota, North Dakota, and Michigan. Conference participants concluded: (1) a *common* narrow row width (row widths less than 28 - 30 inches) is needed for all row crops grown on a farm to avoid duplication of machinery;

¹ Standard row widths in Michigan are 28 and 30 inches for corn, dry beans, sugarbeets, and soybeans. Some soybeans are grown in 7 inch rows, but it's much less common than in Southern Michigan, Ohio and Indiana.

² Estimates are 39% of navy beans are grown in 20-22 inch rows versus 54% grown in 28-30 inch rows (Poindexter and Rouget, 1989). Estimates are 22% pinto beans are grown in 20-22 inch rows versus 78% grown in 28-30 inch rows. Comparable survey information is not available on sugarbeets, but narrow rows are common.

(2) agricultural equipment manufacturers need to provide narrow equipment; (3) narrow row cropping systems can be more profitable than 28 or 30 inch rows systems when dry beans, sugar beets, or soybeans are a significant component of the system; and (4) there is a need for more research to clarify the conditions under which narrow row dry bean yields are increased. A particular issue to be addressed is pest and plant disease control, with white mold and related diseases in dry beans being the primary concern.

Conference participants suggested a row width of 22 inches for the following reasons. An earlier canopy develops for 22 inch rows than 28 or 30 inch rows. This leads to improved natural weed control. A 22 inch row spacing permits mechanical cultivation for weed control. In rows narrower than 22 inches it is difficult to cultivate with large equipment. Dry beans can be pulled *or* direct harvested. In narrower rows than 22 inches, the same difficulty encountered in mechanical cultivation prevents pulling dry beans. Finally, the 22 inch width is adequate for mechanical harvesting of sugar beets.

Much of the information regarding narrow row cropping systems presented at the conference was the subjective opinion of the conference participants. Most of this subjective information was disorganized and not in a form which could be utilized in a formal decision framework. Information from controlled experiments running 3-5 years under Michigan conditions is insufficient in length and quality to generate probabilistic information needed in decision analysis. Additionally, there was conflicting evidence on the response of dry beans yields to narrow rows, and farmers remain very concerned about the potential for increased risk of white mold. Also, while experiments have been done for individual crops, few studies have been done on narrow row crops in rotations over extended periods of time.

1.2 Problem Statement

To address the issues raised at this conference, this study will focus upon determination of the conditions under which the switch from 28 or 30 inch row spacings to 22 inch row spacings will result in an increase in the net returns to fixed resources of farmers in Michigan's sugar beet/dry bean/corn production area of the fine textured soils of the Saginaw Valley and Thumb. The primary consideration is upon whether the conversion is profitable, under the most likely values for systems parameters, and an estimate of the probability of the conversion being profitable. The study assumes relatively high managerial skills upon the part of farmers, which is typical for those growing sugar beets under contract.

A formal decision approach, grounded in economic theory and formal statistical analysis, is needed to organize subjective information and experimental data on the question of whether there is an economic incentive to change from 28 or 30 inch spacings to 22 inch row spacings. The decision framework must consider:

- (1) subjective information and experimental information on changes in yields and input requirements between 28-30 inch rows and 22 inch rows;
- (2) the pertinent economic parameters (e.g., commodity and input prices, interest rates);
- (3) the break-even machinery conversion costs, from an economic perspective, to warrant converting from 28-30 inch to 22 inch rows;
- (4) and the subjective probability a conversion from 28-30 inch rows to 22 inch rows would be profitable;
- (5) a formal method to revise estimates of parameters as new experimental and farm data become available.

CHAPTER 2. METHODS OF ANALYSIS

2.1. Introduction

This chapter discusses the nature of the decision problem to be addressed, reviews the basic producer problem and discusses basic capital budgeting techniques. Decision analysis is introduced and other decision criteria are discussed. Risk analysis is briefly reviewed. The subjective probability elicitation procedure employed in this thesis is presented and the triangular probability distribution is introduced. A time series model is formulated to predict relative commodity prices.

2.2 Structure of Problem

A farmer currently planting in 28 or 30 inch rows must decide annually whether to continue planting on that row spacing or to switch to a narrow row cropping system. If the decision is made to switch, the farmer must also decide how to convert his machinery-retrofit or replace. The farmer must also decide on the timing of machinery conversion. It is unlikely that most farmers would switch an entire machinery compliment in any given year. This study addresses the strategic question of whether there is an incentive to switch. The question of how and when to switch (if a incentive to switch exists) is left to subsequent investigations.

2.3 Economic Model of Firm Behavior

The Profit Function and Capital Budgeting

In a deterministic framework profits are defined as the sum of revenues minus the sum of operating costs and fixed costs:

$$\Pi = \sum_i P_i * Y_i * A_i - \sum_j w_j * X_j - FC \quad (1)$$

$$s.t. F(y,x) = 0;$$

where P_i is the price for commodity i , Y_i is the yield/acre of commodity i , A_i is the number acres of commodity i , W_j is the price of input j , X_j is the amount of variable or allowable input j , FC is the sum of fixed costs and $F(y,x)=0$ is the production function. Fixed costs include annual ownership costs of machinery, land rent and non-allocated costs. This model is typically maximized with respect to the variable inputs to generate profit maximizing production plans.

In a multi-period, deterministic model, the objective is to maximize the sum of discounted profit (i.e., net present value of total profits). This differs from the single period model in the machinery can be purchased and sold (i.e., there are no fixed costs). Therefore, machinery replacement age becomes a decision variable. To calculate the optimal replacement age of machinery, the net present value of total profits is expressed as a function of machinery age and maximized with respect to replacement age:

$$Max_t \quad NPV(t) = Max_t \quad \sum_{i=1}^T \frac{\pi_i(t)}{(1+d)^i} ; \quad (2)$$

where π_i is profits in year i as a function of replace age (t), d is the annual real discount rate and T is the time horizon of the project. Typically, this function is evaluated by allowing $T \rightarrow \infty$ and iteratively searching for the optimal replacement age (t^*). After the optimal replacement age of machinery (t^*) is found it is substitute back into equation (2). The annualized equivalent return (AR) of this stream of profits is calculated as:

$$AR = \frac{d \cdot NPV(t^*)}{1 - (1+d)^{-T}} \quad (3)$$

(Copeland and Weston, 1987, pp. 47-55).

Alternatively, the optimal replacement age of machinery can be found by minimizing the sum of discounted costs:

$$\min, \sum_i \frac{c_i(t)}{(1+d)^i} \quad (4)$$

where $c_i(t)$ is the ownership of machinery cost in year i as a function of replacement age t (Perrin, 1972). This expression is also typically evaluated iteratively to find the optimal replacement age t^* . Substituting t^* back into equation (4) yields the net present cost of machinery ownership. This net present cost can be expressed on an annualized basis by equation (2). For this study it is assumed that farmers minimize ownership costs of machinery and these costs are known with certainty. Denote the annualized cost as a function of the optimal replacement age as $AC(t^*)$. The net present value of profits as $T \rightarrow \infty$ is found as equation (5):

$$NPV(t^*) = \sum_{i=1}^{\infty} \left[\frac{P \cdot Y \cdot A - AC(t^*)}{(1+d)^i} \right] \quad (5)$$

In a deterministic model the decision maker or farmer would be assumed to maximize the net present value of profits. In a risky environment moments other than the expected value of profits may be of importance to the decision maker. Therefore,

alternative objectives to profit maximization are used to model the decision process in a risky environment. The following section addresses modeling the decision maker in such an environment.

2.4 Decision Analysis, Risk Analysis and Other Evaluation Criteria

The profit functions introduced in equations (1) and (2) are deterministic. All prices and yield relationships were assumed to be known with certainty. However, few real world production decisions are made where all variables are known. Actual production decisions are made in a risky environment. Decision analysis provides a theoretically sound approach to making choices in a position of uncertainty (Keeney and Raiffa, 1976).

Decision analysis mathematically models decision makers as maximizers of expected utility. It is a necessity that the decision maker's preferences and subjective probability assessments of random events are known or can be elicited.

However, frequently only partial information regarding preferences is available. This information may take the form of a risk aversion coefficient. In this case mean-variance analysis might be employed. Mean-variance analysis is based on the argument that risk averse decision makers gain utility from higher mean returns and lose utility from high variability of returns. It can be argued that mean-variance analysis an approximation to expected utility maximization (Robison and Barry, 1987). This approximation may not be without error (DeVuyst and Preckel, 1991). If moments higher than the variance are important to the decision maker, mean-variance analysis may yield in appropriate conclusions (Hanoch and Levy, 1969).

If all that is known of preferences is that the decision maker is risk averse, the second order stochastic dominance criterion may imply actions that are consistent with decision analysis (Hanoch and Levy, 1969). Stochastic dominance criteria require a fully specified probability distribution of returns for each possible action or choice. If this information is available stochastic dominance criteria may narrow the set of feasible solutions to a stochastically efficient set. However, the set may contain multiple actions and thus, fail to choose the action(s) consistent with expected utility maximization.

2.5 Risk Analysis

Similarly to stochastic dominance criteria, risk analysis does not require much knowledge of the decision marker's preferences. Risk analysis merely presents the cumulative probability distribution of returns to a decision maker and allows the decision maker to choose. For an example see Slovic *et al* (1979). From both a research and a cooperative extension point view, this approach is not satisfying. A goal of these groups is to help improve farmers' decision making processes and to make sound recommendations. Risk analysis does little to aid in making recommendations but does provide information to the decision maker which may improve the decision process.

2.6 An Approximate Decision Criteria

For the problem addressed in this thesis, preferences of decision makers are assumed to not be available. Nor given the complexity of the problem and lack of experimental data is it assumed the decision makers (i.e., farmers) can form subjective probability distributions for yields of rotation crops grown in a narrow row system. Thus, the standard decision criteria are inapplicable to this problem at the time of this study.

Despite the inapplicability of these decision criteria in this strategic decision problem, a method which systematically organizes available information and generates a first approximation to the optimal planting width is presented in this study. In order to develop this approximate decision method the available information is organized and some simplifying assumptions are made. It assumed throughout this study that real input prices are known and constant and the expected relative output prices are known and held with subjective certainty.

Available Information

The available information at the time of this study is in the form of expert opinion. There have been few long run agronomic experiments studying narrow rows and their effects on yields for rotation crops. It is unreasonable to have confidence in expert subjective joint probability distributions for yields crops under these assumptions. The availability and frequency heuristic (Hogarth, 1987) suggest that expert opinion for mean yields and mean yield distributions are more reliable and can be confidently employed in the decision process. An appropriate elicitation procedure can be used to elicit mean yield distributions for crops grown in various rotations for both 28 or 30 inch rows and 22 inch rows.

An Approximate Risk Analysis Framework

Utilizing the subjective probability of mean yield distributions, the row width which maximizes expectation of mean returns to machinery costs can be calculated for a given rotation the cumulative probability distribution of mean returns to transition for a conversion from 28 or 30 inch rows to 22 can be found.

The cumulative distribution of mean returns to transition cost is computed by calculating the distributions of mean or expected profits for 28 or 30 inch rows for a given rotation as in equation (5).

$$E[\Pi|y_i] = p \cdot y_i - w \cdot x - AR, \forall y_i \quad (6)$$

where $E[\Pi|y_i]$ is the expected profits given the yield vector y_i has occurred, p is the vector of output prices, w is the vector of input prices, x is the level of variable inputs and AR is the annual ownership costs of machinery. Note, the assumption that only yields are stochastic is implicit in this equation and therefore the distribution of expected profits is a linear combination of the random mean crop yields.

The distribution of mean or expected returns to machinery costs are computed for 22 inch rows and the same rotation and the annual ownership costs of machinery for 28 or 30 inch rows is subtracting. The distribution found in equation (5) is subtracted from the distribution of 22 inch returns to machinery costs less the annual ownership costs of machinery for 28 or 30 inch rows. This generates the distribution of mean returns to transition costs for a conversion from 28 or 30 inch rows. This distribution can be viewed as a first approximation of a risk analysis.

An Approximate Decision Analysis Framework

To find the new width which maximizes the expectation of mean returns to machinery costs, the distribution of mean returns to machinery costs are calculated for both 28 or 30 inch rows and 22 in rows. This is computed by equation (6):

$$\max E[\Pi(Y_i|\Theta_n)], \Theta_n \in [22,30] \quad (7)$$

where $\Pi(Y_i|\Theta_n) = E[p \cdot (Y_i|\Theta_n) - W \cdot (X|\Theta_n)]$; is the realization of yield vector Y_i given a row spacing Θ_n , p is a vector of output prices, W is a vector of input prices, $(X|\Theta_n)$ is a vector of variable input levels for row width Θ_n and $E[\cdot]$ is the expectations operator. Equation (6) is maximized by the row width which has the highest expected mean returns to machinery ownership costs. This can be viewed as a first approximation to profit maximization. Note, throughout this discussion land rental costs have been ignored. The focus of this study is on the economic differences in mean returns between wide rows and narrow rows. In a partial equilibrium analysis, land rental rates do not differ between the row widths under consideration. Thus, land rental rates do not effect the relative economic advantages or disadvantages of 22 inch rows over 28 or 30 inch rows.

2.7 Elicitation of Joint Probability Distributions

The procedure utilized to elicit the joint probability distributions of mean yields was designed to capture important interactions. The first interaction is the rotation effect on mean crop yields for crops grown in rotation for a given row width. For example, soybeans grown in rotation and in 30 inch rows with corn might increase mean corn yields and vice versa. The elicitation procedure was designed to aid the expert explicitly encode this rotation effect. The next relative effect is the interaction of row widths on mean yields. For example, crops grown in 22 inch rows might have higher mean yields than crops grown in 30 inch rows. This interaction also is explicitly incorporated into the elicitation procedure. It should also be noted that rotation effects might differ across row widths.

To capture these interaction effects the availability and frequency heuristics were employed with the anchoring and adjustment process (Hogarth, 1987). As previously mentioned the availability and frequency heuristics imply expert opinion regarding the distribution of mean yields is likely to be more accurate than expert opinion regarding the distribution of yields. These heuristics also imply that an expert yield is likely to accurately assess the mode of the mean yield distribution. The mode or most likely mean yield is a point an agronomic expert easily conceptualize.

The anchoring and adjustment process is a method that is used (often subconsciously) to estimate the relative magnitude of uncertain outcomes. In using this method, a well established or relatively certain point is used as a point of reference and the magnitude all other points are judged relative to this point of relative certainty. The point of relative certainty is referred as the anchor point around which adjustments are made. This method can help improve judgements. In the present context, the mode of a mean yield distribution may be utilized as an anchor point and enable the expert to improve his judgements regarding other points on the mean distribution. In the elicitation procedure employed in this study, the expert was also given another anchor or reference point. Continuous corn rotation in 28 or 30 inch rows have been well studied by the agronomic community. The availability heuristic suggests that this rotation is a good anchor point. The distribution of mean continuous corn yields grown in 30 inch rows is elicited and used in this study to aid the expert in formulating distributions of mean corn yields for other rotations and other row spacings (i.e., 22 inch rows).

The last set of anchors utilized was the distributions of mean yields for rotations in 30 inch rows. Rotations grown in thirty inch rows have been studied more extensively than rotations in narrow rows. The availability heuristics suggest that once elicited these

distributions serve as good reference points when formulating the distributions of mean yields for rotations grown in 22 inch row spacings.

The steps of this elicitation procedure are outlined here:

1. Elicit the mode or mostly like mean yield of corn grown in a continuous corn rotation and thirty inch rows.
2. Elicit approximate tenth and ninetieth percentile mean yields for corn grown in continuous corn rotation and thirty inch rows.
3. Repeat steps 1 and 2 for corn grown in rotation(s) to be studied (e.g., corn-soybeans-wheat) grown in thirty inch rows.
4. Elicit the approximate mode, tenth percentile and ninetieth percentile yields of the other crops of the rotation grown in 30 inch rows.
5. Repeat steps 1 through 4 for twenty inch rows.
6. Steps three through five are repeated for each rotations grown on the farm being evaluated.

By imposing a probability distribution on the three points elicited for each crop mean yield, the subjective probability distributions needed for the approximate decision analysis (or decision aid) and approximate risk analysis are generated. The probability distribution chosen this study is the triangular distribution.

2.8 Triangular Probability Distributions

The triangular probability distribution is often used to represent continuous distributions under sparse data conditions (Keefer and Bodily, 1983). While this is an

imperfect representation, it does provide a reasonable approximation of the mean and variance. Black (1990) demonstrated the triangular distribution reasonably approximates several unimodal distributions. Black generated small (10 to 20 observations) random samples for these distributions and statistically tested the hypothesis that the samples were generated by triangular probability distributions. These tests were unable to reject this hypothesis.

It seems reasonable to expect that mean crop yields are unimodally distributed. It is, therefore, reasonable based on Black's studies to approximate mean crop yields with triangular probability distributions.

The triangular probability distribution is uniquely defined by its mode and endpoints of its support. The density function is in fact expressed as a function of these three points:

$$f(x) = \begin{cases} \frac{2 * (x - a)}{(b - a) * (c - a)} & \text{if } a \leq x \leq c \\ \frac{2 * (b - x)}{(b - a) * (b - c)} & \text{if } c < x \leq b \end{cases} \quad (8)$$

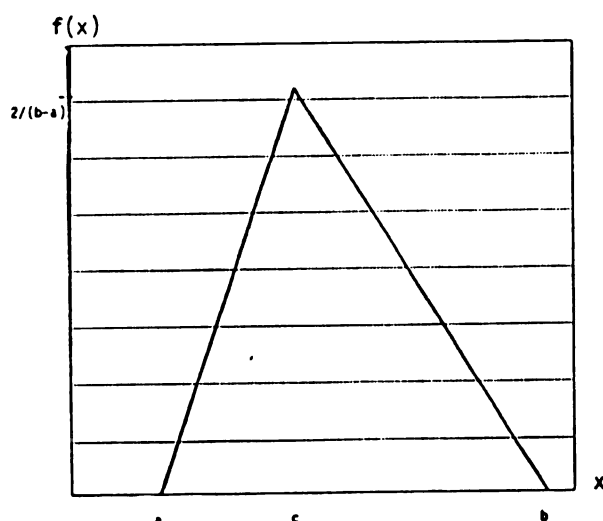
where a is the left endpoint of the distribution, b is the right endpoint of the distribution and c is the mode of the distribution. This is also demonstrated graphically in Figure 2.1.

2.9 Budgets as Random Variables

In equations (5) and (6) only mean yields are considered random. As result average profits or average returns to machinery costs are linear combinations of affine

transformations of the random variables mean crop yields. This implies the average profits as average returns to machinery costs are distributed as triangular distributions. For the distributed elicited in this study, mean returns to transition costs can be shown to be distributed triangularly. This is not true in general. For a complete discussion of transformed random variables see Hogg and Craig (1970).

Figure 2.1 The Triangular Probability Density Function.



2.10 Updating Probability Distributions of Expected (Mean) Returns to Transition Cost

Annual agronomic experiments will provide new probabilistic information for the present problem. This new information needs to be incorporated annually into the approximations generated in this study. Expert resolution is a general method of combining multiple sources of probabilistic information. Genest and Zidek (1986) review the various methods of expert resolution commonly used in the literature. Many methods of expert resolution are conceptually difficult and computationally cumbersome. A simplified method of expert resolution is presented in Chapter IV. This approach provides an analytically simple method to incorporate new probabilistic information

regarding mean yields into the approximation of the distribution of returns to mean transition costs.

2.11 Projecting Commodity Prices, Input Prices, and the Discount Rate

A real discount rate of ten percent is used in net present value and annuity calculations. A ten percent real discount rate was chosen to reflect the riskiness of agriculture production and to exceed the real borrowing rate. All prices are expressed in 1990 dollars. The prices used are estimated long-run equilibrium prices for the period of 1991 to 2000. All capital is assumed to be borrowed from either a lending institution or the farmer borrows from himself; issues such as capital constraints, debt structure, and income taxes are not considered in the analysis.

The method used to estimate commodity and discount rate assumes commodity markets are efficient. Prices reflect the relative marginal valuations of the commodities in the market. To estimate these relative valuations, simple time-series models were developed using historical Michigan on-farm prices with corn price as the numeraire as in equation (8):

$$\left(\frac{P_{Commodity_t}}{P_{Corn_t}} \right) = \beta_0 + \beta_1 * Time + \beta_2 * (Govt\ program\ variable)_t, \quad (9)$$

The addition of the time variable to the equation was to reflect drifts in relative technological change and/or preference.

In order to have a reasonable level of confidence in these models, at least 25-30 historical observations are needed; that ensures outliers in the data do not dominate the estimation. However, if too long of a time span is used, the market structure can change during the time period chosen in more ways than can be accommodated with a time

trend. To compromise between these conflicting criteria, a time period of 1960-1988 is used.

Corn price was used as the numeraire in the models for soybeans, navy beans, sugar beets, and wheat. Figures showing the change in relative prices over time are presented in appendix A. The soybean, navy bean, and sugar beet price were regressed on corn price. Two additional regressors were used, year and the fraction of acres diverted under the government corn program. Year was used to measure possible drift in the relative prices over time due to technology or demand forces. The fraction of acres diverted under the government corn program served two purposes. First, it serves as a proxy for remaining corn stocks (it assumed that as remaining stocks increases the government requires a higher fraction of acres to be diverted). Second, it serves as a variable indicating price distortions due to government influence. In the wheat price model, two more regressors were used. The first is the fraction of acres diverted under the government wheat program. This serves a similar function as the fraction of acres diverted under the government corn program. The other regressor is a dummy variable used to indicate the distortion in the long-run corn-wheat price relationship during the Johnson Administration (1962-1968). The data used in these regressions and statistical results are summarized in appendix A.

CHAPTER 3. INFORMATION NEEDED AND SOURCES

3.1 Introduction

The following discussion is focused on how the budgets used in this study were constructed. There are seven primary sections. These include rotations, commodity prices, allocated and unallocated costs, and annualized whole farm budgets for the elicited most likely yields. The remaining sections report the annualized change in mean returns to transition costs associated with the tenth and ninetieth percentile yields and the net present value of mean returns for the tenth percentile, the most likely and the ninetieth percentile yields.

3.2 Rotations

The rotations used are representative of those found in Michigan's Thumb and Saginaw Valley. Hoskin (1981) Michigan State University's TELFARM Records (1987, 1988) and Michigan Agricultural Statistics (NASS, 1988) were reviewed in developing these recommendations. Also, discussions were held with Extension specialists, agronomists, and agribusiness.

This study is not intended to be an exhaustive review of crops and rotations growing the Thumb and Saginaw Valley. The attention is on the major field crops and those crops which might have economic incentives for a transition to narrow rows. This review of available information is revealed the comments the follow. More corn is grown than any other crop in the seven counties studied. Sugar beets, soybeans, and navy beans (and other dry edible beans) are common. The review of the Telfarm records suggested a range of 15-25% of tillable farm acres in wheat. Sugar beets are rarely grown

following wheat. Farmers believe that wheat stubble forms a straw mat that, when plowed down, sugar beets can have difficulty penetrating³. Both winter wheat and sugar beets are generally grown after dry beans or soybeans.

Therefore, to represent a representative farm in the Thumb or Saginaw Valley, two separate rotations are used for each farm - one with sugar beets and one with winter wheat. Typical sugar beet acreage is 10-20% of total farm acres (TELFARM, 1987). The average sugar beet contract was 80 acres for a 600 acre farm; therefore, each crop in the sugar beet rotations has eighty acres. The balance of the 600 acres is divided among the crops in the wheat rotation.

The four representative farms are represented by the following rotation pairs:

1. $C - C - NB - B$ and $C - NB - W$;
2. $C - NB - B$ and $C - NB - W$;
3. $C - C - SB - B$ and $C - SB - W$;
4. $C - SB - B$ and $C - SB - W$

where C: corn, SB: soybeans, NB: navy beans⁴, B: sugar beets, and W: wheat.

3.3 Commodity Price

In soybean, navy bean, and sugar beet price models the regressors corn price, year, and fraction of government acres diverted under the government corn program were all found to be significant. In the wheat price model, fraction of wheat acres

³ Source: Discussions with Michigan Cooperative Extension Service county agents and district agronomy agents in the Thumb and Saginaw Valley.

⁴ For this study navy beans were considered. However, most dry edible beans will have similar results.

diverted and corn price were the only independent variables found to be statistically significant. Table 3.1 summarizes the regression results.

The long-run corn price used in this study was the result of a model built primarily by Dr. John Ferris⁵ and is estimated in 1989 dollars to be \$2.59 per bushel. Ferris' model assumes that government programs are replaced in the early 1990's by the Conservation Reserve Program. Using this as the base, the long-run prices for the other commodities were estimated for year 1995 (this is the midpoint of the time period being estimated). This estimates are reported in table 3.1:

Table 3.1 Estimated Relative and Absolute Commodity Prices

Crop	Relative Price	Absolute Price
Corn	1.00	2.59 (\$/bu.)
Soybeans	2.86	7.42 (\$/bu.)
Wheat	1.34	3.47 (\$/bu.)
Sugar beets	14.83	38.41 (\$/bu.)
Navy beans	10.43	27.02 (\$/bu.)

After these estimates were calculated, estimated hauling cost were subtracting. Prices used in this study are net of hauling cost. Prices net of hauling cost are reported in table 3.2.

⁵Professor, Department of Agricultural Economics, Michigan State University.

Most experts agree that the sugar content of beets grown in 22 inch rows is higher than in sugar beets grown in 30 inch rows. For an average increase of 0.5% (Christenson, 1987), Michigan (Pioneer) Sugar company pays a premium of \$0.97 per ton above the base (Pioneer Newsheet, 1989). Therefore, for 22 inch row sugar beets a price of \$0.97 per ton above the estimated \$38.41 per ton was used in this study.

To test for multicollinearity, the correlations of the independent variables were calculated. The highest correlation was found between Michigan farm price for corn and year (0.754). As an additional test, an auxiliary regression with corn price regressed on year, fraction of acres diverted under the government corn programs, fraction of acres diverted under the government wheat program, and the Johnson dummy variable was done. Only year was found to be significant in this auxiliary regression and the adjusted R^2 was only 0.53 (Table A3 contains the complete auxiliary regression results). From these tests, multicollinearity was judged not to be a problem in these models.

Table 3.2 Estimated Prices Net of Hauling Costs

Crop	Price	Hauling Cost	Net Price
Corn	\$2.59/bu	0.20	\$2.39/bu
Soybeans	7.42/bu	0.20	7.22/bu
Wheat	3.47/bu	0.20	35.01/ton
Sugar beets	38.41/ton	3.40	35.01/ton
Navy beans	27.02/cwt	0.34	26.68/cwt

3.3 Seed Costs

Corn

Corn for both 30 and 22 inch was seeded at a population of 27,000 seeds per acre (Erdmann, *et. al.*, 1989). Corn seed is usually sold in 80,000 kernel units, with a price of a unit ranging from \$65 to \$90, dependent on variety. A unit price of \$75 was assumed in this study. The resultant seed cost for corn was \$25.31 per acre.

Wheat

Wheat was seeded at a rate of 120 pounds (2 bushels) per acre (Leep, *et. al.*, 1981). Wheat seed was priced at \$0.08 per pound. Seed cost for wheat (both systems) was estimated at \$9.60 per acre.

Navy beans

Navy beans were seeded at a rate of 104,000 and 131,000 seeds per acre (40 and 55 pounds per acre) for 30 and 22 inch rows, respectively (Christenson and Adams, 1983). At a price of \$0.50 per pound, 30 inch dry bean seeded costs were estimated at \$20 per acre. Navy beans seeded in 22 inch rows were estimated to have a seeding cost of \$25 per acre (Copeland and Leep, 1983).

Sugar beets

Sugar beets in 30 inch rows were seeded at a rate of one pound per acre, in 22 inch rows at 1.4 pounds per acre. At a price at \$15 per pound of seed, sugar beet seeding costs were estimated to be \$15 and \$21 per acre for 30 and 22 inch rows, respectively.

Soybeans

Soybeans were seeded at a rate of 150,000 seeds per acre for 30 inch rows and at 175,000 seeds per acre for 22 inch rows (Hesterman, *et. al.* 1987). At 2500 seeds per

pound and a price of \$13 per pound of seed, 30 inch row soybeans seeding are \$13 per acre. With 25,000 seeds per pound and a seed price of \$13 per bushel, 22 inch row soybeans was seeding cost of \$15 per acre.

3.4 Fertilizer Costs

Fertilizer application rates are generated using Extension Bulletin E-550 using yield goal of 10-15% above average yields (Warnke, 1985). Table 2.1 summarizes these rates. Soil tests levels were assumed to be 100 pound available phosphorous and 200 pounds available potassium on a clay loam soil. Micronutrients were assumed to be adequate, with the exception for Boron for sugar beet acres. Table 3.2 summarizes the fertilizers and associated prices. Table 3.3 summarizes fertilizer rates and per acre costs. In all cases, recommendations were higher for 22 inch rows since the yield goal was higher.

3.5 Herbicide Costs

Herbicides were chosen on the basis of three criteria. First, herbicide programs along with cultivation, must provide reasonable control of both annual grasses and annual broadleaves. Second, herbicide programs must be recommended by Michigan State University (Kells and Renner, 1990). Third, herbicide programs must not have carry-over and interaction problems with the crop and herbicides that follow in the rotation. Herbicides, prices, rates, and per acre

Table 3.1 Fertilizer Use

Crop	Mean yield		Fertilizer Use lbs/acre					
	30" row	22" row	N		P ₂ O ₅		K ₂ O	
			30" row	22" row	30" row	22" row	30" row	22" row
Corn	130 bu	134 bu	202	210	0	0	83	90
Corn	115 bu	119 bu	172	186	0	0	57	70
Sugarbeets	22 ton	24 ton	96	104	53	63	105	125
Wheat (7"rows)	70 bu	70 bu	93	93	0	0	115	115
Soybeans	40 bu	45 bu	0	0	0	0	9	18
Navy beans	20 cwt	23 cwt	40	60	0	0	7	7

Table 3.2 Fertilizer Prices

Fertilizer	Unit	\$/unit
18-46-00	ton	240
00-00-60	ton	115
82-00-00	ton	213
Boron	lb.	2

Table 3.3 Fertilizer Costs, \$/acre

Crop	Type of Fertilizer										Total Fertilizer Cost/acre		
	82-0-0		46-0-0		18-46-0		0-0-60		Boron				
	30" rows	28" rows	30" rows	22", rows	30" rows	22" rows	30" rows	22" rows	30" rows	22" rows	30" rows	22" rows	
Corn, high	26.25	27.72						8.05	8.62			34.70	36.34
Corn, low	23.98	24.52						5.75	6.90			29.73	31.42
Sugar beets			4.20	4.20	14.40	16.80	10.06	12.07	4.20	4.20		39.86	45.32
Wheat (7" rows)			14.00	14.00			11.50	11.50				25.50	25.50
Soybeans			11.20	12.25			0.86	2.01				0.86	2.01
Navy beans			6.21	8.97			0.86	1.72				7.04	10.69

costs are summarized in Table 3.4. In those crops where herbicides are banded, 22 inch row crops had a higher herbicide cost since there are more rows per acre. A brief discussion of each crop herbicide program is presented here.

Corn Herbicide Notes

Atrazine is a very effective, low-cost herbicide. However, carry-over can cause crop damage if high rates are applied. Therefore, if a crop other than corn is to be raised the next year, a lower rate of atrazine is necessary. If sugar beets are grown in rotation with corn, no atrazine should ever be used. Bladex provides broadleaf weed control with less soil persistence and its substitute for atrazine in these cases.

Wheat Herbicide Notes

For the purpose of this study, wheat is assumed not to have been seeded with a legume. If a legume is seeded with wheat, Weedar 64(2-4D Amine) cannot be used, and MCPA must be substituted.

Soybean Herbicide Notes

To select soybean herbicides, the computer software package SOYHERB (Renner, *et. al.*, 1988) was used. When sugar beets follow soybeans in the rotation, Sencor should not be used for weed control in the soybeans.

Sugar Beet Herbicide Notes

For sugar beets, two separate herbicide applications are usually necessary. The second application is applied post emergence in a 7 inch band.

Table 3.4 Herbicide rates/acre, prices, and costs/acre

Current crop	Next crop	Row width, inches	Herbicide	Application Method ¹	Rate	Price \$/unit	Cost \$/acre
Corn	Corn	30/22	Atrazine 4L	PPI	1 qt	2.03/qt	2.03
			Dual	PPI	1 qt	11.76/qt	<u>11.76</u>
							13.79
		30.22	Atrazine 4L	PPI	0.5 qt	2.03/qt	1.01
			Dual	PPI	1 qt	11.76/qt	11.76
			Bladex 4L	PPI	1 qt	4.31/qt	<u>4.31</u>
							17.08
Soybeans	Wheat	30/22	Command	PPI	1 pt	7.44/pt	7.44
			Dual	PPI	1 qt	11.76/qt	<u>11.76</u>
							19.20
	Wheat	30/22	Sencor	PPI	0.75 pt	11.93/qt	8.95
			Dual	PPI	1 pt	11.76/qt	<u>11.76</u>
							20.71
Navybeans	Beets	30/22	Amiben 4L	PPI	4 qt	3.59/qt	14.36
	Wheat		Dual	PPI	1 qt	11.76/qt	<u>11.76</u>
							26.12
							<u>Total</u>
Wheat	Corn	7"	2-4D Amine	Post	1 pt	1.01/pt	1.01
Beets	Corn	30"	Pyramin PRE ²		2/3 qt	15.27/qt	10.69
			Norton EC	PRE ²	2/3 qt	14.50/qt	18.03
			Antor	PRE ²	1/2 qt	10.75/qt	5.02
			H 273	Post ²	1/3 pt	4.38/pt	1.31
			Betamix Post ²		6.2 pt	7.25/pt	<u>10.51</u>
							45.56
Beets	Corn	22"	Pyramin PRE		1/3 qt	15.27/qt	6.84
			Norton EC	PRE	5 1/3 qt	14.50/qt	24.59
			Antor	PRE	2 qt	10.75/qt	14.58
			H 273	Post ²	1 1/3 pt	4.38/pt	1.75
			Betamix Post ²		6.2 pt	7.25/pt	<u>14.50</u>
							60.51

¹ Definitions: PPI = Pre-plant Incorporate; PRE = Pre-Emergence; Post = Post-Emergence.² 7 Inch Band.

3.7 Insecticides

All crops are exposed to insect pests, and outbreaks of various insects occur at anytime. However, it is not possible to predict when "rescue" pesticides will be needed. Therefore, this study did not include any costs related to unpredictable insect problems. For these rotations, only second year corn was predicted to consistently have an infestation of corn rootworm larvae. For second year corn, a seven-inch band of Dyfonate 20G at a rate of six ounces/1000 of foot row was applied pre-plant. This equals 1.5 pounds per acre in 30 inch rows and 2.8 pounds per acre in 22 inch rows. At a price of \$1.71 per pound of Dyfonate 20G, second year insecticide costs were estimated to be \$2.56 per acre and \$4.79 per acre for 30 and 22 inch rows, respectively.

3.8 Machinery Budgets

All 600 acres were assumed to be fall plowed with a moldboard plow. Corn stalks are chopped before being plowed down. Spring tillage was a single pass with a field cultivator. Any incorporated herbicides were applied at this time (corn, soybean and dry bean herbicides). Herbicides for sugar beets and wheat were applied preemergence or post emergence. Sugar beets, corn, soybeans, and navy beans were planted with a row crop planter, and wheat was planted in early fall with a grain drill.

Starter fertilizers were assumed to be applied with the row crop planter. Anhydrous ammonia was applied to corn with a rented applicator. All other fertilizers were applied with a rented spreader. Urea was applied to wheat in split applications.

Navy beans and soybeans were cultivated twice. Sugar beets were cultivated 4 times.

Wheat, navy beans, and soybeans were harvested with a floating cutterbar. Corn was harvested with a corn header. Sugar beets were topped prior to being lifted.

All machinery was assumed to last ten years, before being salvaged. Acres per hour, fuel consumption per acre, and purchase price were taken from "Minnesota Farm Machinery Economic Cost Estimates for 1988 (Fuller and McGuire, 1988). Net purchase costs were assumed to be 80% of list prices. Insurance costs were estimated to be 0.25 percent per year of list cost (Black, et. al., 1989). Shelter costs were estimated to be 0.75 percent (Black, et. al., 1989) per year of list cost. Depreciation was calculated as the annualized equivalent cost of the net of purchase price less discounted salvage. Repairs and salvage were estimated using ASAE (1988) standards.

The fixed costs for power equipment, tractors and combine, were taken from "Minnesota Farm Machinery Economic Cost Estimates for 1988 (Fuller and McGuire).

Interest cost on operating was approximated by charging 10 percent for 6 months on seed, herbicide, insecticide, fertilizer, fuel and labor costs.

Table 3.5 summarizes implement costs for the four year rotation including sugar beets with a three year rotation including wheat. Table 3.6 summarizes implement costs for a three year rotation including sugar beets with a three year rotation including wheat. Table 3.7 summarizes the fixed costs for tractors and combines.

Table 3.5 Annual tractor and equipment Costs for 4 year beet rotation and 3 year wheat rotation

Implement	Size	Acres/gal/acre ¹	Fuel consumption	Total labor ²	Equipment annual	Fuel	Total annual cost
Moldboard Plow	6-16"	600	\$2.06	\$1032	\$1304.00	\$1236.00	\$3572.00
Field Cultivator	28"	600	0.71	300	1270.10	426.00	1996.10
Beet Topper/Stalk Chopper	6-30"	334	1.29	432	2179.30	430.86	3042.16
Row Planter	12-30"	507	0.61	312	3986.70	309.27	4607.97
Grain Drill	12"	93	0.50	120	1216.50	46.50	1383.00
Beet Harvester	4-30"	80	1.73	138	5225.50	138.40	5501.90
Com Header	6-30"	666	0.62	684	528.40	412.92	1625.32
Cutterbar	Med	266	1.74	384	1195.70	462.84	2042.54
Row Cultivator	6-30"	666	0.62	684	528.40	412.92	1625.32
Sprayer	30"	253	0.17	108	555.00	43.01	706.01
Anhydrous Application Med.	Med.	254	0.75	120	659.00	190.50	969.50
Fertilizer Spreader	—	773	0.09	134	290.00	69.57	493.57
				\$4,154	\$20,975.00	\$4,332.00	\$29,461.00

¹ Source: Fuller and McGuire (1988).² At a wage of \$5/hour.³ Diesel fuel price of \$1/gal.⁴ Based on a rental rate of \$21.43/ton.⁵ Based on a rental rate of \$5.87/ton.

Table 3.6 Annual tractor and equipment costs for 3 year beet rotation and 3 year wheat rotation

Implement	Size	Acres/year	Gallons/acre	Total			Total annual cwt
				Labor ¹	Equipment annual ownership	Fuel ²	
Moldboard Plow	6-16"	600	2.06	\$1032.60	\$1304.70	\$1236.00	\$3572.70
Field Cultivator	28'	600	0.71	\$300.00	\$1270.10	\$426.00	\$1996.10
Beet Topper/Stalk Chopper	6 row	280	1.29	\$360.00	\$2179.30	\$361.20	\$2900.50
Row Planter	12-30"	480	0.61	\$246.00	\$2986.70	\$292.80	\$4525.50
Grain Drill	12'	120	0.51	\$150.00	\$1216.50	\$60.00	\$1425.50
Beet Harvester	4-30"	80	1.73	\$138.00	\$5225.50	\$138.40	\$5501.90
Corn Header	6-30"	200	2.23	\$306.00	\$2564.80	\$446.00	\$3316.80
Cutbar	Med.	320	1.74	\$462.00	\$1195.70	\$556.80	\$2214.50
Row Cultivator	6-30"	520	0.62	\$1196.00	\$744.00	\$322.40	\$2262.40
Sprayer	30'	280	0.17	\$120.00	\$555.00	\$47.60	\$722.60
Anhydrous Appl.	Med.	200	0.75	96.00	\$536.00 ³	\$150.00	\$782.00
Fertilizer Spreader	--	720	0.09	\$114.00	\$311.00 ⁴	\$64.80	\$489.80
				\$4520.00	\$21089.30	\$4102.00	\$29711.30

¹ At a wage of \$6.00/hour.² Diesel fuel price of \$1/gal.³ Based on a rental rate of \$21.43/ton.⁴ Based on a rental rate of \$5.87/ton.

Table 3.7 Annual Ownership

Machine	Annual Ownership Cost
120 H. P. Tractor	5,266
160 H. P. Tractor	6,865
Combine, Medium H. P.	9,334
Total	21,465

3.9 Whole Farm Budget

Whole farm budgets were developed by combining of budgets for:

$$\begin{aligned}
 &C - C - NB - B \text{ with } C - NB - W, \\
 &C - NB - B \text{ with } C - NB - W, \\
 &C - C - SB - B \text{ with } C - SB - W \text{ and,} \\
 &C - SB - B \text{ with } C - SB - W
 \end{aligned}$$

when C: Corn; NB: navy beans; B: sugar beets; SB: soybeans; and W: wheat.

Tables 3.8 through 3.11 summarize the whole farm budgets for the difference in twenty-two inch row spacing and thirty inch row spacing annualized mean returns. These detailed budgets are on an annualized basis and are reported for the elicited most likely mean yields. The annualized mean returns for the tenth and ninetieth percentiles are reported in table 3.12.

The differences in annualized mean returns were divided by the discount rate to generate the net present value of mean returns to transition. These net present values are reported in table 3.13.

**Table 3.8 Whole Farm Budget for 600 Acre Farm
with 80 Acres Per Crop in C - C - NB - B Rotation
and 93 Acres Per Crop in C - NB - W Rotation**

Crop	Acres	Gross Revenue \$/year	
		30" Rows	22" Row
Corn, 1st year	174	54,062	55,725
Corn, 2nd year	80	21,988	22,753
Navy beans	173	92,313	106,160
Sugarbeets	80	61,618	69,082
Wheat	93	<u>21,288</u>	<u>021,288</u>
		25,269	275,008
Allocated Costs, \$/Year			
Seed		\$11,982	\$13,327
Herbicide		11,046	12,453
Insecticide		205	383
Fertilizer		15,194	16,683
Interest on Operating		2,346	2,567
Machinery, labor & fuel		<u>50,926</u>	<u>50,926</u>
		\$91,699	\$178,669
Annual net return to land, management, and other costs		\$159,570	\$178,669
<i>Increase in net return to land, management and other unallocated costs associated with changing from 28-30" rows to 22" rows</i>			\$19,099

**Table 3.9 Whole Farm Budget for 600 Acre Farm
with 80 Acres Per Crop in C - NB - B
and 120 Acres Per Crop in C - NB - W**

Revenue Crop	Acres	Gross Revenue \$/year	
		30" Rows	22" Rows
Corn, 1st year	200	62,140	64,052
Navy beans	200	106,720	122,728
Sugarbeets	80	61,618	69,082
Wheat	<u>120</u>	<u>27,468</u>	<u>27,468</u>
	600	257,946	283,330
Allocated Costs, \$/Year			
Seed		11,414	12,634
Herbicide		10,382	11,822
Insecticide		0	0
Fertilizer		14,497	16,092
Interest on Operating		2,246	2,459
Machinery, labor & fuel		<u>51,176</u>	<u>51,176</u>
		89,715	94,183
Annual net return to land, management, and other costs		168,231	189,147
<i>Increase in net return to land, management and other unallocated costs associated with changing from 28-30" rows to 22" rows</i>			20,916

**Table 3.10 Whole Farm Budget for 600 Acre Farm
with 80 Acres Per Crop in C - C- SB - B
and 120 Acres Per Crop in C - SB - W**

Revenue Crop	Acres	Gross Revenue \$/year	
		30" Rows	22" Rows
Corn, 1st year	174	54,062	55,725
Corn, 2nd year	80	21,988	22,753
Soybeans	173	49,962	56,208
Sugarbeets	80	61,618	69,082
Wheat	<u>93</u>	<u>21,288</u>	<u>21,288</u>
	600	208,918	225,056
Allocated Costs \$/Year			
Seed		11,030	11,626
Herbicide		12,015	13,888
Insecticide		205	383
Fertilizer		13,814	15,182
Interest on Operating		2,278	2,453
Machinery, labor & fuel		<u>50,926</u>	<u>50,926</u>
		90,268	93,958
Annual net return to land, management, and other costs		118,650	131,098
<i>Increase in net return to land, management and other unallocated costs associated with changing from 28-30" rows to 22" rows</i>			12,448

**Table 3.11 Whole Farm Budget for 600 Acre Farm
with 80 Acres Per Crop in C - SB - B
and 120 Acres Per Crop in C - SB - W**

Revenue Crop	Acres	Gross Revenue \$/year	
		30" Rows	22" Rows
Corn, 1st year	200	62,140	64,052
Soybeans	200	57,760	64,980
Sugarbeets	80	61,618	69,082
Wheat	120	<u>27,468</u>	<u>27,468</u>
		208,986	225,582
Allocated Costs, \$/Year			
Seed		10,014	11,835
Herbicide		11,502	12,874
Insecticide		0	0
Fertilizer		13,361	14,356
Interest on Operating		2,175	2,384
Machinery, labor & fuel		51,176	51,176
Total Allocated Costs		88,228	92,625
Annual net return to land, management, and other costs		120,758	132,957
<i>Increase in net return to land, management and other unallocated costs associated with changing from 28-30" rows to 22" rows</i>			12,199

Table 3.12 Annualized Difference in Mean Returns to Unallocated Costs for the Tenth and Ninetieth Percentiles

Rotation Pair	30" Rows		22"	
	Rows		Percentile	
	Percentile		10th	90th
	10th	90th		
C-C-NB-B C-NB-W	130149	179661	127139	224783
C-NB-B C-NB-W	135382	190408	132543	239936
C-C-SB-B C-SB-W	101448	135852	99386	162008
C-SB-B C-SB-B	102053	139482	99265	166169

Table 3.13 Net Present Value of Differences in Mean Returns to Transition Costs

Rotation Pair	Percentile	
	10th	90th
C-C-NB-B C-NB-W	-30106	451219
C-NB-B C-NB-B	-28388	495280
C-C-SB-B C-SB-W	-20618	261558
C-SB-B C-SB-W	-27882	266866

CHAPTER 4. ANALYSIS AND RESULTS

4.1 Introduction

The net present value budgets developed in chapter III were assumed to be generated from a subjective triangular distribution. Three budgets were developed for each rotation pair. The budgets associated with the tenth and ninetieth percentile yields approximate the tenth and ninetieth percentiles of the underlying triangular distribution. The budget associated with the most likely yield approximates the subjective mode of the underlying distribution.

A triangular density function was imposed on these three points. Adjustments were made to the tenth and ninetieth percentile budgets to insure the resulting function satisfied the definition of a probability density function. These resulting distributions are used in this study to compare the relative economic advantages and disadvantages of twenty-two inch row spacing to thirty inch spacing.

4.2 Results

Risk analysis typically leaves the decision of what action to be taken up to a manager. The information presented to the manager often takes the form a cumulative probability distribution. A primary result of this study is a cumulative probability distribution of expected returns to transition. This is not as complete as a cumulative probability distribution of returns to transition. However, it does provide considerable information to a farmer manager or to cooperative extension staff. These distributions of break even mean returns to transition are reported in table 4.1. The expected value of

each distribution is also reported. By the definition of a triangular distribution, each of these distributions are uniquely determined by its lower and upper bounds and the mode.

Each of these rotation pairs has considerable promise for increased profitability based the results reported in Tables 3.8 through 3.11 and Table 4.1. The expected values of mean returns to transition costs range from \$119,748 to \$229,666. However, for each rotation pair there is a positive probability of a negative mean return to transition costs. The probability of a negative mean return ranges from approximately twelve to fourteen percent. This implies on average a farmer could expect to loose money by converting to twenty-two inch rows twelve to fourteen percent of the time.

Without the complete distribution of break even returns to transition, it is inappropriate to apply mean-variance analysis to this study. However, it is noteworthy that as the expected value increases across the distributions, the support of the distributions also increases. This does not necessarily imply that the variability of the break even returns to transition are similarly affected. However, the rotations with the highest mean returns on average are those rotation with dry beans. Dry beans are generally considered a risky crop (relative to the to the other field crops grown in the Saginaw Valley). Therefore, it follows that the variability of returns associated with dry bean returns is relatively high and the variance of the mean return is also expected to be high. The results reported in this study are consistent existing information regarding the relative riskiness of dry beans.

In each of the rotations studied here, the expected mean return to unallocated cost is higher for 22 inch rows than the same rotation grown in 30 inch rows. This is a first approximation of expected profit maximization. While this is an incomplete

analysis, it does provide evidence to suggest that expected profits are higher for these rotation when grown in a 22 inch row width.

Finally, it should be noted which crops in the rotation pairs support the cost of transition. From the budgets reported in chapter three, it is clear sugar beets, dry beans and soybeans are the crops which generate increased profitability when grown in narrow rows. This is due the expected increase in yields due to narrow rows. Corn has very little change in returns. Wheat is drilled in both systems and, therefore, does not generate added profitability.

Table 4.1 Triangular Probability Distributions of Mean Returns to Transition Costs

Rotation Pair	Lower Bound	Mode	Upper Bound	Expected Value
C - C - NB - B C - NB - B	-203106	190989	634831	207571
C - NB - B C - NB - W	-215388	209156	695229	229666
C - C - SB - B C - SB - W	-126618	124461	365506	121116
C - SB - B C - SB - W	-137882	121982	375144	119748

4.3 Updating Subjective Probability Distributions

As experimental evidence is collected, the prior estimates collected in this thesis need to be updated to include the new information. Expert resolution is a general approach to combine multiple probability distributions of an event into one posterior probability distribution. Genest and Zidek (1986) discuss at length the various methods

of expert resolution. In the present context the prior distribution is the distribution of average returns to transition costs. The posterior distribution is the combined subjective probability distribution of the prior and the experimental data.

A simple combination of these two sources of probabilistic information can be computed as follow. Divide the support of the prior distributions into a fixed number of disjoint and exhaustive intervals and calculate the probability of falling within that interval for both distributions. The combined distribution is found by averaging the probability under the prior for a given interval with probability implied by the experimental data. This method is consistent with many of the axiomatic approaches described by Genest and Zidek. Examples of this procedure are displayed in Tables 4.2 and 4.3. In Table 4.2 the support of the distributions are divided into two intervals, the probability of falling below zero and the probability of exceeding zero. In Table 4.3 the distributions are divided into five intervals.

An alternative to this simple averaging would be to weigh one distribution more heavily than the other. This would be necessary if there was reason to believe one distribution was more representative of the true probability distribution of mean returns to transition. The weights are chosen to represent the relative confidence of each distribution and should sum to one.

In Table 4.2 and Table 4.3, $\text{Prob}(S)$ denotes the subjective probability of falling within a given interval, $P(E)$ denotes the probability implied by experimentation of falling within a given interval, and $P(C)$ denotes the combined probability falling within a given interval.

Table 4.2 Example of Expert Resolution for Two Intervals

Range	Probability that mean returns are	
	< 0	> 0
PROB (S)	0.142604	0.857396
PROB (E)	0.14	0.86
PROB (C)	0.141302	0.858698

Table 4.3 Example of Expert Resolution for Five Intervals

Range	<-10000.	-10000. to 0	0 to 100000	100000 to 20000	> 200000
PROB(S)	0.010764	0.13184	0.281857	0.339354	0.236185
PROB(E)	0.015	0.125	0.332	0.348	0.18
PROB(C)	0.012882	0.12842	0.3069285	0.343677	0.2080925

CHAPTER 5. CONCLUSIONS AND FUTURE RESEARCH

5.1 Introduction

This study has addressed the issue of the potential economic incentives for growing crops in narrow rows in Michigan's Thumb and Saginaw Valley. Prior experience in soybean production has demonstrated yield and economic advantages of narrow row soybeans. There exists some evidence that dry beans and sugar beets also have increased profit potential when grown in narrow rows. The objectives of this study have been to organize the available information regarding narrow production and provide an estimate of the economic incentives of narrow row cropping systems for Thumb and Saginaw Valley dry bean and sugar beet farms.

Due to a lack of experimental data, a complete probability distribution of crop yields under alternative sequences for narrow rows as contrasted to conventional row widths can not be accurately approximated. Decision analysis and methods consistent with decision analysis require complete probability distributions. Complete decision analysis tools are not appropriate to investigate this issue at the time of this study. Therefore, a decision aid was developed to organize the existing biological and engineering information and to provide a first approximation of the expected returns to transition for farm managers and cooperative extension staff. The framework developed can be used for subsequent assessments as new information becomes available.

The decision aid utilized subjective probability distributions of mean rotation crop yields. The estimated probability distributions of mean crop yields were generated by an elicitation procedure. The elicitation procedure was designed to utilize commonly known heuristics about how people judge and process information.

The input requirements for crops grown in narrow rows differ from the input requirements of crops grown in conventional row widths. Input requirements also differ across crop rotations. The decision aid employed incorporated these differences. Estimates of the value of input prices and input requirements were taken from the referenced sources.

Relative commodity prices were estimated using econometric models. Mean crop yields were treated as jointly distributed random variables. All other relevant economic variables were treated as deterministic or held by the decision maker with subjective certainty.

Cumulative probability distributions of net returns to unallocated costs were constructed for both 22 and 30 inch rows using the distributions of mean crop yields, input requirements and prices, and the forecasts of relative commodity prices. The cumulative probability distribution of mean returns to transition costs was found by subtracting the probability distribution of returns to unallocated costs for 30 inch row crops from the probability distribution of returns for 22 inch row crops. The expected returns to transition costs are the amount on average a farmer could pay to retrofit his equipment from conventional row widths to narrow row widths. The primary focus of this was on these cumulative probability distribution of expected returns to transition and choosing the row width which generates the highest expected mean returns to unallocated costs.

Using the cumulative probability distribution as a decision aid, the questions to be answered are: Is there sufficient evidence of economic gains to encourage further research? Is there sufficient evidence of a economic gains that cooperative extension staff should in encourage farm managers to retrofit their equipment sets and plant

narrow row crops? Based on the available information at the time of this study the answer to the first question is affirmative. The second question remains unanswered. However, there is sufficient evidence to suggest that farmers should consider narrow row cropping systems as an alternative production practice.

5.2 Conclusions and Future Research Requirements

From the results present in chapter IV it can be concluded that crops grown in narrow rows have a large probability of increasing average farm profits. It also can be concluded that more research is needed to fully analyze this problem. Agronomic research regarding the joint distribution of yields of rotation crops grown in narrow rows is lacking. Experiments with the same rotations but different row spacings need to be conducted to produce the complete probability information required by decision analysis.

These experiments need to investigate the effect narrow row spacings have on yield interactions due crop rotations, fertilizer requirements, diseases, weed infestations and other pests, and drought, flood, heat tolerance, and the tillage problems associated with narrow rows. This research needs to be incorporated via expert resolution into the results of this study on an annual basis. This will improve the estimates generated here.

As this research is conducted, the relevant research issue is when is there enough experimental evidence to move from the decision aid method presented in this study to a complete decision analysis. Economic researchers do not have a rule which tells what method should be employed. The decision is generally left to the researcher and his/her audience is left to decide how confidence to have in the results. However, Cooperative Extension staff require a large degree of confidence in their own analysis before

recommending large scale changes to a farmer's production methods. Thus, a large amount of consistent information needs to be available prior to such recommendations. In the case of narrow row cropping systems versus common row spacings, it is clear that until complete rotations can be grown and harvested in experiments the data for decision analysis needed will not exist. This will take from three to seven years depending the length of the rotation and the experiments will need to be conducted at several locations to increase confidence in the results.

After completing at least one full rotation on the same plot and several locations, a decision can be made on the appropriateness of the various decision analysis tools outline in this study. The experimental data may be combined with expert opinion via expert resolution to increase confidence in the cumulative probability distributions and reduce the impact of outlying data points.

The potential for improved farm profitable by utilizing narrow row cropping systems clearly exists for farms with rotations containing dry beans, soybeans and/or sugar beets. This preliminary study indicates that there is a high probability the narrow row cropping will increase average farm profits for Michigan's dry bean and sugar beet farms. However, the adoption of this system will vary with the risk aversion of farm operator/managers, their position in the life cycle, the financial health of the farm and numerous other factors. The questions of which farmers will adopt this technology, when it will be adopted and how (referring to the dynamics of the transition process) farmers will adopt it are beyond the scope of this study.

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APPENDIX A

APPENDIX A

COMMODITY PRICE MODEL

Introduction

The prices used are based on 1960-1988 price relationships. Figures A1 - A4 depict the relationship of wheat, soybean, dry bean and sugarbeet prices to the corn price over time; that is:

$$\frac{P_t^{\text{Crop}}}{P_t^{\text{Corn}}}.$$

Two models were built. The first model was formed by regressing the price of each crop on corn price and the fraction of corn acres diverted under the USDA acreage reduction program. The fraction of corn acreage diverted is a proxy for two influences. First, is as an indicator of price distortions due to government influence. Second, it serves as a proxy for U.S. stocks; when stocks are large relative to utilization, the government diverts a higher percent of corn acreage. A second model was built to test for a change in the market structures over time due to changes in relative rates of change in technology, preferences, etc. With the exception of wheat, time was found to be statistically significant and, therefore used to measure the trend at relative price changes. Figures A1-A4 demonstrate graphically the trend in relative prices over time. Table A1 contains the data used in the regressions.

As a simple test for multicollinearity, correlations of the explanatory variables were computed. Table A3 summarizes those correlations. The highest correlation was between the price of corn and year (0.7537). From this, it was judged that multicollinearity is not a serious problem in these models.

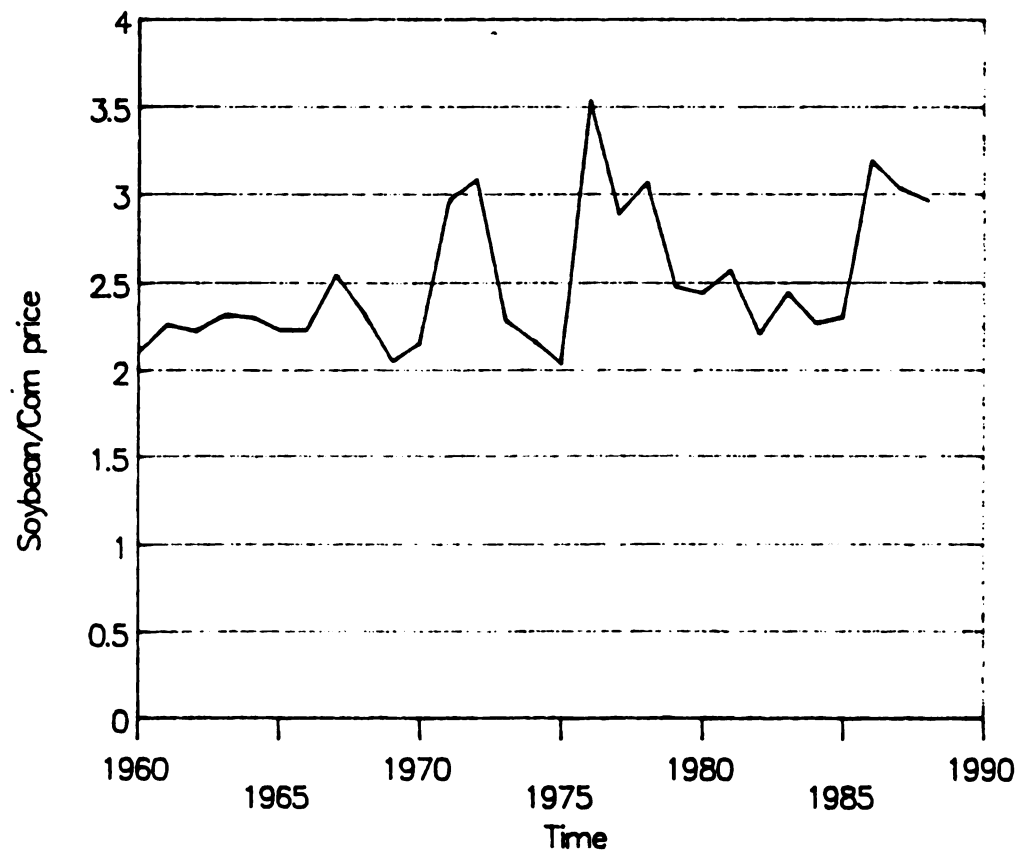
Figure A.1 Relative Soybean Price vs. Time

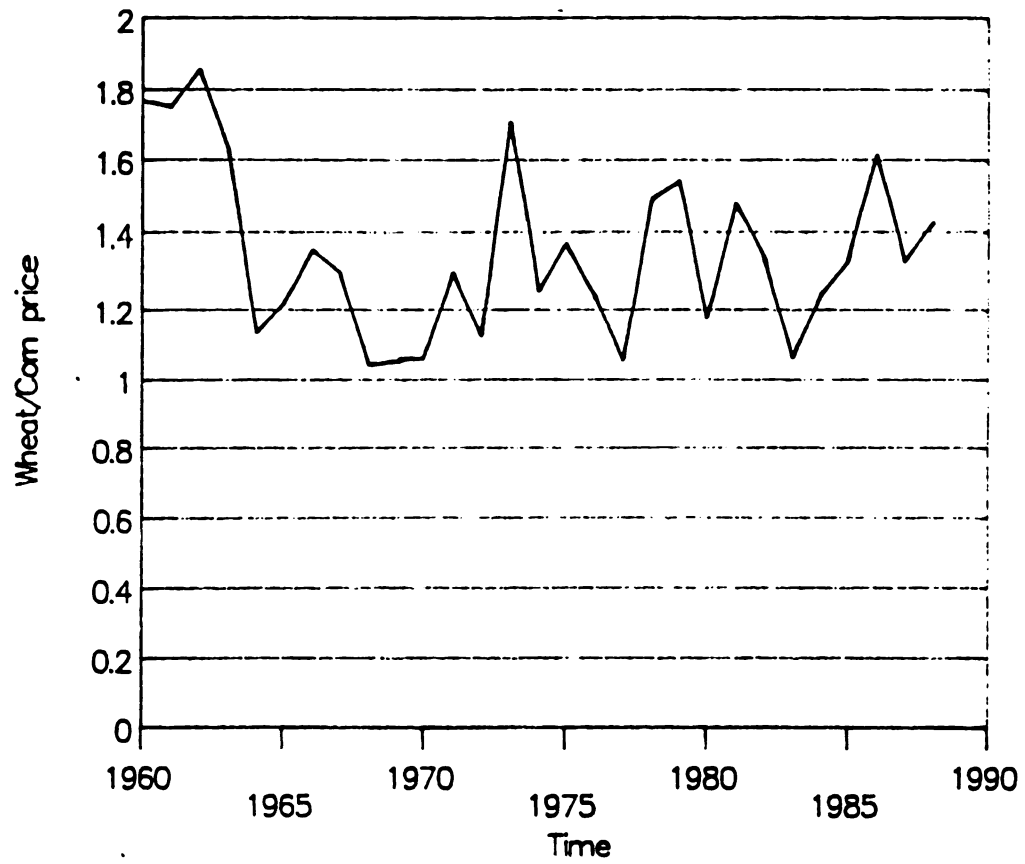
Figure A.2 Relative Wheat Price vs. Time

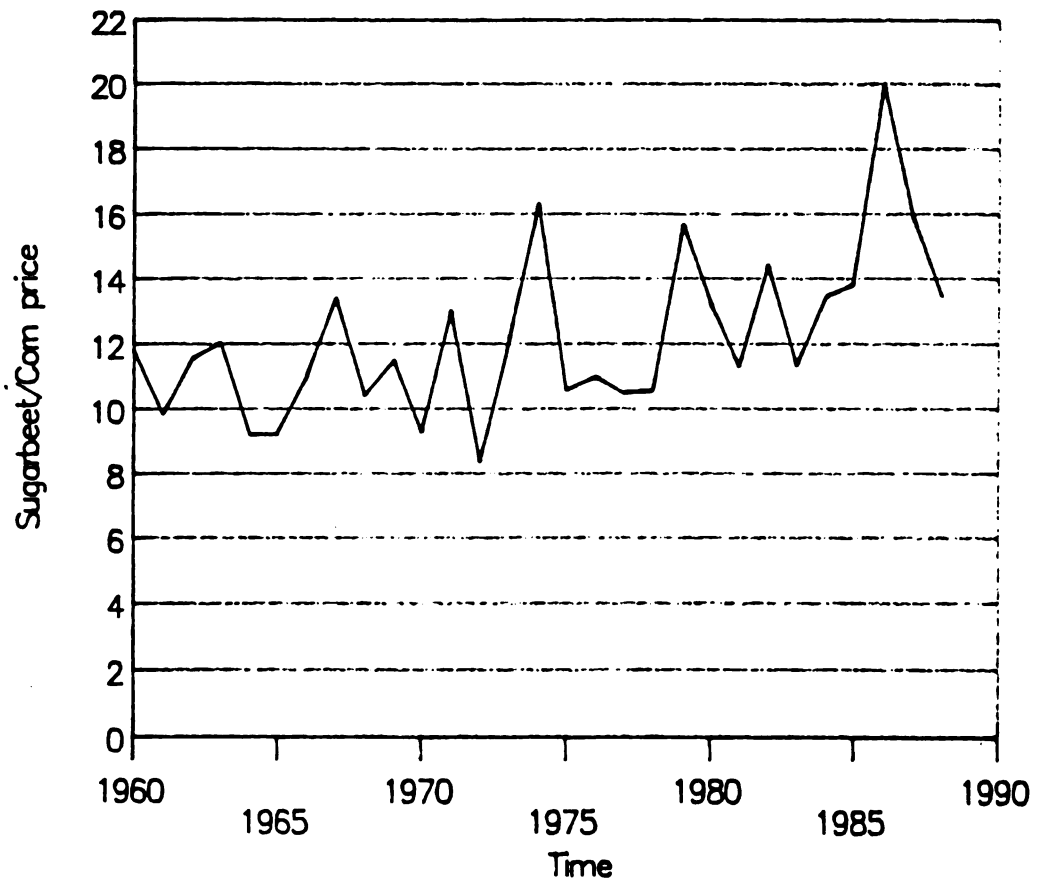
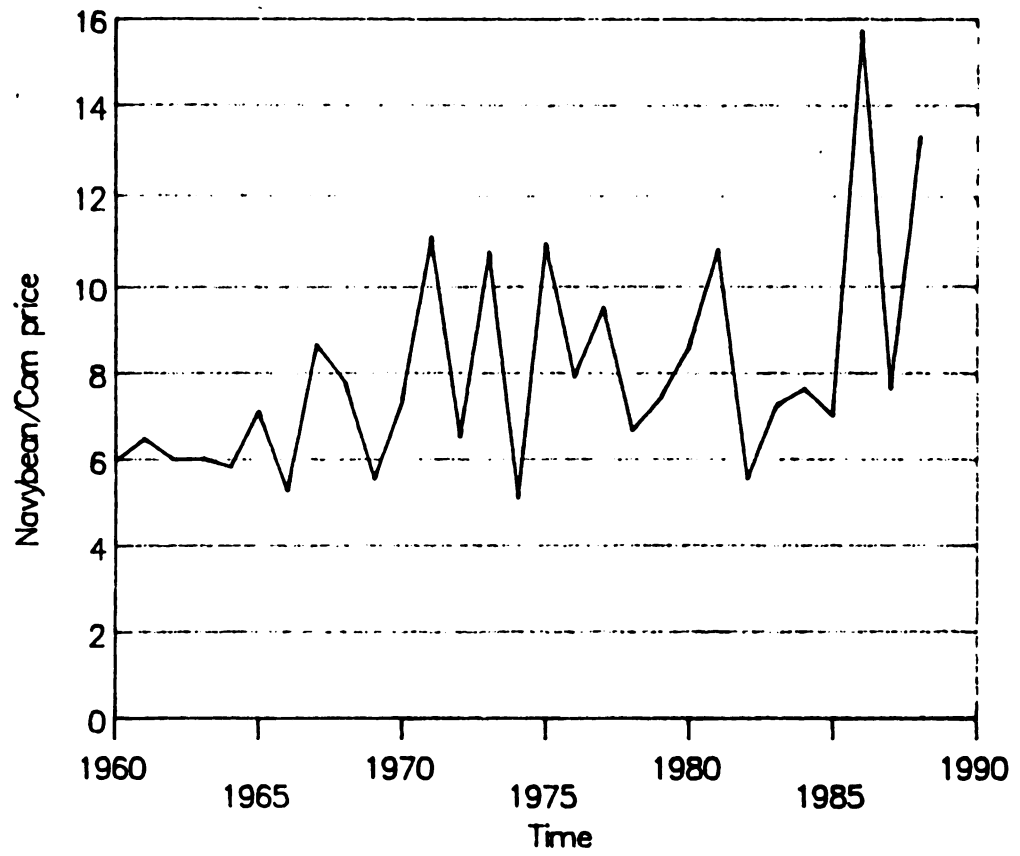
Figure A.3 Relative Sugar Beet Price vs. Time

Figure A.4 Relative Navy Bean Price vs. Time

Corn

The corn price based upon AGMOD⁶ developed by Ferris. The average corn price over the 1990's predicted by the model is \$2.59/bu (in 1989 dollars). The AGMOD model run assumed government programs are replaced in the mid-1990's by the Conservation Reserve. This prediction is used as the basis for predicting the price of the other crops.

Soybeans

The soybean price model regresses the prices of soybeans on the corn price fraction of corn acres diverted, and year. Each of the explanatory variables was statistically discernably greater than zero. The resulting equation is:

$$P_t^{\text{Soybeans}} = 143.90 + 1.247 * (\text{Fraction of corn acres diverted}) \\ + 1.851 * P_t^{\text{Corn}} + 0.07345 * \text{Year}$$

To find the long-run average soybean price in 1989 dollars, the \$2.59/bu corn price of fraction of corn acres diverted was assumed to be zero, (assumes federal government price and income support programs are decoupled from acreage diversion), and year was varied from 1989 to 2000. The resulting prices were then averaged to find the long-run average soybean price.

Wheat

The wheat price model regressed the price of corn, fraction of corn acres diverted, fraction of wheat acres diverted under government programs, and a binary variable as a proxy for the distortion to the long-term corn-wheat price relationship

⁶Dr. John Ferris, Department of Agricultural Economics, Michigan State University.

during the "Johnson" administration (1960-1968), and year. Only two explanatory variables--corn price and fraction of wheat acres diverted were significant. The nonsignificant variables were dropped resulting in the following equation:

$$P_t^{\text{Wheat}} = 0.2212 - 0.984 * (\text{Fraction of wheat acres diverted})_t \\ + 1.252 * P_t^{\text{Corn Price}}$$

The long-run average wheat price in 1989 dollars, was found using the same averaging method described in the soybean model.

Sugarbeets

The sugar beet model was developed using the same explanatory variables as the soybean model. All explanatory variables were significant. The resulting equation is:

$$P_t^{\text{Sugarbeet}} = -501.2589 - 14.7134 * (\text{Fraction of corn acres diverted})_t \\ + 11.905 * P_t^{\text{Corn}} (\text{Corn Price}) + 0.355 * \text{year}$$

Navy beans

The navy beans model was developed using the same explanatory variables as the soybean model. The price of corn, fraction of corn acres diverted and year were statistically significant. the resulting equation is:

$$P_t^{\text{Navybeans}} = 695.754 - 7.089 * (\text{Fraction of corn acres diverted})_t \\ + 5.581 * P_t^{\text{Corn}} + (\text{Corn Price}) + 0.355 * \text{year}$$

This model exhibited positive auto-correlation, with a Durbin-Watson of 2.713. Since this study focuses mainly on long-run differences, no attempt was made to explain or correct for this auto-correlation. Table A1 reports the prices used to forecast and used in the economic evaluation.

Table A.1 Forecasted Relative Commodity Prices

Crop	Units	Relative Price	Absolute Price
Corn	Bu.	1.00	2.59
Soybeans	Bu.	2.86	7.42
Wheat	Bu.	1.34	3.47
Sugar beets	Ton	14.83	38.41
Navy beans	Cwt	10.43	27.02

Table A.2 Regression Data

Michigan farm prices for corn, soybeans, dry beans, wheat, and sugarbeets, fraction of corn and wheat acres diverted, and Johnson era dummy variable.

<u>YEAR</u>	<u>MFPCN</u>	<u>PDDVR</u>	<u>JNDUM</u>	<u>WHTDIV</u>	<u>MFPSOY</u>	<u>MFPDRY</u>	<u>MFPWHT</u>	<u>MFPBTS</u>
1960	0.99	0.0	0.0	0.0	2.08	5.9	1.75	11.7
1961	0.99	0.17	0.0	0.0	2.23	6.4	1.73	9.7
1962	1.05	0.17	1.0	0.11	2.33	6.3	1.95	12.1
1963	1.08	0.12	1.0	0.17	2.50	6.5	1.76	13.0
1964	1.15	0.14	1.0	0.04	2.64	6.7	1.30	10.5
1965	1.15	0.14	1.0	0.07	2.56	8.2	1.40	10.6
1966	1.22	0.13	1.0	0.11	2.72	6.4	1.65	13.4
1967	0.97	0.0	1.0	0.0	2.47	8.4	1.26	13.0
1968	1.03	0.11	1.0	0.0	2.39	8.0	1.07	10.7
1969	1.14	0.11	0.0	0.13	2.33	6.3	1.20	13.1
1970	1.32	0.1	0.0	0.13	2.84	9.7	1.40	12.2
1971	1.03	0.0	0.0	0.0	3.05	11.5	1.34	13.4
1972	1.49	0.32	0.0	0.34	4.60	9.7	1.67	12.4
1973	2.52	0.1	0.0	0.17	5.73	27.3	4.30	30.5
1974	2.91	0.0	0.0	0.0	6.28	14.8	3.64	47.5
1975	2.35	0.0	0.0	0.0	4.78	25.9	3.22	24.8
1976	2.04	0.0	0.0	0.0	7.22	16.1	2.53	22.4
1977	1.92	0.0	0.0	0.0	5.54	18.3	2.02	20.1
1978	2.22	0.09	0.0	0.0	6.81	14.8	3.30	23.5
1979	2.48	0.09	0.0	0.0	6.13	18.5	3.82	38.9
1980	3.07	0.0	0.0	0.0	7.49	26.4	3.60	40.7
1981	2.35	0.0	0.0	0.0	6.04	25.6	3.47	26.5
1982	2.48	0.0	0.0	0.0	5.46	13.7	3.31	35.8
1983	3.20	0.32	0.0	0.31	7.82	23.2	3.39	36.2
1984	2.56	0.0	0.0	0.2	5.79	19.6	3.18	34.4
1985	2.14	0.0	0.0	0.1	4.93	15.0	2.84	29.6
1986	1.50	0.03	0.0	0.03	4.78	23.6	2.42	30.0
1987	1.94	0.15	0.0	0.0	5.88	14.8	2.57	31.0
1988	2.60	0.1	0.0	0.0	7.70	34.6	3.70	35.0

PDDVR: Fraction of corn acres diverted,
 JNDM: Binary variable for years 1962-68,
 WHTDV: Fraction of wheat acres diverted,
 MFPSOY: Michigan farm price for soybeans,
 MFPDRY: Michigan farm price for dry beans,
 MFPWHT: Michigan farm price for wheat,
 MFPBTS: Michigan farm price for beets.

Table A.3 Models Describing the Relationship Between the Crop Prices and Explanatory Variables⁷

Explanatory Variables	Models			
	Soybeans	Wheat	Sugarbeets	Navybeans
Constant	-143.90	0.22	-501.26	-695.76
	(3.21)	(0.091)	(1.8)	(-2.26)
Year	0.073	NS	0.255	0.355
	(3.21)	---	(1.81)	(2.26)
Corn price	1.851	1.252	11.905	5.581
	(6.96)	(12.3)	(7.28)	(3.0)
Corn acreage diverted	1.247	NS	(-14.74)	-7.089
	(0.87)	---	(-1.6)	(-0.72)
Binary variable 1960-1968	NC	NS	NC	NC
	---	---	---	---
Wheat acreage	NC	-0.983	NC	NC
	---	(-1.28)	---	---
<u>Statistics</u>				
Adjusted R ²	0.882	0.843	0.868	0.673
Standard Error	0.67	0.390	4.12	4.60
Durbin-Watson	1.54	1.90	1.94	2.71

NC: Not considered

NS: Not significant

⁷The parameter estimates depicted are the regression coefficient and the associated "t" statistics.

Table A.4 Correlations Between Explanatory of Variables

	Year	Corn	Fraction of Corn Acreage Diverted	Fraction of Wheat Acreage Diverted
	1.000			
Corn Price	0.7577	1.000		
Fraction of Corn Acreage Diverted	-0.1953	-0.1409	1.000	
Fraction of Wheat Acreage Diverted	-0.0379	0.0482	0.6743	1.000

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