OPTIMAL REPLACEMENT INTERVAL AND DEPRECIATION METHOD OF A COMBINE ON A REPRESENTATIVE DRYLAND GRAIN FARM IN NORTHCENTRAL MONTANA

by

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ABSTRACT

Economic uncertainty is one of the foremost problems in agriculture and introduces many complexities into the decision making process. To account for these risks and uncertainties in the replacement problem, a model is formulated within a dynamic programming framework and applied to a typical cash grain farm in northcentral Montana. The decision criterion used under conditions of risk is the minimization of costs associated with each asset through the firm's planning horizon.

The asset under study is a combine and the optimal replacement decision regarding this asset is based on the stochastic nature of winter wheat prices. Transition probabilities for price changes are calculated from a single equation price prediction model. The other state variables are deterministic and include fifteen asset ages and sixteen tax conditions. Together, they completely summarize the costs associated with the combine. The optimal decision minimizes the expected immediate costs and those from the n–1 stage process which are a function of the state variables and decision alternative selected. Besides being able to keep or replace, the decision variable for replacement also includes all the possible depreciation schedules and investment incentives which can be used on the new asset.

The optimal policy selected is dependent upon the state of the process. The accelerated cost recovery system is used in high income years after five years of service and a longer recovery period when returns are very low. The evidence also indicates the value of investment tax credit. The practical and wide ranging results obtained through the use of stochastic dynamic programming contributes to the body of theoretical knowledge on replacement analysis.

CHAPTER 1

INTRODUCTION

Introduction

The technological revolution in agriculture is a well-known phenomena which has drastically changed the structure of the sector. The impetus for adoption of the new changes are provided for by the ability one has to expand output and lower production costs. Since agriculture in both the U.S. and Canada developed under conditions of plentiful land and a scarcity of labor, the innovations have concentrated in expanding the capacity of labor. Such labor-saving technology is primarily of a mechanical nature rather than biochemical. Economies of scale in on-farm production are directly related to mechanization and they can only be realized through farm enlargement and labor displacement. The result is an agriculture sector that is heavily dependent on mechanization to sustain its production.

Other structural changes which have accompanied this technological revolution include growing capital and credit requirements and a rising ratio of farm production expenses to gross farm income. With the trends expected to continue and production to become more heavily dependent on purchased inputs, greater emphasis will be placed on financial management. Among these capital outputs used by agriculture today, the average farm's annual equipment cost is matched only by the charge for land use. The opportunity thus exists for an increase in farm profits or, alternatively, financial ruin depending upon how this sector of total farm expense is managed.

Proper investment planning of farm equipment consists of analyzing two important problems. The first involves deciding if machinery services should be acquired through ownership, leasing or custom hire. The latter two alternatives for control are not considered here. Instead, this study focuses on the second problem of asset replacement over time.

To properly analyze the replacement problem, the investment decision should be compared to others available to the firm. However, this depends on such factors as the amount of capital accumulated and operator goals which in turn transforms the problem into one dealing with firm growth. Such an analysis is beyond the scope of this study, so to keep the focus on asset replacement, only a partial analysis of the real problem can be considered.

Since the mechanization of agriculture is nearly complete, the purchase of a new asset results from a need to succeed an older machine whose services must eventually be replaced if the production system is to continue. Besides being no longer reliable, the present asset may be replaced if it has become obsolete or if its operating costs have become excessive. Even though economic savings will result with replacement based on the above reasons, there still frequently exists a reluctance on the part of managers to supplant physically satisfactory equipment. On the other hand, many farms use the purchase of a new asset to try and elevate their comparative social status despite the fact that the reasoning induces earlier replacement than is warranted. Letting such intangible considerations get entangled in the final investment decision results in a replacement age different from the proper economic one.

The optimal time between purchases is determined by the basic marginal principle of replacement theory which compares the gains from keeping the current asset for another period with opportunity gains which could be realized from a replacement asset during the same interval. From this deceptively simple criterion arises the real problem of specifying all the relevant cost elements. Traditionally, the rising variable costs of repair and maintenance were added with the declining fixed costs as determined by net investment to calculate accumulated costs. Recent works have added the important effect of income taxes in decision analysis and parameters to account for inflation and the asset's true remaining market value.

While these are determinants of cost, their impact on the firm's investment decision is also greatly influenced by the economic environment surrounding the firm. Due to the inherently unstable nature of the agriculture sector, uncertainties with regard to new technology and risks with respect to returns must be recognized as important factors in analysis. These risks and uncertainties introduce many complexities into the decision making process and are an important influence on replacement analysis.

Purpose

The purpose of this research effort is to develop a decision making model which will focus on the effects of economic uncertainty in the evaluation of optimal farm equipment replacement decisions given the present tax laws and structure. The results should provide farmers with a profit maximizing decision criterion and may aid policy makers in identifying the impact of various tax methods on replacement. In order to accomplish this, the specific objectives of this study will be to:

1. develop the general methodology for analyzing replacement decisions and then adapt a dynamic programming procedure where the selection of an optimal policy is dependent on stochastic variables, and to
2. apply the model to a representative cash grain farm in northcentral Montana where the asset is a combine and the optimal replacement interval and depreciation schedule for this asset is based on the stochastic nature of winter wheat prices.

CHAPTER 2

LITERATURE REVIEW

Literature Review-General Replacement Principles

Martin Faustman (1849) was the first to fully develop the concept of net present worth when discussing the forest management problems of rotation length and creation of a normal forest. Faustman used present discounted values to put a fair price on forest land which is comprised of both the land and of all income and expenditures associated with the forest. This principle of discounted cash flow has become the basis for solving many investment decisions including optimal replacement patterns.

Unfortunately it was not until Fisher's article in 1906, that an economist put forth the idea of discounted revenues. With the delay, the first replacement articles were not presented until 1923 by Taylor and 1925 by Hotelling. They determined the economic life of an asset with one cycle by maximizing the present value of the output minus the operating cost of the asset, the interest on the salvage value and the associated rate of depreciation and dividing this sum by the machine's rate of production. The minimum total unit cost of the product defines the economic lifetime of the asset and this is found through substitution into the value function at time zero. The derivation is possible because they assumed total dependence of operating cost on the value of the machine.

Preinreich (1940) was one of the first to deal specifically with replacement in economics since most previous discussion of the topic was done in depreciation articles. He feels that the Taylor-Hotelling criterion for economic replacement had severe limitations because it did not consider relevant dynamics. To correct this, Preinreich studies a number of situations in which an asset may be under three classifications; scope of replacement, input and output limitations and economic conditions.

He concludes that replacement theory will have a separate solution for every kind of rigid scarcity and for every volume of limited supply. In the case of demand, the problem is simplified into making the cost per unit of output a minimum, which is the Taylor-Hotelling proposition. In all other cases, the entrepreneur should maximize profit per unit of input where the shortage is felt. When he combines all scarcities, Preinreich states "that excess profits must be made a maximum in terms of a composite index of productive activity, not with reference to any single ingredient" (p. 36).

In his 1937 article, Samuelson shows that the value of capital invested in an asset will at all times be equal to the capitalization of the subsequent income stream discounted at the market interest rate. As a result, the market price of an asset is identical to its capitalized value. In addition, he dismisses Boulding's proposition (1935) that rational investors should maximize the internal rate of return over the whole period of an investment. Samuelson proves that given the market interest rate, an operator should choose a replacement age that will maximize the present value of the associated income stream. The result is true for varying rates too since with "the time shape of interest being given and income known, the capital invested up to any time is always equal to the value of the (investment) account at that time, the value being a capitalization of subsequent income" (p. 487).

In one of the first articles demonstrating the basic procedures involved in determining the optimum replacement pattern for agricultural assets, Faris uses three types of enterprises of a sequential nature in a 1960 JFE publication. He follows the principle that the "optimum time to replace is when the marginal net revenue from the present enterprise is equal to the highest amortized present value of anticipated net revenue from the following enterprise" (pp. 761-762). For an operation that will be replaced several times a year such as cattle finishing, he uses a discount rate of zero in which case the highest average net revenue is used as a basis for comparison rather than the amortized present value.

In examining the longer production period enterprises, Faris incorporates the interest on the unpaid balance of the establishment costs in determining net revenue for operations in which revenue was realized by the sale of the asset and for ones in which there was a flow through the life of the asset. In both cases it was found that if marginal net revenue for the present asset was changed, the amortized present value of the new asset would change by the same amount thus having no effect on optimum replacement pattern. The implication of this result is that fixed costs can be left out of such calculations.

In a subsequent comment on the preceding article, Winder and Trant (1961) argue that the opportunity costs should not only include the usual elements which Faris used, but also the foregone earnings of the time to apply the asset in consideration. In their criticism they use a situation with a zero discount rate and a second with a positive rate of time preference. They define opportunity costs as alternative income possibilities and time preference proper as the preference for income in one time period rather than another.

They found in the no time preference situation that equating the marginal net rate of profit per unit of time (marginal value product) to the average net rate of profit per unit of time (marginal factor cost) will maximize profit per unit of time. When time preference proper is considered, the optimum replacement age is where the marginal net rate of return per unit of time equals the average net rate of return per unit of time multiplied by the constant $(1+q)\ln(1+q)^{1/q}$ where $(1+q) = (1+r)^n$. With the time preference discount rate (r) greater than zero, a shorter production (n) is implied than that of the first situation.

Chisholm (1966) claims that the two previous articles overlooked some of the elements of marginal cost with respect to time. There is agreement that the fixed and variable costs involved should be compounded at an appropriate interest rate in order to compare costs and returns incurring at differing points of time but Chisholm adds that money tied up in the actual replacement asset under study is also part of the relevant opportunity costs. He suggests that the annual running cost, the interest on total revenue obtainable from sale of the asset and the amortized value of net returns from the next asset are elements to be incorporated in marginal cost. Optimum replacement age can then be selected which maximizes net present value of future profits for a perpetual sequence of production periods and not for just a single period.

Perrin (1972) ties together past developments and presents a general model of asset replacement which applies to both appreciating and depreciating assets in a number of different settings. With a single asset, he found that acquisition age is irrelevant and the optimum replacement age is that at which the residual earnings plus changes in asset value (marginal revenue) equals the interest which could be earned by selling the asset (marginal opportunity costs). If it is to be replaced by a series of identical assets, the opportunity cost of delaying the future earnings of these assets must be included. Replacement will then occur when the net flow of benefits equals the flow which could be realized by immediate replacement. If the new assets are technologically improved, their higher capitalized value will induce earlier replacement than the previous scenario.

In reality, the relevant elements are discrete values rather than continuous and using the marginal criterion in a discrete world will often lead to a one year error in calculation of optimum replacement interval. In lieu of this, Perrin states that finding the present values for each replacement year may be a better evaluating procedure.

The operator must choose the economic life which will maximize these net present values of future income streams from the asset. Perrin notes that this maximum will be zero due to the action of market forces. If the value of the residual earnings is temporarily positive, input prices will be bid up and/or output prices will fall with expanded production until the rent is eliminated. The effect of this process on optimum replacement age will depend upon the elasticity of supply of those assets of various ages.

Perrin also examined the theoretical implications of changing the discount rate on replacement. With appreciating assets such as a forest, a higher rate will result in earlier replacement. However this general statement is not necessarily true for other assets and the effect will depend upon the shape of the earnings flow.

The appropriate choice for the discount rate depends on the circumstances at hand. The cost of capital may be used as an indication of the return on alternative investments if the owner faces a perfect capital market. If there is no such market, then his personal preference rate may be appropriate. A third alternative is the internal rate of return. Since this value is determined by the market prices of the inputs, market forces will drive up the asset price if the internal rate of return is above the market rate for activities of similar risk. The latter rate can be viewed as the appropriate discount rate if equilibrium prices of all inputs are expected to prevail by the first replacement date.

Chisholm (1974) was one of the first to analyze the effects of income tax policy on the optimal timing of farm machinery replacement. To do so, he develops a discrete time period model in which the firms are assumed to minimize the present value costs of obtaining a constant flow of identical machinery services over an infinite planning horizon. A firm will continue to maintain the current asset until the marginal cost of holding that machine for another year exceeds its amortized cost. His results show that higher rates of discount are associated with longer replacement intervals and higher income tax rates with shorter replacement intervals. Since the annuity value of the tax saving from an investment allowance is a decreasing function of age, Chisholm concludes that such a tax credit will significantly shorten replacement intervals. However such decisions are only slightly influenced by the method of depreciation used.

Kay and Rister (1976) extended Chisholm's work on tax policies. Using a similar model but under United States rather than Australian tax regulations, they found that the after tax discount rate had the largest impact on replacement while the income tax rate causes only slight differences in optimal policy. Like Chisholm, they concluded that the depreciation method had little effect. They also found that though the tax regulations have a small impact on replacement age, they do lower the present value of any policy which has encouraged the trend towards larger equipment.

Kay and Rister listed some of the possible reasons why predicted replacement age in their study and other previous ones is longer than that actually observed particularly for farmers with a high discount rate. These include using the wrong pattern of repair costs or not adequately covering the cost associated with a loss in reliability as the machine ages. A shorter replacement policy may also be explained by continual technological improvements and the farmer's desire for larger machines.

In their continuous time model, Bates, Rayner and Custance (1979) proved that the rate of inflation can have a significant impact on the optimal age of replacement. The inclusion of inflation is justified on the basis of two facts. First, since taxes are based on historic costs, a significant level of inflation will reduce the real value of depreciation allowances. Secondly, the receipts and benefits from tax allowances are lagged and thus depreciated. In addition, resale prices for equipment will often be greater than the unexpired depreciation costs during inflationary times which results in a gain in ordinary income in the form of depreciation recapture and possibly capital gains. Bringing these factors into the model, they conclude that "the higher the rate of inflation, the greater the real value of costs and the higher the optimal replacement age; but in each case, the absolute difference made decreases as the rate of inflation becomes higher" (p. 333). The effect is greater, particularly on costs, the higher the tax rate.

Reid and Bradford (1983) continue the improvement of the previous models by specifying a more generalized equation to estimate remaining market value which along with tax incentives is the most important parameter influencing agricultural replacement decisions. Using tractors, they include more situation specific explanatory variables such as horsepower, realized new farm income, the tractor make and indexes for technological change. They use this remaining value equation in a discrete model similar to that of Kay and Rister but with additional terms for investment credit recapture and tax gains. This adjustment gave them results with a wider range of replacement ages than previous studies. As an example, they found that larger tractors and ones of a certain make have shorter replacement intervals because they retain a higher market value relative to their initial costs than do smaller horsepower machines and other manufactured models.

They also examined the effects of the Economic Recovery Act of 1981 (ERTA-81), detailed explanation of which will be provided later. Replacement intervals are shorter with no expensing under ERTA-81 than with expensing emphasizing the value of investment tax credit. The ability to reduce taxable income with expensing does not offset the reduced value of a lower investment tax credit. The replacement ages are shorter under ERTA-81 without expensing than under the pre-ERTA-81 conditions while the effect with the expensing option depends on the remaining value equation used and on the discount rate. They also found that under the new conditions, the after-tax ownership costs are higher because the tax rate reduction more than offsets the gain in the write off value of a more rapid depreciation. As a result, there is a smaller incentive to buy larger machines though there are more funds available for reinvestment.

Dynamic Programming Definitions and Concepts

The dynamics involved in the farm firm decision making process must be included if the previous work on replacement is to be extended. To incorporate the effects of risk and uncertainty on future events, this paper uses dynamic programming to analyze the replacement decision. Dynamic programming is an optimization technique which solves a multistage decision problem by converting it into a problem requiring the solution of sequential single period problems rather than a programming algorithm that solves for a specific type of problem (Dreyfus, p. 213). It is a backward mathematical induction process that seeks to find the sequence of decisions that will maximize, or in this case minimize, the appropriately defined objective function.

The multistage decision process is divided into time intervals or stages as shown by Figure 1 with a policy decision required at each one. Each stage has a number of states associated with it that describe the current situation at any stage. The sum total of all relevant information about the process at a given stage is defined by the magnitudes of the state variables. The policy decision made at each controls the state in which the process will be found in the following stage. The transition from one state to another can be made with certainty or stochastically according to a probability distribution.

time (t)	1	2	3		t-1	t	t+1
stage (n)	n	n-1	n-2		2	1	0

Figure 1. Relationship of chronological time and stages in dynamic programming.

In dynamic programming or DP as it will be referred to in the rest of the study, the objective function must be one of Markovian nature. Given the state of the process at a given stage, the decision process depends only on the state of the process in that stage and not on the state at preceding stages. Thus, for DP to be applicable, the set of state variables must include all necessary information required to ensure that the optimal policy depends only on the present stage and state and not upon how one got to that state. To satisfy the Markovian requirement, the researcher must achieve adequate realism of state description which will vary depending upon the depth of analysis.

Bellman is credited with the formal conceptualization of dynamic programming in 1951 and his principle of optimality lies behind the operation of the DP technique.

> An optimal policy has the property that whatever the initial state and initial decision are, the remaining decisions must constitute an optimal policy with regard to the state resulting from the first decision (1961, p. 57).

This principle allows one to divide the total problem and solve the last decision stage, then work backwards and solve the second-to-last decision until the first decision is solved. The solution procedure moves backward stage by stage through the use of a recursive relationship. It identifies the optimal policy for each state at the present stage, given the optimal policy for each in the future time period is available. If these optimal returns in the next stage are known, one would make the decision that maximizes (or minimizes) the total of the immediate return and the optimal return from the process in the next time period starting in the new state. Solution of the following recurrence relation yields the sequence of decisions that optimizes the objective function;

$$v_i(n) = \mathrm{Max}[q_i^k(n) + B\, p_{ij}^k(n)\, v_j(n-1)]$$

where,

$v_i(n)$ = total value of a n-stage process where an optimal policy is used and the initial state of the process is i

Max = the maximum operator

k = the set of decision decision alternatives

$q_i^k(n)$ = the expected immediate returns given the ith stage, kth decision alternative and the nth stage of process

B = the discount factor

$p_{ij}^k(n)$ = the transition probability for being in the jth state in stage (n−1) given the process is in the ith state and the kth decision is made in stage (n) of process

$v_j(n \dagger 1)$ = the total value of a (n−1) stage process where an optimal policy is used and the initial state of the process is j.

Dynamic programming provides a great computational saving over exhaustive enumeration to find the optimal sequence of interrelated decisions, especially for large problems. However, it does require formulating an appropriate recursive relationship for each individual problem. DP is not described by a set of equations in a standardized format nor does a pre-programmed computational algorithm exist. Instead, it is a general type of approach to problem solving that requires the development of equations fitted for each distinct situation. The literature review to follow will outline the various approaches different authors have used to examine the replacement problem with DP as the optimization technique.

Literature Review of DP Replacement Problems

Appropriately enough, it was Bellman (1955) who published the first paper using DP to determine the optimal replacement age of equipment. He did not use a specific situation but did set up the following functional equation;

$$\begin{aligned} f(t) = \mathrm{Max}[&K{:}r(t) - u(t) + af(t+1)] \\ [&P{:}s(t) - p + r(0) - u(0) + af(1)] \end{aligned}$$

With no technological improvement in equipment or practice, the only state variable is machine age. The return associated with keeping the machine for another time period (K) is the output of the machine (r) minus the upkeep for that year (u) plus the future discounted return ($af(t + 1)$). The decision to purchase a new machine (P) involves the return linked to the new asset ($r(0) - u(0)$) and the discounted return when it is a year old ($af(1)$) plus the difference between the salvage value and the purchase price ($s(t) - p$). It is assumed that the trade-in value and output of the machine are decreasing functions of age while its associated cost is increasing over time. The optimal replacement policy found by solving the above recurrence relation will maximize the overall return from the machine. Bellman adds that if technological improvements increase the future returns from the same machine, absolute time must be included as another state variable.

In his textbook, Howard (1960) considers an automobile replacement problem over a ten year planning horizon. The state variable is described by the age of the car in three month periods and a replacement decision is made at each of these intervals. The first decision alternative, $k = 1$, is to keep the present car for another three months and the other, $k > 1$, is to buy a car of age $k - 2$. The functional equations are much the same as Bellman's, however Howard has included the probability that a car of a certain age will survive to the next year without incurring a prohibitively expensive repair. A car that suffers a major breakdown is sent directly to state 40 indicating that it is worn out. The result is 40 states with 41 alternatives in each and thus 40 to the 41st power possible replacement policies.

This example is presented in a textbook by Bellman and Dreyfus (1962) along with additional explanation of the original Bellman article which involved an infinite time problem. In contrast, they present a technique with an example to solve a finite duration process by means of the iteration of a recurrence relation. This allows them to include cost variations as a function of real time as well as of age. They also describe a variety of replacement problem formulations. For example, the purchase of a used machine may be included as a third decision alternative if one can define the appropriate cost function for such a transaction. The DP replacement problem could also be designed to contain the posssibility of an overhaul with the inclusion of another state variable which describes the age of the asset at the last overhaul. In this problem, it must be assumed that the repairs will give the machine characteristics of a younger asset depending upon the age and the effort devoted to the overhaul.

Burt (1963) formulates the multistage decision process of replacement in a different way. He defines the stage as the number of replacements yet to be made during the firm's planning horizon and the state variable as the number of years in that horizon. The age at which to replace the equipment of the current stage becomes the decision variable. Using this format, Burt finds that in the discrete case, the optimal age to replace the current asset is where net marginal return of the next year is less than, and at the current age is greater than or equal to, the present value of returns under an optimal replacement policy reduced to a perpetual annuity. With a continuous model, optimal replacement age is where the marginal net returns are equal to the perpetual annuity equivalent of net returns. The net return function must be independent of the optimal replacement policy for the model to be applicable.

It was Burt, along with Allison (1963), who first indicated the potential application of dynamic programming for farm management decisions. The use of DP was illustrated by examining the wheat-fallow decision on a dryland farm. The amount of soil moisture at seeding was defined as the state variable upon which the decision to plant a crop or leave the land fallow was based. Though it is not a specific replacement problem as such, the article does clearly present the formulation and use of DP in agriculture. They also show how the optimal policy converges and how to derive long run expected yields under a specific policy by obtaining the probabilities of being in a particular state after a number of transitions.

In another paper, Burt (1965) extended the analytical results of replacement theory to the case where the asset is subject to involuntary replacement due to chance events. Age is again the state variable used to indicate the asset's expected future economic productivity. However Burt includes both a voluntary replacement cost (price of new asset minus terminal value of used one) and a cost for replacement caused by random factors. The latter reflects the salvage value under failure, the cost of a new machine and the average proportion of periodic net revenues received under involuntary replacement. It may also be assumed that the gross returns from an asset are constant, thus simplifying the problem to one in which costs are only considered. In this model, Burt has an infinite planning horizon in which the revenue, cost and probability parameters remain constant. This implies that the replacement age will be constant for all machines and is unaffected by the age of the initial asset. As a result, the optimal policy is one that maximizes the expected value of returns from the first asset held and expected present value of returns from all future assets. Using a marginal approach instead of the aforementioned discrete method, one should maintain the current asset until the expected marginal net revenue minus expected marginal cost of planned replacement is less than the weighted average net revenue from the potential replacement. The weights are products of the discount factor and probability of survival for each age which is not accounted for in the measure of risk in the discount factor. Burt extends this general model to cases in which the revenue associated with the first asset is different and for various probability distributions of asset failure. He also goes through the model when the maximum rate of return is the appropriate criterion for optimization rather than present value which would occur under conditions of capital rationing.

The traditional replacement models examined so far have not accounted for the possible situation where the replacement age of the currently held asset influences the value of future assets. Burt accommodates this relationship in his 1971 article on the optimal timing for clearing brush and scrub timber from pasture and range. As the length of time between pasture improvements increases, the brush and timber continually deteriorate the pasture and in the process reduce quasi-rents of the range in the renewal cycle after their removal. With this scenario, Burt formulates the model in a method similar to his 1963 article. The stage of the process is the number of pasture renewals yet to be made in the planning horizon rather than a discrete time period. One state variable is the number of years remaining in the planning horizon and the other is the length of the immediately preceding renewal period. With this format, an optimal replacement age is one that maximizes the present value of all quasi-rents from the remainder of the planning horizon.

Since this time the use of DP as a useful analytical technique has grown. Textbooks such as Dreyfus and Law (1977) even contain a chapter devoted to replacement models, yet there remains an apparent lack of popularity for DP among agricultural economists which Burt (1982) has recently addressed. Using the past works cited as a basis for the methodology, this study will show the practicality and flexibility of dynamic programming when applied to the problem of optimal replacement in agriculture.

CHAPTER 3

FORMULATION AND IMPLEMENTATION OF EMPIRICAL MODEL

The General Decision Model

With the substitution of capital for labor projected to continue in agriculture, greater emphasis will be placed on replacement. Use of capital inputs require annual cash outflows whereas, to some degree at least, returns to farmer labor can be postponed in years of adversity. The result is that the farming sector is becoming increasingly sensitive to fluctuations in income as the use of purchased inputs increase.

Machinery represents the largest sector of capital inputs on the farm so it also has a large impact on the viability of individual enterprises. The acquisition of a major farm asset requires a substantial investment on the part of the owner and so is often purchased with the use of borrowed funds. A cash commitment is necessitated regardless of the circumstances surrounding the ability to pay which explains in part the farming sector's vulnerability to income shortfalls. The farmer may delay purchases to avoid the above situation during low income periods. However, if his returns are high, the ability to decrease taxable income through depreciation and investment incentives may offset the cash costs associated with acquisition. Regardless of the level of returns, the impetus for replacement may be brought about by reliability loss and repair costs that are increasing with the age of the asset. The farmer must take into consideration all these factors and cost elements when contemplating the replacement decision.

Noting the increased sensitivity of agriculture to income fluctuations due to capitalization and the inherently unstable nature of returns in farming, any study on optimal replacement decisions in this sector of the economy must be considered in a stochastic framework. If there was no uncertainty surrounding income, the analysis would turn into a single-stage deterministic problem. However, the variability of returns requires the problem to be formulated as a sequence of annual decisions in which the owner must decide whether to replace or keep his combine for another time period. He is unsure of the possible price levels in the next year but current conditions are an indication if returns are assumed to be jointly distributed over time. The new information determines the relative value of tax deductions which the owner must weigh against purchase costs and increasing repairs when making his replacement decision.

The problem is thus properly viewed as a sequential decision process. The process is summarized at any point in time by the stochastic price level, and the age of the asset and the depreciation schedule and incentives used. These state variables completely describe the combine and form the basis on which the decision rule is made. The optimum replacement interval is then determined by solving the sequence of decisions which will minimize the present value of all cash flows associated with the combine. Since it is difficult to distinguish which returns are attributable to a particular asset, the model is formulated so as to minimize these flows rather than as a profit maximizing problem. "When a firm's price or output decisions are independent of its replacement decisions then cost minimization and profit maximization are completely separable" (Chisholm, p. 776). As Preinreich noted, the age cannot be determined separately from the economic life of each machine to be used in the firm's planning horizon so the criterion seeks to minimize the costs associated with all assets during that time spectrum.

The preceding description is formulated in terms of a general model with the following notation and definitions. The model is represented in terms of discrete time variables and is evaluated by calculating the present value of all relevant costs associated with each decision alternative and for each possible replacement year and depreciation schedule. All variables are on an annual basis and the stage of the process is denoted by n where $n = 0, 1, \ldots, N$.

S = set of all possible asset ages and tax alternatives (decision variables) at the present stage,

u = the particular decision variable selected from the set S,

s = the state variable which designates status of combine at the present stage in terms of age and depreciation method,

$\vec{p}$ = set of expected product prices which are state variables.

The transition of the combine status is deterministic and does not involve the price state variable and is denoted as follows;

$$s(n-1) = h(u, s)$$

The transition of the price vector is stochastic and does not involve the decision variable, u, or the present physical and financial status of the combine and is described mathematically as follows;

$$\vec{p}(n-1) = \vec{g}(\vec{p}, \vec{v})$$

where,

$\vec{v}$ = is the vector of random variables where there is an element of $\vec{v}$ associated with each element of $\vec{p}$.

$\vec{g}$ = is the vector of functions associated with the elements of $\vec{p}$ and $\vec{v}$.

With these definitions, the recurrence of the dynamic programming formulation for the replacement problem is as follows;

$$f_n(s, \vec{p}) = \underset{u \Sigma S}{\mathrm{Min}} \; [R(u, s, \vec{p}) + \beta E f_{n-1}((h(u, s), \vec{g}(\vec{p}, \vec{v}))]$$

where,

$f_n(s, \vec{p})$= the expected value of discounted costs from a n-stage process under an optimal replacement policy when the initial state is described by s, the financial and physical status of the combine, and $\vec{p}$, the vector of price state variables,

$R(u, s, \vec{p})$ = the expected costs in stage n which are a function of age, tax alternatives and the vector of expected prices,

β = the appropriate discount factor $(1/1+(1-t)r))$ where r is the real rate of interest and t is the marginal tax rate,

E = the expectation operator.

Representative Farm

The setting for the replacement model is a northcentral Montana dry-land grain farm and the asset under consideration is a self-propelled combine harvestor. A representative farm has been constructed for analysis rather than grouping results to avoid aggregation bias. While the firm structure for grain farms may be more standardized than for many farm types, there will still exist discrepancies between individual enterprises and the described representative farm. Despite this, it is felt that the assumptions and model coefficients are very characteristic of this dry-land grain farming region.

A combine represents one of the major farm assets for this farm type, so proper replacement of this machine is essential to the firm's viability. Historically on these farms, the owners hauled in and stored their grain. The protection from the weather eliminated the timeliness factor involved in threshing, enabling the common practice of joint ownership of threshing equipment. But with the shortage of labor brought about by World War II, farmers switched increasingly to threshing directly in the field. The concern of losing a crop due to prolonged bad weather caused conflicts among the co-operators of a threshing ring and resulted in a move towards individual ownership. The prosperous years following the war were marked by an expansion of farm size and a major wave of new farm mechanization. To own the machines and/or to purchase bigger machines, farmers had to expand their grain acreages which in turn required additional machinery. This process has slowed somewhat during the current period so technology in this study is assumed to be constant through the firm's planning horizon. Thus, each combine of which the farmer is the sole owner is replaced by an identical machine based on the current technology. With inflation assumed to be nonexistent, each combine carries a \$80,000 price tag and has a 160 horsepower engine that will handle a 24 foot grain header.

The owner is assumed to be married with two children and neither his wife nor himself earn any supplemental income from off-farm employment or from rents, royalties or trusts. Thus, their sole means of support is derived from growing grain on 2400 acres of crop land. The owner has a 90 percent equity in his land base which is valued at \$500 per acre. Each year, winter wheat will be sown on 1000 acres, barley on 500 acres and the remaining ground left as summer fallow. This typical cropping pattern is commonly used in order to reduce risk during planting time and to increase soil moisture. The sequence is fixed as are the crop yields with wheat fields presumed to average 35 bushels per acre and the barley crop 50 bushels per acre. The stochastic nature of returns are thus accounted for solely by the price level. Yield could also be included as another state variable but there is no dynamic trend associated with it. Since the firm operates in a perfectly competitive market with price and output independent of one another, the inclusion of yield variability to enhance the authenticity of risks in returns is not significant enough to justify the addition of another state variable. While some of the ripple effect on returns will be missing, it is easier to assume average yields and then plug in different values later if necessary.

Price times the output determines gross farm income for this study, and to simplify the computations, barley price is expressed in terms of wheat price equivalents through the following regression equation;

$$\underset{}{BP} = \underset{(.0512)}{.72736} + \underset{(.04478)}{.47822}\,(WP)^{1} \qquad (1)$$

[1] Annual prices for the last seventeen years were converted into present day dollars. Source: Montana Agricultural Statistics.

where BP is barley price per bushel in current dollars and WP is winter wheat price. The adjusted coefficient of determination is .8828 and Durbin Watson statistic is 2.0323.

The enterprise costs are assumed to be deterministic. The machinery complement and its usage per acre are summarized in the following table for a similar size farm in the north-central region of Montana.[2] To obtain the ownership costs associated with the equipment, some arbitrary assumptions were made. First, the appraised value of the new assets were deflated by the prices paid index for tractors and other farm machinery to determine original purchase price.[3] The second assumption involved grouping these purchases into a restricted number of acquisition dates and depreciating the machines purchased during the same time period together. These deductions were determined by multiplying the basis or original investment cost by the percentages given under the present accelerated cost recovery system for the appropriate classification of 3, 5 and 15 year property. The owner is assumed to have a 90 percent equity in his machinery complement similar to his land.

The variable operating costs listed in the following table were generated on the basis of the cropping practice assumed to be used in the region.[4] The other expenses listed in the table that are necessary to calculate net farm profit are not well documented. They were obtained through an interview with the operator of a farm comparable to the one being studied. The amount of extra labor hired, utility bills and the building and liability insurance figures were values that this individual had experienced in the past and expects to face again in the future. The remaining values in the table are itemized deductions which are needed to compute taxable income. They will ordinarily change with income levels as outlined by the *Wall Street Journal.*[5] However the small variation in their amount through

[2] Data obtained from an unpublished Montana Agricultural Experiment Station Bulletin dealing with cost of production on Montana farms according to region.
[3] Indexes obtained from Inputs; Outlook and Situation. United States Department of Agriculture, Economic Research Service, June 1983, p. 17.
[4] Costs are from the same unpublished Experiment Station bulletin as above.
[5] Figures obtained from the *Wall Street Journal*, 8 December 1982, p. 1.

Table 1. Depreciable Assets on the Farm Excluding the Combine.

Depreciable Asset	Purchase Price
Buildings–15 year assets	
–grain storage of 50,000 bushels purchased 3 years ago in April	$37,000
–machine storage and shop space of 4000 square feet additions and renovations occurred during same time as bin purchase	7,000
	44,000
Machinery–5 year assets	
2 year old machines	
–Truck: 2 ton box and hoist (.2x)	26,200
–Grain Drill: 36 ft shovel (1x)	25,500
–Tillage Equipment: 37 ft; Tool Bar (5x)	15,500
Rod Weeder (3x)	2,300
Flexitine Harrow (1x)	2,000
	71,500
4 year old machines	
–Tractor: 175HP 4WD	63,000
–Grain Auger: 40' X 8" PTO (.02x)	2,000
	65,000
Fully Depreciated Machines	
–Truck: 2 ton box and hoist (.2x)	
Machinery–3 year assets	
–Pickup Truck: 3/4 ton 2 years old	11,000

*Bracketed number indicates usage per acre.

the range of earning levels to be examined led to the standardized values which have been used. The medical expenses and charitable contributions are average rates based on the WSJ findings for the relevant levels of income. The interest expense is lower because many farmers claim assets such as the home and car for both personal and business use.

The property taxes associated with the farm assets must also be deducted from net farm profit to calculate taxable income.[6] The mill level of 200 is an approximate value that has been used. The land is graded at the highest possible level due to its productivity

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[6] Percentages from Montana Agricultural Experiment Station Bulletin 723, "The Taxation and Revenue Systems of State and Local Government in Montana" (August 1980).

Table 2. Variable Operating Costs Per Acre for a Representative Dry-land Grain Farm in Northcentral Montana.

Direct Crop Expenses	Wheat	Barley	Fallow
Seed	$ 4.00 (50 lbs/acre)	$ 4.80 (48 lbs/acre)	–
Fertilizer–Nitrogen	4.00 (16 lbs/acre)	1.50 (6 lbs/acre)	–
Phosphate	7.00 (35 lbs/acre)	7.00 (35 lbs/acre)	–
Machine Hire-Sprayer	3.75	3.75	–
Crop Insurance	5.00	5.00	–
Fuel and Lube*	9.16	11.50	$ 5.31
Repairs & Maintenance*	4.24	5.22	4.84
Interest on Operating Expenses	1.49	.78	.61
Total Variable Cost (per acre)	$38.64	$39.65	$10.76

Assumptions

[1] price of nitrogen is 25¢ per lb. and of phosphate is 20¢ per lb.
[2] interest rate on operating expense is 6 percent and money is used for:
8 months-winter wheat
4 months-barley
12 months-fallow
[3] repair and maintenance costs exclude those associated with the combine
[4] * based on equipment usage in previous table

Other Deductible Expenses

Hired Labor (500 hrs × $5/hr)		$1,500
Building Insurance and Repairs		1,200
Liability Insurance		3,400
Utilities		2,000
Itemized Deductions:	Personal Interest Expenses	1,900
	Charitable Contributions	650
	Medical Expenses	600

so the assessed value is $61.37 per acre, while the amount for the buildings and equipment is based on the book value. To determine the property taxes to be paid, the assessed value is multiplied by the mill levy divided by 1000 and again by a given percentage depending on the asset involved. For agricultural land this percentage is 30 percent, 8.55 percent for buildings and improvements and 11 percent for all agricultural implements and equipment.

All elements necessary to calculate taxable income for the individual farmer have been stated except for those costs attributable to the combine. They are directly linked to the replacement decision and it is the owner's objective in making that decision to determine the replacement age which minimizes the present value of those costs incurred in obtaining a constant flow of services from each combine over his planning horizon. To determine that optimal interval between purchases, the following empirical model is used.

The Empirical Problem

Stages

Dynamic programming is the transformation of a large, multistage sequential decision process into a series of single-stage problems that can be solved one at a time. As is traditional in DP, the end of the planning horizon becomes the point of reference instead of the beginning with the stage of the decision process measured by the number of discrete time periods remaining in the firm's planning horizon. At each stage, a replacement decision must be made. Since the major factors that influence that decision occur on an annual basis, a year is an appropriate choice for the time interval between stages. Conceptually, an infinite number of stages is possible, but to an individual farmer, a finite planning horizon is more relevant. For such a person, his active farming days are limited to a period of approximately thirty years. This study sets the maximum length of the planning horizon at thirty stages or years.

States

The state variables must be defined so that the condition of the decision process at the beginning of a stage or time period is completely described. In his effort to minimize costs associated with his combine, the owner is interested in the variables that will affect current and future expenses. All the costs attributed to the combine and relevant to the replacement decision must be reflected through these state variables. Enough information must be contained in them so that the future behavior of the system can be predicted in response to the decisions made.

Age of the asset is an obvious determinant of machine cost. It is closely associated with wear and obsolescence and in turn affects both repairs and used price. The combine age also determines the amount of depreciation that can be expensed and the remaining loan balance to be paid. The exact impact of machine age will be discussed later, but in general terms, aging will increase the variable operating expenses while decreasing the ownership costs. Fifteen possible ages are assumed in the study but upon reaching its fifteenth year, the combine is presumed to come to the end of its operational life forcing replacement. Replacement must always be with a new machine.

Costs are also significantly influenced by the particular tax options attached to the asset. The time pattern of depreciation deductions and the presence of any special investment incentives alters the tax liability and in turn the replacement decision. Depreciation is an accounting procedure by which the purchase cost of an asset with an economic life of more than one year is prorated over its projected life. Instead of writing off the entire cost in one year, a certain amount is deducted annually as an expense. However, it is not an actual cash expense itself so charging depreciation actually increases cash available to the firm by reducing taxable income.

The cost recovery (depreciation) deductions for property placed in service after 1980 are calculated with ACRS, the accelerated cost recovery system. Farm equipment, such as a combine, are classified as 5-year property items under the present system and are depreciated as such over that time period. The deductions are calculated by multiplying the unadjusted basis or measure of investment in the property, which in this case will always be \$80,000, by the annual percentages given for 5-year property. The depreciation rates over the recovery period are 15%, 22% and 21% for the last three years.

Under ACRS, the owner may choose to use an alternate method of calculating the deductions. This method uses a recovery percentage based on the straight line method of depreciation and is used in place of the above percentages. For the 5-year class of property, there are three different alternative recovery periods; 5, 12 or 25 years. The owner is thus left with four depreciation schedules from which to choose.

The owner also has the choice of treating a certain part of the cost of the combine as an expense rather than as a capital expenditure. He must decide for each item of qualifying property whether to deduct, subject to the yearly limit, or capitalize and depreciate the property's cost. At the present time, the maximum amount that can be expensed is $7500 and is deductible in the year the property is placed in service. This study assumes that the owner elects to expense the allowable limit or none at all. The amount he chooses to deduct is subtracted from the cost of the property to determine the adjusted basis used in computing depreciation and investment tax credit.

Investment credit is another method the government uses to stimulate investment in the economy. It allows taxpayers to deduct a certain percentage of the purchase price of a depreciable asset directly from their tax liability in the year the asset is first purchased. The reduction is 10 percent of the eligible investment basis which in the case of new property will be the acquisition cost minus the amount the taxpayer has chosen to deduct as an expense. The maximum credit allowable is $25,000 plus 85 percent of the tax that is more than $25,000, but in this study the restriction is not relevant. If investment credit is taken, then the basis from which depreciation deductions are calculated must be reduced by 50 percent of the tax crecit. The owner may elect to take a percentage reduction in the regular investment credit rather than make the basis adjustment. However using 8 percent instead of 10 is not considered since in most situations farmers are advised to use the option permitting the maximum investment credit, even though this means losing some depreciation deductions. This leaves four possible investment incentives; regular investment tax credit, expensing, neither or both. Any of these options may be used with any of the four possible tax conditions or states which the combine may be under.

The advantages to any of the tax options depend upon the returns received from the crops grown. There is no benefit to be gained from depreciation deductions when taxable income is already low. In addition, the ability to purchase a new machine is restricted during periods of low returns. To account for the economic environment surrounding the firm, the price per bushel of winter wheat has been included as a state variable. Six price levels ranging from $1.50 to $6.50 have been designated with the increments between them being one dollar. For each possible price state, there are fifteen possible ages and for each combine age, there are sixteen different tax options. The result is a model which consists of 1440 (6×15×16) states.

Decision Alternatives

The decision made in one stage controls the state of the process in the following stage. Any replacement model includes two basic decision alternatives; keep or replace. In addition to determining the optimum replacement interval, this study also seeks to find the optimal tax option to be employed. The attainment of this goal forces the expansion of the replace decision to include all such tax options. The result is sixteen replace decisions plus the keep alternative which are summarized in Table 3.

Expected Immediate Returns

The optimal decision minimizes the total of the expected immediate costs and the minimum costs from the n-1 stage process starting in the new state. The costs are a function of the state variables and the decision alternative selected.

Age is a state variable which has a direct influence on the cash costs attributed to the combine. As the asset grows older, repairs costs are presumed to increase due to wear and tear through operation. The actual expenses for parts and labor to fix a down self-propelled

Table 3. Decision Alternatives Available in DP Replacement Model.

k	Decision Alternative: Options	Depreciation Method	Decision
1	—	5 year ACRS	REPLACE
2	Expensing		
3	Investment Tax Credit		
4	Expensing & ITC		
5	—	5 year straight line	
6	Expensing		
7	Investment Tax Credit		
8	Expensing % ITC		
9	—	12 year straight line	
10	Expensing		
11	Investment Tax Credit		
12	Expensing & ITC		
13	—	25 year straight line	
14	Expensing		
15	Investment Tax Credit		
16	Expensing & ITC		
17	Maintain Present Tax Conditions		KEEP

combine are calculated by the following equation given in the Agricultural Engineers Yearbook (1980);

$$F(X) = .076X^{2.122} \tag{2}$$

where F(X) is the accumulated repair costs as a percentage of purchase price and X is accumulated hours of usage divided by 1000. Since 1500 acres of grain are to be harvested each year at a rate of six acres per hour, costs are based on 250 hours of annual operation. Added to these values to obtain total repair costs is the opportunity cost of time associated with a breakdown. The Agricultural Engineers Yearbook estimates that there will be no down time during the first 900 acres of use but from then on one can expect to suffer one hour of repairs for every 70 acres through the rest of the combine's life. The cost associated with breakdown time is the marginal value product of this hour during harvest but it will vary from farm to farm depending upon such constraints as weather and labor. It is assumed here that opportunity costs are $20 per hour consisting of the custom hire rate for a similar combine and the manager's labor cost.

There is also an opportunity cost associated with a major breakdown which is an infrequent yet possible occurrence. The probability of such an event shown in Table 4 and Figure 2 is estimated based on the cumulative logistic probability function;

$$P = F(Z) = 1/1 + e^{-(\alpha + \beta X)} \tag{3}$$

where P represents the probability of a major breakdown given the age of the combine X. "The appeal of the logit model is that it transforms the problem of predicting probabilities within a (0, 1) interval to the problem of predicting the odds of an event occurring within the range of the entire real line" (Pindyck and Rubenfeld, pp. 248-249). Assuming there is a 1 percent chance of a major failure in the first year of use and a 50 percent chance by age nine, the logit probability model can be estimated in the following form $\ln(P/1 - P) = \alpha + \beta X)$ with the use of those two coordinates. The resulting parameters are $\alpha = -4.59512$ and $\beta = .510569$ and the model based on them is summarized in Table 4. While there is no factual data to support the assumptions, the results are intuitively acceptable. The conditional probabilities of a major breakdown occurring in a particular year given that one has not previously occurred are continually rising. The annual probabilities used are unconditional in the same way that the repair function of the Agricultural Engineers is. Since the chance of a major failure will drop after one has happened, the use of the conditional probabilities would mean the addition of another state variable describing the age of the asset when it occurred and/or the overhaul required.

The incremental annual probabilities are multiplied by the cost of employing a custom operator to finish harvest. The breakdown is equally likely to occur at any point during the harvest season so it is assumed that it will occur when half the crop is cut or 750 acres. Multiplying this value by the custom rate of $14 per acre provides the cost estimate of $10,500 for a major breakdown. The amortized cost of the combine for the half season the machine is not used is subtracted from the custom expense and an arbitrarily high pen-

Table 4. Probability of a Major Breakdown Occurring at Various Machine Ages.*

Age	Incremental Probability	Cumulative Probability
1	.0166	.0166
2	.0107	.0273
3	.0173	.0446
4	.0276	.0722
5	.0426	.1148
6	.0629	.1777
7	.0871	.2648
8	.1103	.3751
9	.1249	.5000
10	.1249	.6249
11	.1103	.7352
12	.0871	.8223
13	.0629	.8852
14	.0426	.9278
15	.0276	.9554

*Based on Equation 3.

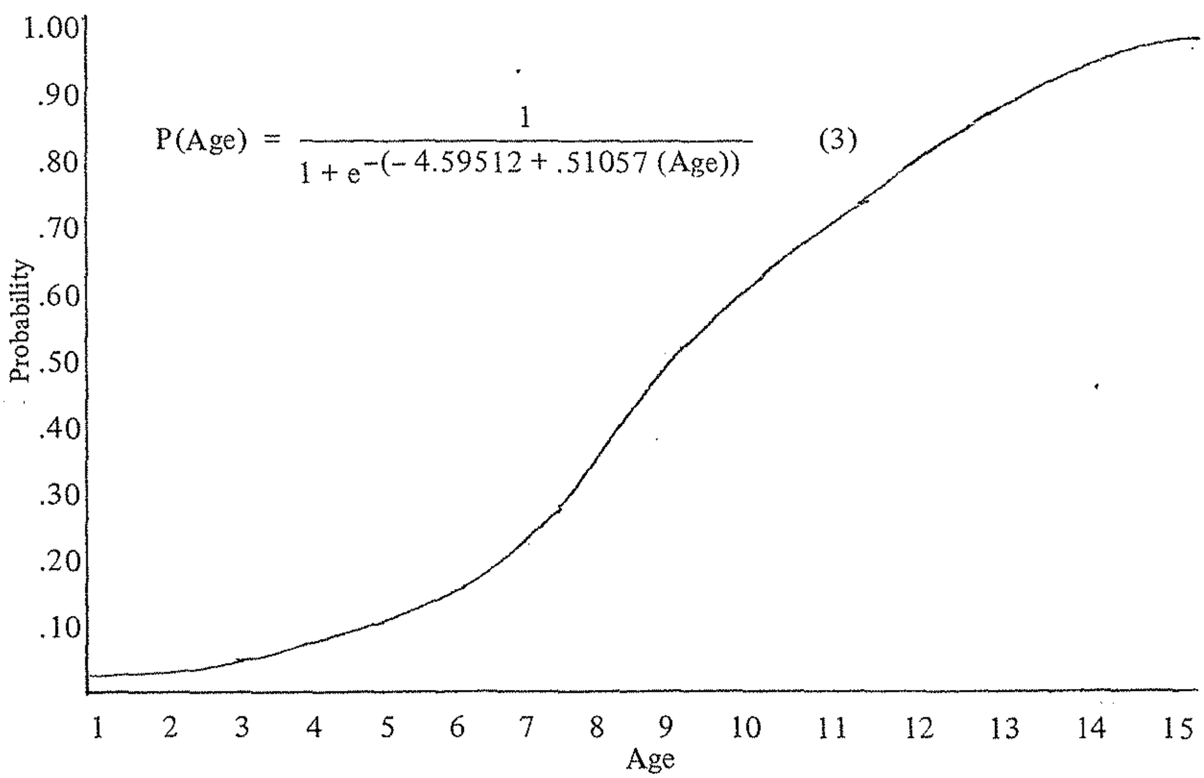


Figure 2. Probability of a major breakdown occurring at various machine ages.

alty value are also used to examine the effect of varying opportunity costs associated with a major breakdown.

Reid and Bradford's study showed the importance of the remaining market value forecast on optimal replacement decisions but their estimated used price equations were for tractors. To obtain a similar function for combines, time series data was gathered on present used prices for five combine makes up to six years old with comparable features to the assumed model (National Farm and Power Equipment Dealers Association). The market value for each age of the John Deere 7720, International 1460 Axial Flow, New Holland TRTM75, Massey Ferguson 550 and the Allis Chalmers N5 were converted to percentages of present new price for easy comparison and calculation. Since the market value declined at a decreasing rate with age, an exponential functional form was chosen. The function was converted to the inverse semi-log form by logging the dependent variable and leaving the independent variables in their natural form so that ordinary least squares could be used as the estimating technique. The resulting equation which has an adjusted coefficient of determination of .87 is;

$$RV = e^{4.4994 - .13023\,(\mathrm{Age})} \tag{4}$$

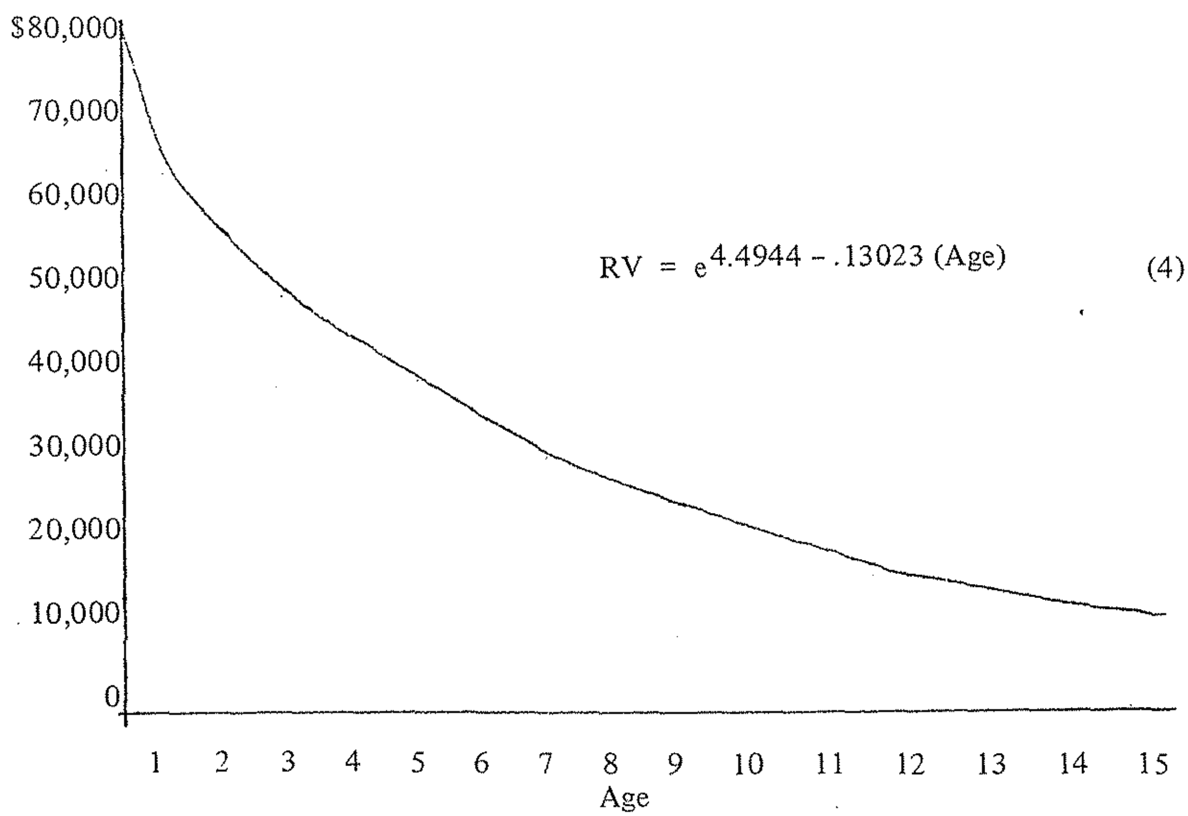
The age of the machine which is closely associated with wear and obsolence is the most obvious explanatory variable but others were tried without much success. Net farm income was used to account for expectations regarding returns to investments and opportunity costs of retention but the negative relationship was statistically insignificant. So was a dummy variable used to capture possible farmer preferences between combines of different design and make.

Property tax is determined in the same way as it is for other assets except that the assessed value is based on the combine's used price rather its the book value. The equation for remaining market value allows for a more accurate assessment of asset value and consequently of property taxes associated with the combine.

Table 5. Remaining Market Value of Combine at Various Ages.*

Age	Percentage of List Price	Remaining Value
0	100.00	$80,000.00
1	78.98	63,182.44
2	69.33	55,467.46
3	60.87	48,694.52
4	53.43	42,748.60
5	46.91	37,528.72
6	41.18	32,946.22
7	36.15	28,923.27
8	31.74	25,391.55
9	27.86	22,291.08
10	24.46	19.569.19
11	21.47	17,179.67
12	18.85	15,081.92
13	16.55	13,240.32
14	14.53	11,623.59
15	12.75	10,204.27

*Based on Equation 4.



$$RV = e^{4.4944 - .13023 (Age)} \qquad (4)$$

Figure 3. Remaining market value of combine at various ages.

The equation also determines the amount the owner will receive upon sale of his combine which is assumed to be sold privately rather than as a trade-in with a dealer. This allows him to receive cash on the sale and provides a consistent investment basis throughout the planning horizon. The selling price is determined in Equation 4 for the remaining market value which expresses used price as a real dollar percentage of the combine's original and present list price of $80,000. The percentage and thus the sale price will decline with asset age. However if there is any remaining debt on the combine, it must be paid upon the sale since the loan was acquired with the machine as collateral. The actual amount that the farmer receives is found by subtracting the existing loan balance from the sale price.

If the sale price is greater than the book value, an additional cost is incurred in the form of depreciation recapture. The gain (or loss) on the sale must be reported as an addition (or deduction) to ordinary income. If this gain is greater than the accumulated depreciation, 40 percent of the difference is added to income as capital gains income.

Investment tax credit is also subject to recapture in the same way as depreciation allowances are. If an asset is disposed of before the end of its estimated economic life, the investment credit is recomputed to reflect its actual life by recapturing a certain percentage of the credit. Multiplying the percentage by the original investment credit determines the amount of recapture which is a direct addition to the tax liability. Table 6 provides those percentages necessary for computing the recapture of investment credit. They are effective when the asset is disposed in a cash sale which is the case that is assumed to occur here. If instead, the combine was sold through an installment plan with payments extending beyond its original estimated economic life, the recapture could have been delayed.

The money received on the sale is used as a downpayment in the purchase of a new machine. Typical financing arrangements require that one-third of the new price be put down which in this study always is $26,400. If the used price on the sold combine is greater

Table 6. Percentages for Investment Credit Recapture.

Recovery Property Disposed of	Recovery Percentage for Other than 3-year Property
within 1 full year	100
between years 1 and 2	80
between years 2 and 3	60
between years 3 and 4	40
between years 4 and 5	20
after 5 full years	0

than this value, the difference is assumed to be placed in a savings account and earns interest which is added to income. However if the market price is less than the required downpayment, then money will have to be borrowed to meet lender stipulations and the resulting interest is deducted from income. The remaining loan balance on two-thirds of the new price requires equal principal payments spread over seven years. The interest expense is thus a declining function of age and can be calculated for each year there is a debt remaining on the combine by multiplying the loan level by the interest rate.

It has been assumed the owner's equity position is such that he has to borrow all the remaining funds necessary to acquire the combine. If the combine was a small capital item on the farm, its replacement would not affect gross receipts and the financing arrangements would be inconsequential. However, since the combine purchase represents a significant capital expense to the firm, the fixed costs are important in the analysis. This is true, unless the owner has a cash fund to completely pay for the asset. With the assumption of a perfect capital market, this ability to completely generate the money internally means that the cost of borrowing, should he decide to do so, is offset by the interest earned on his savings account. The effects of financing are negated as a result.

Without sufficient equity to cover the required cost, the interest paid on borrowed funds is greater than the interest earned on savings resulting in a greater amount of tax deductions. By influencing the marginal tax rate, the other parameters in the decision criterion are also affected. Provided that the owner is not able to generate all the funds internally, the financing arrangements must be included in the analysis due to its impact on marginal tax rates and the after tax discount rate. The interest paid is the catalyst for the effect and it is a function of the amount borrowed. Thus the study could be extended to determine optimal financing arrangements under various equity positions. That is beyond the scope of this research effort so it is assumed here that he has to borrow all funds necessary to purchase a new combine except for those provided by the sale of the current one.

The final element comprising immediate cash costs are income taxes. The preceding cost adjustments associated with the combine are influenced by the decision alternative chosen and the state variables describing asset age and tax conditions. The final state variable, the price of winter wheat, allows for the computation of taxable income and thus both federal and state taxes based on the 1983 tax tables. It also permits the calculation of net farm profit on which self employment tax is paid on at a rate of 9.35 percent. It is payable on the first $35,700 of farm profit.

Each of the components of the expected immediate costs occur at different points during the year and thus must be discounted accordingly. If the decision is to replace, a downpayment is required immediately so this value is not discounted. The other expenses are incurred after the January 1 decision period. Repairs are made six months later during harvest, property tax and loan repayments are made at year end and income taxes are paid in April of the following year. The discussion is summarized with the following equation;

$$q_i^k(n) = \text{Downpayment} + (\text{Repair} + \text{Brkdn}) \times 1/(1+r)^{.5}$$
$$+ (\text{Paymnt} + \text{Proptax}) \times 1/(1+r) + (\text{FT} + \text{ST} + \text{SET}) \times (1/(1+r))^{4/3}$$

where,

$q_i^k(n)$ = the expected immediate costs given the ith state, kth decision alternative, and nth stage of process

Repair = costs of parts and labor involved in repairs

Brkdn = opportunity cost of a major breakdown times the probability of such an event

Paymnt = repayment of loan

Proptax = property tax

ST = state income tax

SET = self employment tax

r = rate of interest.

Discount Factor

It is assumed that the owner faces a perfect capital market in which the lending and borrowing rate are in equilibrium. If this were not the case, the model would direct the owner to either borrow all his funds or else none at all. As Perrin noted, the appropriate discount rate in such a market is represented by the cost of capital since it is the rate at which the owner has the opportunity to trade present for future dollars. The interest rate of six percent chosen as the cost of capital contains components to reflect time preference and a risk premium but not inflation which is assumed out of the model. The real after-tax discount factor used to put the expected costs from each n-stage decision process in present dollars is $1/1 + (1 - t)r$ where t is the marginal tax rate and r is the rate of interest. Income taxes are determined in the computational process of the expected immediate costs and thus the marginal tax rates are readily available.

Transitional Probabilities

The replacement problem is formulated as a stochastic decision process, the state of which is controlled at any stage by the transition probability density function. The state transitions for age and tax conditions are deterministic so the uncertainty is accounted for solely in the stochastic nature of price.

The conditional transition probabilities were calculated using the following annual price prediction equation for winter wheat in which current price is a function of last year's price;

$$P_t = \underset{(1.076)}{1.602} + \underset{(.228)}{.643}\,(P_{t-1}) + u_t \tag{5}$$

where P is the price of winter wheat and u is the disturbance term. The adjusted coefficient of determination is .6328 and the Durbin Watson statistic is 1.148. Montana winter wheat prices for the past 17 years were converted into present day dollars using the index of prices received by farmers.[7] A dummy variable was used to account for the unusual events in 1973 that affected crop prices. The resulting parameter estimates were taken as known parameters and the disturbance term u was assumed normally distributed with mean zero and variance equal to the square of the standard error of the estimate of the regression equation which as 1.125. The transitional probabilities were then calculated using the following standardized normal variate;

$$Z = \frac{P_{t+1} - u}{@}$$

where,

Z = standard normal variate

u = estimated mean $1.602 + .643P_t$

$@$ = estimated standard error 1.125

P_{t+1} = price level in next time period

The price level states as defined earlier from \$1.50 to \$6.50 are actually midpoints of the dollar interval surrounding them except for the lower and upper bounds which represent

[7] Index obtained from Prices Received by Farmers, United States of Agricultural, Statistical Reporting Service.

the price level below \$2.00 and above \$6.00. The probabilities of price reaching the dollar interval beyond these bounds is very small so they were added to their respective boundary intervals.

The transitional probabilities in the table below are constant throughout the firm's planning horizon. Without inflation considered in the model, the same relationship between P_t and P_{t+1} that existed for the past 17 years is assumed to continue in the next 30. As a result, the computed distribution provides the same probability that next year's price will be a certain level given the present price whether the firm is in its first or last year of operation.

Table 7. Distribution of Random Price Levels.

		Prices in j-th State					
		\$1.50	\$2.50	\$3.50	\$4.50	\$5.50	\$6.50
	\$1.50	.4771	.3200	.1602	.0381	.0043	.0003
Prices in	\$2.50	.2647	.3379	.2721	.1045	.0191	.0017
the i-th	\$3.50	.1150	.2627	.3405	.2106	.0620	.0092
state	\$4.50	.0382	.1504	.3137	.3122	.1482	.0373
	\$5.50	.0096	.0633	.2129	.3409	.2605	.1128
	\$6.50	.0019	.0196	.1063	.2742	.3372	.2609

More information could be provided to the decision maker if the price prediction equation included an additional lagged price variable such as $P_t = \alpha_1 + \alpha_2 P_{t-1} + \alpha_3 P_{t-2} + u_t$. Price in the next period would be conditional on current price and the level of prices overall, however this would involve another state variable. It was felt that the improvement in realism by the inclusion of another state variable would not be sufficient to justify the additional complexity and computational cost.

Terminal Values

The terminal value for any state is the used price minus the remaining loan balance and any investment credit recapture. The latter two deductions are irrelevant after seven years of age so the terminal value is represented after that time by the remaining market value.

CHAPTER 4

RESULTS

Results

Optimal policies and the expected net present value of costs are obtained by solving the recursion relation for all relevant stages and states. The solution of the dynamic programming model specifies the age at which to replace an existing combine and the tax options to be used for the new combine. This decision is dependent upon the state of the process including price. Since price changes are random, it is not possible to determine at the beginning of a year what decisions will be made in subsequent years. With the probability distribution for price changes assumed to be known, the expected costs can be calculated which are shown with each policy. They include repair costs, opportunity cost of breakdown time, downpayment, loan repayment, property tax and income taxes but do not consider costs incurred before the decision period. These expected costs are minimized in the model subject to the condition that optimal decisions will be made in the following stages.

Results are presented for planning horizons of thirty years in length. By stage twenty, the optimal policy had become invariant to the length of the planning horizon. It had converged into one which was a function of state only. A listing of the output including the optimal policy and expected present value of costs for each state are shown in the following tables. Each interval of sixteen signifies one year of age and within that bracket are the states indicating the tax options used. Every four states represents a depreciation schedule with the accelerated method first and then sequentially the five, twelve and twenty-five straight line deduction systems. For each depreciation schedule, there are four possible investment options. The first option involves neither of the incentives with just straight depreciation deductions, the expensing option second, the investment tax credit third and the fourth option represents the use of both incentives together. The decision alternatives regarding replacement and subsequent tax conditions are numbered in a systematic order comparable to the states within each asset year and have been summarized earlier. The last decision policy, seventeen, is to keep the asset for another time period under the present tax conditions.

The optimal policies are presented for four different price levels. Both the \$1.50 and \$2.50 prices are below the break even point for the representative farm if the cost adjustments associated with the combine are included. Negative returns are the consequence and in part explain the similar policies for almost all states within each price range. The same effect was produced in the two highest price levels so they have also been grouped together in the presentation to reduce the volume of output.

In the lowest price levels, the optimal decision rule instructs the farmer to keep his new asset for the first three years of its operation. The same holds true for the next two years, except if the combine is being depreciated under ACRS or 5 year straight line without the investment credit option. In these four cases, the combine should be replaced and depreciated under 25 year straight line. The same option is suggested for all states in years six through twelve unless the present asset is already being depreciated with any of the alternatives under the 25 year straight line method. The decision rule is to replace with plain 25 year straight line in the final three years of the asset's life regardless of the capital recovery method.

The results indicate that when net returns are negative, there is no value to a high level of depreciation deductions and the presence of investment incentives. However, such periods will not last for a prolonged length of time and the owner will want these expenses

Table 8. Optimal Policy and Total Expected Costs in Stage 30 for a Price of $1.50.

AGE	STATE	POLICY	RETURNS
	1	13	-.37350052E+06
	2	13	-.37350052E+06
	3	17	-.37553062E+06
	4	17	-.37648916E+06
	5	17	-.37289625E+06
	6	13	-.37350052E+06
	7	17	-.37527694E+06
	8	17	-.37582391E+06
	9	17	-.36823778E+06
1	10	17	-.37026892E+06
	11	17	-.36939955E+06
	12	17	-.37120532E+06
	13	17	-.36340887E+06
	14	17	-.36528451E+06
	15	17	-.36511614E+06
	16	17	-.36661695E+06
	17	13	-.37359264E+06
	18	13	-.37359264E+06
	19	17	-.37625860E+06
	20	17	-.37678616E+06
	21	17	-.37326449E+06
	22	13	-.37359264E+06
	23	17	-.37591926E+06
	24	17	-.37619494E+06
2	25	17	-.36818561E+06
	26	17	-.36997047E+06
	27	17	-.36893180E+06
	28	17	-.37045029E+06
	29	17	-.36266681E+06
	30	17	-.36421169E+06
	31	17	-.36392761E+06
	32	17	-.36512530E+06
	33	13	-.37274273E+06
	34	13	-.37274273E+06
	35	15	-.37589750E+06
	36	15	-.37577014E+06
	37	13	-.37274273E+06
	38	13	-.37274273E+06
	39	17	-.37577908E+06
	40	15	-.37577014E+06
3	41	17	-.36804321E+06
	42	17	-.36954020E+06
	43	17	-.36849084E+06
	44	17	-.36970667E+06
	45	17	-.36229130E+06
	46	17	-.36333889E+06
	47	17	-.36298927E+06
	48	17	-.36381232E+06
	49	13	-.37106578E+06
	50	13	-.37106578E+06
	51	15	-.37376773E+06
	52	15	-.37368282E+06
	53	13	-.37106578E+06
	54	13	-.37106578E+06
	55	15	-.37376773E+06
4	56	15	-.37368282E+06
	57	17	-.36776373E+06
	58	17	-.36881884E+06
	59	17	-.36792195E+06
	60	17	-.36883045E+06
	61	17	-.36195747E+06
	62	17	-.36256302E+06
	63	17	-.36216377E+06
	64	17	-.36272612E+06
	65	13	-.36866280E+06
	66	13	-.36866280E+06
	67	13	-.37062507E+06
	68	13	-.37044110E+06
	69	13	-.36866280E+06
	70	13	-.36866280E+06
5	71	13	-.37062507E+06
	72	13	-.37044110E+06
	73	17	-.36721203E+06
	74	17	-.36768275E+06
	75	17	-.36714710E+06
	76	17	-.36763766E+06
	77	17	-.36174672E+06
	78	17	-.36225472E+06
	79	17	-.36162787E+06
	80	17	-.36214449E+06
	81	13	-.36562245E+06
	82	13	-.36562245E+06
	83	13	-.36562245E+05
	84	13	-.36562245E+06
	85	13	-.36562245E+06
	86	13	-.36562245E+06
	87	13	-.36562245E+06
	88	13	-.36562245E+06
	89	13	-.36562245E+06
6	90	13	-.36562245E+06
	91	13	-.36562245E+06
	92	13	-.36562245E+06
	93	17	-.36155360E+06
	94	17	-.36206417E+06
	95	17	-.36146081E+06
	96	17	-.36193922E+06
	97	13	-.36430581E+06
	98	13	-.36430531E+06
	99	13	-.36430581E+06
	100	13	-.36430581E+06
	101	13	-.36430581E+06
	102	13	-.36430581E+06
	103	13	-.36430581E+05
	104	13	-.36430581E+06
	105	13	-.36430581E+06
7	106	13	-.36430581E+06
	107	13	-.36430581E+06
	108	13	-.36430581E+06
	109	17	-.36058677E+05
	110	17	-.36105996E+06
	111	17	-.36047261E+06
	112	17	-.36092664E+06
	113	13	-.36555427E+06
	114	13	-.36555427E+06
	115	13	-.36555427E+06
	116	13	-.36555427E+06
	117	13	-.36555427E+06
	118	13	-.36555427E+06
	119	13	-.36555427E+06
	120	13	-.36555427E+06
8	121	13	-.36555427E+06
	122	13	-.36555427E+06
	123	13	-.36555427E+06
	124	13	-.36555427E+05
	125	17	-.35830195E+06
	126	17	-.35874489E+06
	127	17	-.35815990E+06
	128	17	-.35860037E+06
	129	13	-.36865473E+06
	130	13	-.36865473E+06
	131	13	-.36865473E+06
	132	13	-.36865473E+06
	133	13	-.36865473E+06
	134	13	-.36865473E+05
	135	13	-.36865473E+06
9	136	13	-.36565473E+06
	137	13	-.36865473E+06
	138	13	-.36865473E+06
	139	13	-.36865473E+06
	140	13	-.36865473E+06
	141	17	-.36265157E+06
	142	17	-.36306237E+06
	143	17	-.36247277E+06
	144	17	-.36290043E+06
	145	13	-.37137662E+06
	146	13	-.37137662E+06
	147	13	-.37137662E+06
	148	13	-.37137662E+06
	149	13	-.37137662E+06
	150	13	-.37137662E+06
	151	13	-.37137662E+06
10	152	13	-.37137662E+06
	153	13	-.37137662E+06
	154	13	-.37137662E+06
	155	13	-.37137662E+06
	156	13	-.37137662E+06
	157	17	-.36659188E+06
	158	17	-.36699203E+06
	159	17	-.36639973E+06
	160	17	-.36681629E+06
	161	13	-.37376616E+06
	162	13	-.37376616E+06
	163	13	-.37376616E+06
	164	13	-.37376616E+06
	165	13	-.37376616E+06
	166	13	-.37376616E+06
	167	13	-.37376616E+06
	168	13	-.37376616E+06
	169	13	-.37376616E+06
11	170	13	-.37376616E+06
	171	13	-.37376616E+06
	172	13	-.37376616E+06
	173	17	-.37022001E+06
	174	17	-.37065282E+06
	175	17	-.37007227E+06
	176	17	-.37047642E+06
	177	13	-.37586389E+06
	178	13	-.37586389E+06
	179	13	-.37586389E+06
	180	13	-.37586389E+06
	181	13	-.37586389E+06
	182	13	-.37586389E+06
	183	13	-.37586389E+06
	184	13	-.37586389E+06
12	185	13	-.37586389E+06
	186	13	-.37586389E+06
	187	13	-.37586389E+06
	188	13	-.37586389E+06
	189	17	-.37363970E+06
	190	17	-.37410448E+06
	191	17	-.37353642E+06
	192	17	-.37394447E+06
	193	13	-.37770549E+06
	194	13	-.37770549E+06
	195	13	-.37770549E+06
	196	13	-.37770549E+06
	197	13	-.37770549E+06
	198	13	-.37770549E+06
	199	13	-.37770549E+06
	200	13	-.37770549E+06
13	201	13	-.37770549E+06
	202	13	-.37770549E+06
	203	13	-.37770549E+06
	204	13	-.37770549E+06
	205	17	-.37678679E+06
	206	17	-.37721432E+06
	207	17	-.37671470E+06
	208	17	-.37710989E+06
	209	13	-.37932223E+06
	210	13	-.37932223E+06
	211	13	-.37932223E+06
	212	13	-.37932223E+06
	213	13	-.37932223E+06
	214	13	-.37932223E+06
	215	13	-.37932223E+06
14	216	13	-.37932223E+06
	217	13	-.37932223E+06
	218	13	-.37932223E+06
	219	13	-.37932223E+06
	220	13	-.37932223E+06
	221	13	-.37932223E+06
	222	13	-.37932223E+06
	223	13	-.37932223E+06
	224	13	-.37932223E+06
	225	13	-.38074155E+06
	226	13	-.38074155E+06
	227	13	-.38074155E+06
	228	13	-.38074155E+06
	229	13	-.38074155E+06
	230	13	-.38074155E+06
15	231	13	-.38074155E+06
	232	13	-.38074155E+06
	233	13	-.33074155E+06
	234	13	-.38074155E+06
	235	13	-.38074155E+06
	236	13	-.38074155E+06
	237	13	-.38074155E+06
	238	13	-.38074155E+06
	239	13	-.38074155E+06
	240	13	-.38074155E+06

available when positive income returns. This rise to the highest levels will not occur quickly according to the probability distribution of price changes so a rapid depreciation schedule may be wasted. This explains the long recovery period suggested. Neither of the investment incentives are used because they cannot reduce taxable income further in the present and only serve to reduce the investment basis on which future depreciation deducations are calculated. The decision rule to replace through the twelfth year with the 25 year straight line schedule except if the asset is being depreciated with any of the four options under that method, indicates the value of maintaining the deductions for future periods. However, once the asset reaches thirteen years of age, the repair costs become excessive and force replacement regardless of the depreciation schedule. It should be noted that the replace decision is delayed until after the fifth year in order to avoid investment credit recapture. Even if returns are negative and income taxes zero, recapture represents a direct addition to the tax liability and should be avoided especially in these periods.

The possibility of investment tax credit recapture explains the decision to keep the combine for its first five years in the \$3.50 price range. If the asset is six or seven years old with a recovery period of five years, the decision is to replace with ACRS and all the incentives. The policy is to replace with that same depreciation schedule but with just the investment credit option if the asset is under the 12 year straight line method. If it is under the 25 year schedule, then the rule is to replace with the identical depreciation system. For an asset eight and nine years of age, the same decision rule holds if the present combine is depreciated under ACRS or five year straight line. The decision changes to keep for the other two depreciation methods. Upon reaching age ten and eleven, the same optimal policies exist except that only the investment credit option and not expensing is used under ACRS. After age twelve, this rule holds for all depreciation schedules except for the longest recovery period. If the asset is under the 25 year straight line method, then one

Table 9. Optimal Policy and Total Expected Costs in Stage 30 for a Price of $3.50.

AGE	STATE	POLICY	RETURNS
	481	17	-.35493490E+06
	482	17	-.35648239E+06
	483	17	-.35547723E+06
	484	17	-.35672273E+06
	485	17	-.35455079E+06
	486	17	-.35618265E+06
	487	17	-.35527741E+06
	488	17	-.35661108E+06
1	489	17	-.35423235E+06
	490	17	-.35604475E+06
	491	17	-.35690589E+06
	492	17	-.35838059E+06
	493	17	-.35373646E+06
	494	17	-.35559658E+06
	495	17	-.35650103E+06
	496	17	-.35808041E+06
	497	17	-.35695349E+06
	498	17	-.35822339E+06
	499	17	-.35732977E+06
	500	17	-.35843762E+06
	501	17	-.35607658E+06
	502	17	-.35743506E+06
	503	17	-.35646305E+06
2	504	17	-.35771712E+06
	505	17	-.35423524E+06
	506	17	-.35582395E+06
	507	17	-.35609345E+06
	508	17	-.35749090E+06
	509	17	-.35313080E+06
	510	17	-.35483058E+06
	511	17	-.35498099E+06
	512	17	-.35650011E+06
	513	17	-.35871160E+06
	514	17	-.35964775E+06
	515	17	-.35881245E+06
	516	17	-.35965912E+06
	517	17	-.35749686E+06
	518	17	-.35856559E+06
3	519	17	-.35766055E+06
	520	17	-.35863545E+06
	521	17	-.35411527E+06
	522	17	-.35546257E+06
	523	17	-.35514976E+06
	524	17	-.35637394E+06
	525	17	-.35251889E+06
	526	17	-.35406458E+06
	527	17	-.35353930E+06
	528	17	-.35500580E+06
	529	17	-.36065561E+06
	530	17	-.36115618E+06
	531	17	-.36017315E+06
	532	17	-.36067371E+06
	533	17	-.35904591E+06
4	534	17	-.35972694E+06
	535	17	-.35865135E+06
	536	17	-.35931927E+06
	537	17	-.35377267E+06
	538	17	-.35486511E+06
	539	17	-.35413100E+06
	540	17	-.35516252E+06
	541	17	-.35172726E+06
	542	17	-.35315159E+06
	543	17	-.35210273E+06
	544	17	-.35348916E+06
	545	17	-.36383771E+06
	546	17	-.36383791E+06
	547	17	-.36234295E+06
	548	17	-.36284295E+06
	549	17	-.36100430E+06
5	550	17	-.36123967E+06
	551	17	-.36016124E+06
	552	17	-.36043071E+06
	553	17	-.35321366E+06
	554	17	-.35400730E+06
	555	17	-.35311166E+06
	556	17	-.35338792E+06
	557	17	-.35069461E+06
	558	17	-.35197318E+06
	559	17	-.35066784E+06
	560	17	-.35190383E+06
	561	4	-.35986799E+06
	562	4	-.35986799E+06
	563	4	-.35843139E+06
	564	4	-.35843139E+06
	565	4	-.35986799E+06
	566	4	-.35986799E+06
	567	4	-.35843139E+06
	568	4	-.35843139E+06
	569	3	-.35261826E+06
6	570	3	-.35295521E+06
	571	3	-.35247787E+06
	572	3	-.35279953E+06
	573	13	-.34894337E+06
	574	13	-.34994802E+06
	575	13	-.34894337E+06
	576	13	-.34994802E+06
	577	4	-.35706837E+06
	578	4	-.35706837E+06
	579	4	-.35576460E+06
	580	4	-.35576460E+06
	581	4	-.35706837E+06
	582	4	-.35706837E+06
	583	4	-.35576460E+06
	584	4	-.35576460E+06
7	585	3	-.35155532E+06
	586	3	-.35184716E+06
	587	3	-.35137277E+06
	588	3	-.35166319E+06
	589	13	-.34753574E+06
	590	13	-.34846686E+06
	591	13	-.34753574E+06
	592	13	-.34846686E+06
	593	4	-.35695170E+06
	594	4	-.35695170E+06
	595	4	-.35565078E+06
	596	4	-.35565078E+06
	597	4	-.35695170E+06
	598	4	-.35695170E+06
	599	4	-.35565078E+06
8	600	4	-.35565078E+06
	601	17	-.35174108E+06
	602	17	-.35241182E+06
	603	17	-.35142141E+06
	604	17	-.35210997E+06
	605	17	-.34696059E+06
	606	17	-.34809092E+06
	607	17	-.34686621E+06
	608	17	-.34789950E+06
	609	4	-.35885505E+06
	610	4	-.35885505E+06
	611	4	-.35832705E+06
	612	4	-.35832705E+06
	613	4	-.35885505E+06
	614	4	-.35885505E+06
9	615	4	-.35832705E+06
	616	4	-.35832705E+06
	617	17	-.35550861E+06
	618	17	-.35606360E+06
	619	17	-.35517262E+06
	620	17	-.35571163E+06
	621	17	-.35051030E+06
	622	17	-.35156671E+06
	623	17	-.35039543E+06
	624	17	-.35134231E+06
	625	4	-.36110431E+06
	626	4	-.36110431E+06
	627	3	-.36067382E+06
	628	3	-.36067382E+06
	629	4	-.36110431E+06
	630	4	-.36110431E+06
10	631	3	-.36067382E+06
	632	3	-.36067382E+06
	633	17	-.35884329E+06
	634	17	-.35927205E+06
	635	17	-.35845600E+06
	636	17	-.35887107E+06
	637	17	-.35357624E+06
	638	17	-.35455531E+06
	639	17	-.35343597E+06
	640	17	-.35434805E+06
	641	3	-.36319885E+06
	642	3	-.36319885E+06
	643	3	-.36281175E+06
	644	3	-.36281175E+06
	645	3	-.36319885E+06
	646	3	-.36319885E+06
	647	3	-.36281175E+06
	648	3	-.36281175E+06
	649	17	-.36168093E+06
11	650	17	-.36214675E+06
	651	17	-.36146762E+06
	652	17	-.36172258E+06
	653	17	-.35633063E+06
	654	17	-.35721239E+06
	655	17	-.35614320E+06
	656	17	-.35699913E+06
	657	3	-.36506598E+06
	658	3	-.36506598E+06
	659	3	-.36468862E+06
	660	3	-.36468862E+06
	661	3	-.36506598E+06
	662	3	-.36506598E+06
	663	3	-.36468862E+06
	664	3	-.36468862E+06
12	665	3	-.36475126E+06
	666	3	-.36478075E+06
	667	3	-.36438964E+06
	668	3	-.36441914E+06
	669	17	-.35885982E+06
	670	17	-.35964434E+06
	671	17	-.35863959E+06
	672	17	-.35942270E+06
	673	3	-.36671367E+06
	674	3	-.36671367E+06
	675	3	-.36633630E+06
	676	3	-.36633630E+06
	677	3	-.36671367E+06
	678	3	-.36671367E+06
	679	3	-.36633630E+06
13	680	3	-.36633630E+06
	681	3	-.36671367E+06
	682	3	-.36671367E+06
	683	3	-.36633650E+06
	684	3	-.36633630E+06
	685	17	-.36118779E+06
	686	17	-.36190432E+06
	687	17	-.36102066E+06
	688	17	-.36171637E+06
	689	3	-.36816017E+06
	690	3	-.36816017E+06
	691	3	-.36778280E+06
	692	3	-.36778230E+06
	693	3	-.36816017E+06
	694	3	-.36816017E+06
	695	3	-.36778280E+06
14	696	3	-.36778280E+06
	697	3	-.36816017E+06
	698	3	-.36816017E+06
	699	3	-.36778280E+06
	700	3	-.36778280E+06
	701	13	-.36321520E+06
	702	13	-.36385843E+06
	703	17	-.36319416E+06
	704	17	-.36372053E+06
	705	3	-.36943005E+06
	706	3	-.36943005E+06
	707	3	-.36905269E+06
	708	3	-.36905269E+06
	709	3	-.36943005E+06
	710	3	-.36943005E+06
15	711	3	-.36905267E+06
	712	3	-.36905269E+06
	713	3	-.36943005E+06
	714	3	-.36943005E+06
	715	3	-.36905269E+06
	716	3	-.36905269E+06
	717	13	-.36494030E+06
	718	13	-.36556367E+06
	719	13	-.36494030E+06
	720	13	-.36556367E+06

should keep the combine until age thirteen and after that replace with an identical depreciation schedule.

The $3.50 price level puts the farmer in a middle income bracket with the ability to reduce his net farm income well below the maximum level on which he must pay self employment tax. For assets between age six and ten that are depreciated under the two methods with a five year recovery period, there are no more deductions allowable even though there is still a high market value attached. The impetus to replace is present but the owner should depreciate as quickly as possible as well using the expensing option in order to reduce depreciation recapture and thus self employment tax. Beyond this age, recapture is lowered as used price falls and so the ability to reduce taxable income in the year of purchase does not offset the reduction in future depreciation deductions and in investment tax credit. Since the book and market value do not have this large divergence in the longer recovery period, the desire for immediate deductions is not as great and so only the investment credit option is used in the replace decision.

The decision rule in the $4.50 price range is to keep the present asset for its first five years of operation if it is depreciated under the two methods with a recovery period of that length. With the two other depreciation schedules, the policy suggests to replace the asset in age three with the accelerated system and the investment tax credit option. Beyond age two, the recapture in investment credit and acquisition cost is offset by the higher deduction levels, the negative depreciation recapture and the new tax credit. The same policy holds for the other depreciation schedules after age five. The expensing option is not a viable alternative since net farm profit cannot be significantly reduced below the maximum amount that self employment tax is payable on. It only acts to reduce investment tax credit and depreciation deductions.

The owner is continually seeking to reduce taxable income in these high brackets and this is further emphasized in the $5.50 and $6.50 price levels. The results are very similar

Table 10. Optimal Policy and Total Expected Costs in Stage 30 for a Price of $4.50.

AGE	STATE	POLICY	RETURNS	AGE	STATE	POLICY	RETURNS	AGE	STATE	POLICY	RETURNS
	721	4	-.46117381E+06		801	3	-.47241587E+06		881	3	-.47245030E+06
	722	17	-.46422918E+06		802	3	-.47241587E+06		882	3	-.47245030E+06
	723	17	-.46301880E+06		803	3	-.47058565E+06		883	3	-.47071899E+06
	724	17	-.46563388E+06		804	3	-.47058565E+06		884	3	-.47071899E+06
	725	3	-.45821673E+06		805	3	-.47241587E+06		885	3	-.47245030E+06
	726	4	-.46282432E+06		806	3	-.47241587E+06		886	3	-.47245030E+06
	727	17	-.46342084E+06		807	3	-.47058565E+06		887	3	-.47071899E+06
	728	17	-.46556639E+06		808	3	-.47058565E+06		888	3	-.47071899E+06
	729	4	-.45487146E+06		809	3	-.44958894E+06		889	3	-.46812207E+06
1	730	3	-.45973113E+06	6	810	3	-.45202672E+06	11	890	3	-.46852780E+06
	731	17	-.46275168E+06		811	4	-.44793923E+06		891	3	-.46660713E+06
	732	17	-.46614487E+06		812	3	-.45097642E+06		892	3	-.46701291E+06
	733	4	-.45393491E+06		813	15	-.43932645E+06		893	15	-.44745709E+06
	734	3	-.45878670E+06		814	3	-.44097939E+06		894	15	-.44875022E+06
	735	17	-.46071377E+06		815	15	-.43798634E+06		895	15	-.44600377E+06
	736	17	-.46372764E+06		816	3	[illegible]		896	15	-.44808617E+06
	737	17	-.46502504E+06		817	3	-.46935734E+06		897	3	-.47358560E+06
	738	17	-.46712848E+06		818	3	-.46935734E+06		898	3	-.47358560E+06
	739	17	-.46563996E+06		819	3	-.46752712E+06		899	3	-.47185430E+06
	740	17	-.46768653E+06		820	3	-.46752712E+06		900	3	-.47185430E+06
	741	17	-.46336592E+06		821	3	-.46935734E+06		901	3	-.47358560E+06
	742	17	-.46556501E+06		822	3	-.46935734E+06		902	3	-.47358560E+06
	743	17	-.46507905E+06		823	3	-.46752712E+06		903	3	-.47185430E+06
	744	17	-.46679693E+06		824	3	-.46752712E+06		904	3	-.47185430E+06
2	745	4	-.45439461E+06	7	825	3	-.44994387E+06	12	905	3	-.47214170E+06
	746	3	-.45881531E+06		826	4	-.45256321E+06		906	3	-.47227705E+06
	747	3	-.46015273E+06		827	3	-.44864340E+06		907	3	-.47048259E+06
	748	17	-.46427436E+06		828	3	-.45070637E+06		908	3	-.47061795E+06
	749	3	-.45093276E+06		829	15	-.43669816E+06		909	15	-.44969892E+06
	750	4	-.45539265E+06		830	3	-.43952414E+06		910	3	-.45109707E+06
	751	4	-.45702091E+06		831	15	-.43655098E+06		911	15	-.44822298E+06
	752	17	-.46043277E+06		832	15	-.43905971E+06		912	15	-.45027082E+06
	753	17	-.46850375E+06		833	4	-.46835938E+06		913	3	-.47458228E+06
	754	17	-.47004689E+06		834	4	-.46835938E+06		914	3	-.47458228E+06
	755	17	-.46835891E+06		835	4	-.46679038E+06		915	3	-.47285098E+06
	756	17	-.46974159E+06		836	4	-.46679038E+06		916	3	-.47285098E+06
	757	17	-.46643356E+06		837	4	-.46835938E+06		917	3	-.47458228E+06
	758	17	-.46809415E+06		838	4	-.46835938E+06		918	3	-.47458228E+06
	759	17	-.46697592E+06		839	4	-.46679038E+06		919	3	-.47285098E+06
3	760	17	-.46820520E+06	8	840	4	-.46679038E+06	13	920	3	-.47285093E+06
	761	4	-.45350957E+06		841	4	-.45354384E+06		921	3	-.47458228E+06
	762	3	-.45754980E+06		842	4	-.45523184E+06		922	3	-.47458228E+06
	763	3	-.45737791E+06		843	3	-.45148702E+06		923	3	-.47285098E+06
	764	3	-.46165777E+06		844	4	-.45387206E+06		924	3	-.47285098E+06
	765	3	-.44810148E+06		845	15	-.43787967E+06		925	15	-.45196839E+06
	766	3	-.45166426E+06		846	15	-.44045221E+06		926	15	-.45360835E+06
	767	3	-.45158964E+06		847	15	-.43770987E+06		927	15	-.45143931E+06
	768	3	-.45609431E+06		848	15	-.43992414E+06		928	15	-.45252937E+06
	769	17	-.47256612E+06		849	4	-.47003736E+06		929	3	-.47545727E+06
	770	17	-.47324784E+06		850	4	-.47003736E+06		930	3	-.47545727E+06
	771	17	-.47164293E+06		851	3	-.46795267E+06		931	3	-.47372595E+06
	772	17	-.47228371E+06		852	3	-.46795267E+06		932	3	-.47372595E+06
	773	17	-.47008380E+06		853	4	-.47003736E+06		933	3	-.47545727E+06
	774	17	-.47098485E+06		854	4	-.47003736E+06		934	3	-.47545727E+06
	775	17	-.46926937E+06		855	3	-.46795267E+06		935	3	-.47372595E+06
4	776	17	-.47011830E+06	9	856	3	-.46795267E+06	14	936	3	-.47372595E+06
	777	4	-.45225522E+06		857	3	-.45935741E+06		937	3	-.47545727E+06
	778	3	-.45596913E+06		858	3	-.46053045E+06		938	3	-.47545727E+06
	779	4	-.45486764E+06		859	4	-.45716762E+06		939	3	-.47372595E+06
	780	3	-.45834103E+06		860	4	-.45848066E+06		940	3	-.47372595E+06
	781	15	-.44548028E+06		861	15	-.44097667E+06		941	15	-.45402127E+06
	782	3	-.44844203E+06		862	15	-.44337762E+06		942	3	-.45609141E+06
	783	3	-.44614173E+06		863	15	-.44079423E+06		943	15	-.45324830E+06
	784	3	-.45067571E+06		864	15	-.44292220E+06		944	3	-.45456154E+06
	785	17	-.47682935E+06		865	4	-.47151046E+06		945	3	-.47622541E+06
	786	17	-.47682935E+06		866	4	-.47151046E+06		946	3	-.47622541E+06
	787	17	-.47504423E+06		867	3	-.46942577E+06		947	3	-.47449410E+06
	788	17	-.47504423E+06		868	3	-.46942577E+06		948	3	-.47449410E+06
	789	17	-.47336662E+06		869	4	-.47151046E+06		949	3	-.47622541E+06
	790	17	-.47369125E+06		870	4	-.47151046E+06		950	3	-.47622541E+06
5	791	17	-.47175474E+06	10	871	3	-.46942577E+06	15	951	3	-.47449410E+06
	792	17	-.47206313E+06		872	3	-.46942577E+06		952	3	-.47449410E+06
	793	4	-.45068313E+06		873	3	-.46394445E+06		953	3	-.47622541E+06
	794	3	-.45411562E+06		874	3	-.46462063E+06		954	3	-.47622541E+06
	795	4	-.45145864E+06		875	3	-.46251716E+06		955	3	-.47449410E+06
	796	3	-.45475144E+06		876	3	-.46324995E+06		956	3	-.47449410E+06
	797	15	-.44254523E+06		877	15	-.44375083E+06		957	3	-.45604227E+06
	798	3	-.44546474E+06		878	15	-.44613686E+06		958	3	-.45795726E+06
	799	16	-.44295634E+06		879	15	-.44355573E+06		959	15	-.45514804E+06
	800	3	-.44577323E+06		880	15	-.44565696E+06		960	15	-.45681840E+06

Table 11. Optimal Policy anu Total Expected Costs in Stage 30 for a Price of $6.50.

AGE	STATE	POLICY	RETURNS	AGE	STATE	POLICY	RETURNS	AGE	STATE	POLICY	RETURNS
	1201	3	-.55928168E+06		1281	3	-.57184940E+06		1361	3	-.57187930E+06
	1202	17	-.56358078E+06		1282	3	-.57184940E+06		1362	3	-.57187930E+06
	1203	17	-.56148283E+06		1283	3	-.56985280E+06		1363	3	-.56988270E+06
	1204	17	-.56433043E+06		1284	3	-.56985280E+06		1364	3	-.56988270E+06
	1205	3	-.55633691E+06		1285	3	-.57184940E+06		1365	3	-.57187930E+06
	1206	3	-.56130621E+06		1286	3	-.57184940E+06		1366	3	-.57187930E+06
	1207	17	-.56155364E+06		1287	3	-.56985280E+06		1367	3	-.56988270E+06
	1208	17	-.56448485E+06		1288	3	-.56985280E+06		1368	3	-.56988270E+06
	1209	3	-.55290333E+06		1289	3	-.54753929E+06		1369	3	-.56660987E+06
1	1210	3	-.55819452E+06	6	1290	3	-.55052970E+06	11	1370	4	-.56726929E+06
	1211	3	-.56110070E+06		1291	3	-.54618941E+06		1371	3	-.56489209E+06
	1212	17	-.56549599E+06		1292	3	-.54917982E+06		1372	3	-.56535221E+06
	1213	3	-.55162530E+06		1293	4	-.53259248E+06		1373	4	-.54067284E+06
	1214	3	-.55703630E+06		1294	3	-.53780537E+06		1374	3	-.54477684E+06
	1215	17	-.55982409E+06		1295	4	-.53204513E+06		1375	4	-.53962790E+06
	1216	17	-.56393138E+06		1296	3	-.53715752E+06		1376	3	-.54354004E+06
	1217	17	-.56484504E+06		1297	3	-.56863251E+06		1377	3	-.57286712E+06
	1218	17	-.56716276E+06		1298	3	-.56863251E+06		1378	3	-.57286712E+06
	1219	17	-.56501408E+06		1299	3	-.56663591E+06		1379	3	-.57087052E+06
	1220	17	-.56718533E+06		1300	3	-.56663591E+06		1380	3	-.57087052E+06
	1221	3	-.56252569E+06		1301	3	-.56863251E+06		1381	3	-.57286712E+06
	1222	3	-.56523304E+06		1302	3	-.56863251E+06		1382	3	-.57286712E+06
	1223	17	-.56387591E+06		1303	3	-.56663591E+06		1383	3	-.57087052E+06
	1224	17	-.56622000E+06		1304	3	-.56663591E+06		1384	3	-.57087052E+06
2	1225	3	-.55221903E+06	7	1305	3	-.54827298E+06	12	1385	4	-.57108622E+06
	1226	3	-.55705028E+06		1306	3	-.55080345E+06		1386	4	-.57123972E+06
	1227	3	-.55850705E+06		1307	3	-.54667780E+06		1387	3	-.56928860E+06
	1228	3	-.56271430E+06		1308	3	-.54920827E+06		1388	3	-.56944472E+06
	1229	3	-.54839084E+06		1309	4	-.53080986E+06		1389	3	-.54442185E+06
	1230	3	-.55358098E+06		1310	3	-.53576805E+06		1390	3	-.54740341E+06
	1231	3	-.55487028E+06		1311	4	-.53016300E+06		1391	4	-.54232505E+06
	1232	3	-.55943641E+06		1312	3	-.53500241E+06		1392	3	-.54604883E+06
	1233	17	-.56918414E+06		1313	3	-.56801234E+06		1393	4	-.57360704E+06
	1234	17	-.57073612E+06		1314	3	-.56801234E+06		1394	4	-.57360704E+06
	1235	17	-.56878095E+06		1315	3	-.56601573E+06		1395	3	-.57173773E+06
	1236	17	-.57024246E+06		1316	3	-.56601573E+06		1396	3	-.57173773E+06
	1237	4	-.56559937E+06		1317	3	-.56801234E+06		1397	4	-.57360704E+06
	1238	4	-.56839984E+06		1318	3	-.56801234E+06		1398	4	-.57360704E+06
	1239	17	-.56668034E+06		1319	3	-.56601573E+06		1399	3	-.57173773E+06
	1240	17	-.56823930E+06		1320	3	-.56601573E+06		1400	3	-.57173773E+06
3	1241	3	-.55131982E+06	8	1321	3	-.55172337E+06	13	1401	4	-.57360704E+06
	1242	3	-.55569059E+06		1322	3	-.55379391E+06		1402	4	-.57360704E+06
	1243	3	-.55569823E+06		1323	3	-.54988290E+06		1403	3	-.57173773E+06
	1244	3	-.55960098E+06		1324	3	-.55195344E+06		1404	3	-.57173773E+06
	1245	3	-.54493558E+06		1325	4	-.53173369E+06		1405	3	-.54720926E+06
	1246	3	-.54990487E+06		1326	3	-.53644742E+06		1406	3	-.54996997E+06
	1247	3	-.54963321E+06		1327	4	-.53098730E+06		1407	4	-.54494887E+06
	1248	3	-.55613448E+06		1328	3	-.53556399E+06		1408	3	-.54849759E+06
	1249	3	-.57363684E+06		1329	3	-.56947234E+06		1409	4	-.57438270E+06
	1250	3	-.57442301E+06		1330	3	-.56947234E+06		1410	4	-.57438270E+06
	1251	17	-.57292759E+06		1331	3	-.56747573E+06		1411	3	-.57222021E+06
	1252	17	-.57366161E+06		1332	3	-.56747573E+06		1412	3	-.57222021E+06
	1253	3	-.57004295E+06		1333	3	-.56947234E+06		1413	4	-.57438270E+06
	1254	3	-.57116605E+06		1334	3	-.56947234E+06		1414	4	-.57438270E+06
	1255	17	-.56981487E+06		1335	3	-.56747573E+06		1415	3	-.57222021E+06
4	1256	17	-.57082874E+06	9	1336	3	-.56747573E+06	14	1416	3	-.57222021E+06
	1257	3	-.55022091E+06		1337	3	-.55735598E+06		1417	4	-.57438270E+06
	1258	3	-.55413173E+06		1338	3	-.55868614E+06		1418	4	-.57438270E+06
	1259	3	-.55268998E+06		1339	3	-.55527021E+06		1419	3	-.57222021E+06
	1260	3	-.55628880E+06		1340	3	-.55688080E+06		1420	3	-.57222021E+06
	1261	3	-.54128651E+06		1341	4	-.53481734E+06		1421	3	-.54994397E+06
	1262	3	-.54603493E+06		1342	3	-.53930901E+06		1422	3	-.55248383E+06
	1263	3	-.54420230E+06		1343	4	-.53397145E+06		1423	3	-.54835380E+06
	1264	3	-.54863873E+06		1344	3	-.53830780E+06		1424	3	-.55083366E+06
	1265	3	-.57708606E+06		1345	3	-.57075408E+06		1425	4	-.57506362E+06
	1266	3	-.57708606E+06		1346	3	-.57075408E+06		1426	4	-.57506362E+06
	1267	17	-.57627084E+06		1347	3	-.56875747E+06		1427	3	-.57290114E+06
	1268	17	-.57627084E+06		1348	3	-.56875747E+06		1428	3	-.57290114E+06
	1269	3	-.57309284E+06		1349	3	-.57075408E+06		1429	4	-.57506362E+06
	1270	3	-.57346722E+06		1350	3	-.57075408E+06		1430	4	-.57506362E+06
5	1271	17	-.57222476E+06	10	1351	3	-.56875747E+06	15	1431	3	-.57290114E+06
	1272	17	-.57257445E+06		1352	3	-.56875747E+06		1432	3	-.57290114E+06
	1273	3	-.54895184E+06		1353	3	-.56219283E+06		1433	4	-.57506362E+06
	1274	3	-.55240273E+06		1354	3	-.56295957E+06		1434	4	-.57506362E+06
	1275	3	-.54951159E+06		1355	3	-.56057439E+06		1435	3	-.57290114E+06
	1276	3	-.55280648E+06		1356	3	-.56140532E+06		1436	3	-.57290114E+06
	1277	3	-.53746727E+06		1357	4	-.53779266E+06		1437	3	-.55263241E+06
	1278	3	-.54199484E+06		1358	3	-.54208187E+06		1438	3	-.55495141E+06
	1279	4	-.53772579E+06		1359	4	-.53684723E+06		1439	3	-.55092446E+06
	1280	3	-.54297281E+06		1360	3	-.54096287E+06		1440	3	-.55324346E+06

to the $4.50 price range except that replacement is induced in the five year recovery systems starting when the asset reaches age four unless the investment credit option is used. In this case, replacement is delayed until after five full years have expired. The new asset is depreciated with ACRS and investment credit. Provided that this accelerated system is used, the purchase of a new machine can be justified so early in this high income range. When the marginal tax rate reaches these high levels, the ability to write off the interest expense on the new combine becomes a large benefit.

The results may be interpreted easier with the use of an example. Suppose the young farmer is in his first year of operation and has inherited a nine year old combine from his father that is being written off under the 12 year straight line depreciation schedule. If the price of winter wheat is $3.50 per bushel, the optimal decision rule is to keep. If the price remains at this level, the model recommends the owner replace his asset once it reaches twelve years of age and depreciate the new combine under the accelerated cost recovery system with the investment credit option. After five full years of use with this combine and a price jump to $4.50, the decision model suggests to again replace with the identical depreciation schedule. Besides adding to the clarity of the results, the hypothetical example emphasizes how the optimal policy is dependent on the state of the process as described by the age and tax condition of the combine and the price level of winter wheat.

Cost of Capital

To test the sensitivity of the results to the cost of capital, optimal decisions and expected returns were obtained with an annual interest rate of nine and twelve percent. By increasing the discount rate, the present value of tax benefits to be incurred through replacement are lowered relative to the costs of acquisition. The effect should be to increase the replacement interval which Chisholm and Kay and Rister had concluded.

While the result is true in general, it very much depends upon the state of the process. In the lowest price ranges, the optimal policy remains unchanged for the first five years of the asset's life. However for the next four years, one should keep rather than replace if the combine is being depreciated under any of the options with the 12 year straight line method. This keep decision is extended until age eleven if the interest rate is raised to twelve percent. There are still tax deductions available under the longer depreciation schedules. The relative benefits to having them and not the costs involved in purchasing a new machine increase as the interest rate does.

In comparison, the shorter recovery periods have no deductions left to expense in the present period and for the future. There are economic savings to be gained by buying a new combine now in order to expense when positive income levels return. Since the increase will occur slowly, the replace policy uses the 25 year recovery method with no tax incentives. The exclusion of the latter options maximizes the investment basis and thus future depreciation deductions.

In the $3.50 price level, similar results are obtained for all interest rates during the first seven years of asset age. Beyond this point, the optimal decision is to keep the present asset rather than replace and use the accelerated cost method with all the investment options. This replacement decision is delayed until the asset's tenth year when the discount rate is nine percent and until its twelfth year when the rate is twelve percent.

After age seven, the asset is completely paid off so there are no remaining purchase costs associated with the present asset. The relative importance of these costs in the decision maker's analysis increases with the discount rate. As a result, any comparison of a new combine with its high acquisition costs will induce the keep decision and this interval will increase with the interest rate.

The optimal policies are very similar for the six and nine percent interest rates in the $4.50 price range except for the states dealing with the 25 year depreciation schedule. The

Table 12. Optimal Replacement Age and Depreciation Schedule for Asset Presently Depreciated Under ACRS for Various Discount Rates.

		ACRS Depreciation Method			
Price	Discount Rate	No Options	Expensing	ITC	Expensing & ITC
$1.50	6	4 (13)	4 (13)	6 (13)	6 (13)
	9	4 (13)	4 (13)	6 (13)	6 (13)
	12	4 (13)	3 (13)	6 (13)	6 (13)
$3.50	6	6 (4)*	6 (4)*	6 (4)*	6 (4)*
	9	6 (4)**	6 (4)**	6 (4)**	6 (4)**
	12	6 (4)**	6 (4)**	6 (4)**	6 (4)**
$4.50	6	6 (3)	6 (3)	6 (3)	6 (3)
	9	6 (4)	6 (4)	6 (4)	6 (4)
	12	6 (4)	6 (4)	6 (4)	6 (4)
$6.50	6	4 (3)	4 (3)	6 (3)	6 (3)
	9	5 (3)	5 (3)	6 (3)	6 (3)
	12	5 (4)	5 (4)	6 (4)	6 (4)

First number indicates age at which to replace the current asset and the bracketed number indicates the optimal depreciation schedule for the new asset based on the decision alternatives in Table 3.

*Replacement policy changes to 3 (ACRS with ITC) in later years.

**Keep decision recommended again in later years.

Table 13. Optimal Replacement Age and Depreciation Schedule for Asset Presently Depreciated Under 5 Year Straight Line for Various Discount Rates.

		5 Year Straight Line Depreciation Method			
Price	Discount Rate	No Options	Expensing	ITC	Expensing & ITC
$1.50	6	4 (13)	4 (13)	6 (13)	6 (13)
	9	4 (13)	4 (13)	6 (13)	6 (13)
	12	4 (13)	3 (13)	6 (13)	6 (13)
$3.50	6	6 (4)*	6 (4)*	6 (4)*	6 (4)*
	9	6 (4)**	6 (4)**	6 (4)**	6 (4)**
	12	6 (4)**	6 (4)**	6 (4)**	6 (4)**
$4.50	6	6 (3)	6 (3)	6 (3)	6 (3)
	9	6 (3)	6 (3)	6 (3)	6 (3)
	12	6 (4)	6 (4)	6 (4)	6 (4)
$6.50	6	1 (3)	1 (3)	6 (3)	6 (3)
	9	1 (3)	4 (3)	6 (3)	6 (3)
	12	5 (4)	5 (4)	6 (4)	6 (4)

First number indicates age at which to replace the current asset and the bracketed number indicates the optimal depreciation schedule for the new asset based on the decision alternatives in Table 3.

*Replacement policy changes to 3 (ACRS with ITC) in later years.

**Keep decision recommended again in later years.

Table 14. Optimal Replacement Age and Depreciation Schedule for Asset Presently Depreciated Under 12 Year Straight Line for Various Discount Rates.

		12 Year Straight Line Depreciation Method			
Price	Discount Rate	No Options	Expensing	ITC	Expensing & ITC
$1.50	6	6 (13)	6 (13)	6 (13)	6 (13)
	9	10 (13)	10 (13)	10 (13)	10 (13)
	12	12 (13)	12 (13)	12 (13)	12 (13)
$3.50	6	6 (3)**	6 (3)**	6 (3)**	6 (3)**
	9	6 (3)**	6 (3)**	6 (3)**	6 (3)**
	12	6 (4)**	6 (4)**	6 (4)**	6 (4)**
$4.50	6	1 (4)*	1 (3)	2 (3)	3 (3)
	9	1 (4)*	1 (3)	1 (3)	3 (3)
	12	1 (4)	1 (4)	1 (4)	3 (4)
$6.50	6	1 (3)	1 (3)	1 (3)	2 (3)
	9	1 (3)	1 (3)	1 (3)	3 (3)
	12	1 (4)	1 (4)	1 (4)	4 (4)

First number indicates age at which to replace the current asset and the bracketed number indicates the optimal depreciation schedule for the new asset based on the decision alternatives in Table 3.

*Replacement policy changes to 3 (ACRS with ITC) in later years.

**Keep decision recommended again in later years.

Table 15. Optimal Replacement Age and Depreciation Schedule for Asset Presently Depreciated Under 25 Year Straight Line for Various Discount Rates.

		25 Year Straight Line Depreciation Method			
Price	Discount Rate	No Options	Expensing	ITC	Expensing & ITC
$1.50	6	13 (13)	13 (13)	13 (13)	13 (13)
	9	14 (13)	14 (13)	14 (13)	14 (13)
	12	15 (13)	15 (13)	15 (13)	15 (13)
$3.50	6	6 (13)	6 (13)	6 (13)	6 (13)
	9	5 (13)	5 (13)	6 (13)	5 (13)
	12	5 (13)	5 (13)	6 (13)	5 (13)
$4.50	6	1 (4)**	1 (3)**	2 (3)**	3 (3)**
	9	1 (3)	1 (3)	2 (3)	3 (3)
	12	1 (4)	1 (4)	1 (4)	2 (4)
$6.50	6	1 (3)	1 (3)	2 (3)	2 (3)
	9	1 (3)	1 (3)	2 (3)	2 (3)
	12	1 (4)	1 (4)	2 (4)	2 (4)

First number indicates age at which to replace the current asset and the bracketed number indicates the optimal depreciation schedule for the new asset based on the decision alternatives in Table 3.

**Keep decision recommended again in later years.

higher rate suggests replacing the asset with the accelerated method using investment tax credit rather than with the longest recovery period using the same option. The present value of the future deductions are reduced with the higher discount. This effect is reinforced with the twelve percent rate and explains the addition of the expensing option with the replace decision. Even though the basis for computing investment credit and other depreciation deductions are reduced by a value equal to the expensed amount, the deduction occurs in the year of purchase and consquentially its relative value will rise with the discount rate.

The outcome is identical in the highest price levels. As the interest rate climbs to twelve percent, the expensing option becomes a viable alternative. The owner's time preference is such that the ability to reduce taxable income immediately outweighs the loss of future deductions. The use of the accelerated depreciation schedule augments his desire to maximize his present deductible expenses. Though the depreciation policy changes in these higher income levels with the increased rates, the replacement interval remains constant except in one instance. If the asset is four years old and being depreciated under the two fastest schedules, the policy is to maintain the present asset rather than replace.

Cost of a Major Breakdown

As mentioned previously, the opportunity cost of time associated with a major breakdown will vary between individual farms. The results presented earlier use a value of \$10,500 which is the total custom rate for harvesting one half of the grain crop. To compare the effects of differing values, the operating expenses of the idle harvesting equipment are subtracted from the \$10,500 to arrive at a cost of \$4,000. An arbitrarily high value of \$20,000 is also used to capture some of the possible constraints facing the firm and the concern involved in operating a machine which has an increasing probability of major failure.

In the lower price levels, the optimal policy changes to keep the present asset when it is eight and nine years old regardless of the depreciation schedule. If the higher value is used, the model suggests to replace in year eight even if the present asset is under the longer depreciation schedules. The only changes with the results in the other price ranges occurs at age four in the $6.50 price level with the lowest opportunity cost. If the asset is being depreciated under the two five year systems without investment credit, then the optimal decision is to keep for another year rather than replace.

Intuitively, the impact of changing the opportunity cost of time involving a major breakdown seems obvious; as it increases so would the impetus to replace and vice versa if the opposite occurred. However in the highest income levels, the replace decision is already recommended for the early ages in which the probability a major failure is very low. The unconditional probabilities are highest in the years around age nine at which the conditional probability of such an occurrence is fifty percent. As a result, the predicted effect takes place only in the lower income brackets where both the keep and replace decision are proposed in those particular years. The change affects only the interval and not the replacement policy.

Table 16. Optimal Replacement Age and Depreciation Schedule for Asset Presently Depreciated Under ACRS for Various Opportunity Costs of Breakdown.

Price	Opportunity Cost of Breakdown	ACRS Depreciation Method No Options	Expensing	ITC	Expensing & ITC
$1.50	4,000	4 (13)	4 (13)	6 (13)	6 (13)
	10,500	4 (13)	4 (13)	6 (13)	6 (13)
	20,000	4 (13)	4 (13)	6 (13)	6 (13)
$3.50	4,000	6 (4)**	6 (4)**	6 (4)**	6 (4)**
	10,500	6 (4)*	6 (4)*	6 (4)*	6 (4)*
	20,000	6 (4)*	6 (4)*	6 (4)*	6 (4)*
$4.50	4,000	6 (3)	6 (3)	6 (3)	6 (3)
	10,500	6 (3)	6 (3)	6 (3)	6 (3)
	20,000	6 (3)	6 (3)	6 (3)	6 (3)
$6.50	4,000	5 (3)	5 (3)	6 (3)	6 (3)
	10,500	4 (3)	4 (3)	6 (3)	6 (3)
	20,000	4 (3)	4 (3)	6 (3)	6 (3)

First number indicates age at which to replace the current asset and the bracketed number indicates the optimal depreciation schedule for the new asset based on the decision alternatives in Table 3.

*Replacement policy changes to 3 (ACRS with ITC) in later years.

**Keep decision recommended again in later years.

Table 17. Optimal Replacement Age and Depreciation Schedule for Asset Presently Depreciated Under 5 Year Straight Line for Various Opportunity Costs of Breakdown.

Price	Opportunity Cost of Breakdown	5 Year Straight Line Depreciation Method No Options	Expensing	ITC	Expensing & ITC
$1.50	4,000	4 (13)	4 (13)	6 (13)	6 (13)
	10,500	4 (13)	4 (13)	6 (13)	6 (13)
	20,000	4 (13)	4 (13)	6 (13)	6 (13)
$3.50	4,000	6 (4)**	6 (4)**	6 (4)**	6 (4)**
	10,500	6 (4)*	6 (4)*	6 (4)*	6 (4)*
	20,000	6 (4)*	6 (4)*	6 (4)*	6 (4)*
$4.50	4,000	6 (3)	6 (3)	6 (3)	6 (3)
	10,500	6 (3)	6 (3)	6 (3)	6 (3)
	20,000	6 (3)	6 (4)	6 (3)	6 (3)
$6.50	4,000	6 (3)	6 (3)	6 (3)	6 (3)
	10,500	1 (3)	1 (3)	6 (3)	6 (3)
	20,000	1 (3)	1 (3)	1 (3)	1 (3)

First number indicates age at which to replace the current asset and the bracketed number indicates the optimal depreciation schedule for the new asset based on the decision alternatives in Table 3.

*Replacement policy changes to 3 (ACRS with ITC) in later years.

**Keep decision recommended again in later years.

Table 18. Optimal Replacement Age and Depreciation Schedule for Asset Presently Depreciated Under 12 Year Straight Line for Various Opportunity Costs of Breakdown.

Price	Opportunity Cost of Breakdown	12 Year Straight Line Depreciation Method			
		No Options	Expensing	ITC	Expensing & ITC
$1.50	4,000	6 (13)	6 (13)	6 (13)	6 (13)
	10,500	6 (13)	6 (13)	6 (13)	6 (13)
	20,000	6 (13)	6 (13)	6 (13)	6 (13)
$3.50	4,000	6 (3)**	6 (3)**	6 (3)**	6 (3)**
	10,500	6 (3)**	6 (3)**	6 (3)**	6 (3)**
	20,000	6 (3)	6 (3)	6 (3)	6 (3)
$4.50	4,000	1 (4)*	1 (3)	2 (3)	3 (3)
	10,500	1 (4)*	1 (3)	2 (3)	3 (3)
	20,000	1 (4)*	1 (3)	2 (3)	3 (3)
$6.50	4,000	1 (3)	1 (3)	1 (3)	2 (3)
	10,500	1 (3)	1 (3)	1 (3)	2 (3)
	20,000	1 (3)	1 (3)	1 (3)	2 (3)

First number indicates age at which to replace the current asset and the bracketed number indicates the optimal depreciation schedule for the new asset based on the decision alternatives in Table 3.

*Replacement policy changes to 3 (ACRS with ITC) in later years.

**Keep decision recommended again in later years.

Table 19. Optimal Replacement Age and Depreciation Schedule for Asset Presently Depreciated Under 25 Year Straight Line for Various Opportunity Costs of Breakdown.

Price	Opportunity Cost of Breakdown	25 Year Straight Line Depreciation Method			
		No Options	Expensing	ITC	Expensing & ITC
$1.50	4,000	14 (13)	14 (13)	14 (13)	14 (13)
	10,500	13 (13)	13 (13)	13 (13)	13 (13)
	20,000	13 (13)	13 (13)	13 (13)	13 (13)
$3.50	4,000	6 (13)	6 (13)	6 (13)	6 (13)
	10,500	6 (13)	6 (13)	6 (13)	6 (13)
	20,000	5 (13)	5 (13)	5 (13)	5 (13)
$4.50	4,000	1 (4)**	1 (3)**	2 (3)**	3 (3)**
	10,500	1 (4)**	1 (3)**	2 (3)**	3 (3)**
	20,000	1 (4)**	1 (3)**	2 (3)**	3 (3)**
$6.50	4,000	1 (3)	1 (3)	2 (3)	2 (3)
	10,500	1 (3)	1 (3)	2 (3)	2 (3)
	20,000	1 (3)	1 (3)	2 (3)	2 (3)

First number indicates age at which to replace the current asset and the bracketed number indicates the optimal depreciation schedule for the new asset based on the decision alternatives in Table 3.

**Keep decision recommended again in later years.

CHAPTER 5

SUMMARY AND CONCLUSIONS

Summary

The basic marginal principle of economic theory can dictate the optimal replacement interval by comparing the costs incurred from keeping an asset for another time period which those would be realized from a new asset during the same period. The problem with using this criterion arises in the proper specification of all relevant cost elements. While repair and acquisition costs are basically a function of age, taxes are dependent upon the depreciation schedule used and the economic environment surrounding the firm. Noting the inherently unstable nature of returns in agriculture and thus the impact of these cost elements, any replacement study in this sector must be considered within a stochastic framework. The decision maker cannot ignore the stochastic variables involved nor the time dimensions and thus neither should any model used in the analysis of replacement.

The primary objective of this research effort was to develop a model which accounts for the stochastic, dynamic nature of the replacement problem. In order to properly consider the economic dynamics, the multi-stage decision process is analyzed through the use of stochastic dynamic programming. The model was applied to a representative cash grain farm in northcentral Montana where the asset concerned was a combine and the optimal decision based on the stochastic nature of winter wheat prices. The decision maker's criterion was to minimize the expected cash flows associated with each combine in the firm's thirty planning horizon.

All costs attributed to the combine and relevant to the replacement decision must be reflected through the state variables. They must be complete enough to meet the Markovian requirement which requires the optimal policy to be dependent upon the present stage and state and not on how the system got there. The condition is met and the process summarized at any point in time by the price of winter wheat, asset age and depreciation schedule used on the current asset.

Six price levels ranging from \$1.50 to \$6.50 were designated with the increments being one dollar. Prices were assumed to change annually according to a probability distribution which was based on a regression model that predicted current price as a function of price in the previous year. Without inflation, this relationship is presumed to continue through the planning horizon. Annual winter wheat prices for the state of Montana were converted to present dollars and then used in the regression analysis. The form of the probability distribution for price in year t is

$$P \sim N(\alpha_i + \beta_i (P_{t-1}), SE)$$

where,

α_i is a constant for year i

β_i is a constant for year i

P_{t-1} is price in year $t-1$

SE is the standard error of the estimate of the regression equation that determined the values of α_i and β_i.

Fifteen possible asset ages are assumed with the combine coming to the end of its operational life forcing replacement in its fifteenth year. In general terms, aging affects machine costs by increasing variable operating expenses such as repairs while decreasing ownership costs such as loan repayments.

Costs are also influenced by the tax options attached to the asset. A major farm asset such as a combine may be depreciated under the accelerated cost recovery system or under the straight line method with alternative recovery periods of 5, 12 or 25 years. With each of the four depreciation schedules, the decision maker may choose any combination of two investment incentives. The expensing option allows the owner to treat \$7,500 of the acquisition cost as an expense rather than as a capital expenditure. Investment tax credit allows him to deduct ten percent of the purchase cost directly from his tax liability in the year the asset is first purchased. The incentives may be used together, alone or not at all, with any depreciation method. The sixteen tax conditions can prevail in any of the fifteen asset ages or six price levels resulting in a stochastic model consisting of 1,440 states.

The basic alternatives confronting the decision maker are to keep or replace the current asset. This study also seeks to find the optimal tax option to be employed if the asset is replaced. This necessitates the expansion of the replace decision to include the sixteen possible combination of depreciation schedules and investment incentives resulting in seventeen total decision alternatives.

The optimal decision minimizes the expected immediate costs and those from the n-1 stage process. These costs are a function of the state variables and the decision alternative selected. Comprising the cash expenses include repair costs in terms of both actual parts and labor and the opportunity cost associated with breakdown time. In addition, property taxes, acquisition cost determined by downpayment and loan repayment and income taxes both on the federal and state level are all cash flows related to the combine that are faced by the owner. To put them in comparable terms, each of the components must be discounted according to their occurrence in relation to the January 1 decision period. Dynamic programming determines the optimal replacement interval and depreciation schedule by solving the sequence of decisions which minimizes the present value of these cash flows associated with each combine in the planning horizon.

Conclusions

The results indicate that the optimal decision rule is very dependent upon the state variables describing the conditions surrounding the combine. Despite having the policies contingent to individual financial and physical conditions of the asset, some general conclusions can be drawn concerning the effect of the state variables on replacement.

The first supports the results obtained by recent studies regarding the value of investment tax credit. It allows the direct reduction of tax liability by ten percent of the purchase cost. The advantage to doing so is shown by the majority of replacement policies which suggest the usage of this incentive. The only conditions under which it is not solely recommended occur when the price levels are extremely low or within a small age group in the \$3.50 price range. If returns are negative, tax liability cannot be reduced further and the use of investment credit would only serve to decrease the basis on which future depreciation deductions are calculated. Between the ages of six and nine, depreciation recapture represents a significant gain in ordinary income if the asset is completely written off. In the \$3.50 price range, the expensing option can reduce net farm profit and in turn the amount of self employment tax payable. But for prices above this level, the deduction does not significantly reduce income below the maximum level on which the tax is paid. As a consequence, the expensing option is only employed in this particular situation since the extra value of early expensing does not generally offset the reduced value of the investment credit base and consequently of the credit itself.

The depreciation schedule most often suggested to be used with the investment credit option is the accelerated cost recovery system which allows for the most rapid rate of depreciation deductions. The benefits of such a schedule are best utilized in years of high returns in order to reduce taxable income. In the existence of negative returns, the new asset should be depreciated under 25 year straight line with no options so that the deductions may be preserved for years when positive income levels return.

When replacement should occur is controlled by the tax conditions of the present asset and their impact is governed by the level of returns and combine age. The 25 year straight line replacement policy implemented during periods of negative returns is delayed until age thirteen if the asset is presently being depreciated under such a system. As income levels gradually increase in the future, the ability to claim depreciation deductions is maintained. This is not the case with other systems so replacement takes place at age six due to this factor and a combination of increasing repair costs and the avoidance of investment credit recapture.

As income levels rise, replacement is postponed until the combine has been in service for five full years in order to escape any direct addition to tax liability in the form of this recapture. Its significance declines in high income periods with assets depreciated under the longest recovery periods. During these years, replacement is suggested in age two except for those states in which the current asset is being depreciated rapidly with the investment credit option. The value of deductible expenses are magnified as the marginal tax rate faced by the decision maker increases.

The sensitivity of the analysis to the cost of capital was obtained by increasing the annual interest rate to nine and twelve percent. By lowering the present value of tax benefits relative to the costs of acquisition, the replacement interval is predicted to increase. Chisholm and Kay and Rister concluded that this would have a large impact on optimal policy but the results here are very much dependent upon the state of the process. The hypothesized effect holds for the slowest depreciation schedules in the lower income levels but as price rises, the discount rate does not change the age of replacement suggested earlier. This is mainly due to the dampening effect that the high income levels have on the after tax discount rate. However, it does result in the addition of the expensing option with the replacement policy. As the cost of capital rises, the gains to be incurred through an immediate reduction in taxable income will outweigh the loss of future deductions.

The results were also tested with regard to the effect of differing opportunity costs of time associated with a major breakdown. The unconditional probability of such an event is highest at age nine and thus its impact on replacement policy will be greatest at that time. However, only in the lower income brackets are replacement ages not determined much earlier than this age group. As a result, the obvious impetus to replace as opportunity cost rises and keep if it declines only takes place for a limited number of years in those particular price levels. If has no effect on the depreciation schedule to be used with the new asset.

If a general rule of thumb could be drawn from this study, it would be to replace after five years of service and depreciate under the accelerated cost recovery system with the investment tax credit option. However, the optimal decision rule is dependent upon the financial and physical status of the combine and the economic environment surrounding the firm. Since this environment is inherently unstable in agriculture, dynamic programming was used as the method of analysis in order to account for the risk and uncertainty. The result is a more realistic and wider range of replacement policies than have been provided by previous studies.

Limitations

The model has provided optimal decisions subject to the information that is provided. Any parameter that can lead to better information will in turn lead to better decisions. The policies suggested depend on the marginal tax rate as indicated by price, but these prices are subject to random changes. While the ability of dynamic programming to account for the stochastic nature of returns is an improvement over other models, any progress in price prediction would further enhance the authenticity of the results.

Results could also be improved with a better estimate of repair costs since they are a prerequisite for a variety of decisions common in farm management (Watts, p. 69). The Agricultural Engineers' equation used here is an average assessment and is widely accepted. Kay and Rister showed that varying the pattern of repair costs can cause as much as a five year change in the optimal replacement policy. This emphasizes the need for individual estimates of repair costs to be experienced by the decision maker based on his care and handling of his equipment and the specific machine involved which may be considered a "lemon" or infallible.

These parameters have been included in the model but it could have been improved through the addition of two other variables whose impact can only be speculated upon. Bates, Rayner and Custance showed that inflation produces longer replacement intervals. Since taxes are based on historic costs, the real value of depreciation deductions gained through replacement are reduced as inflation becomes significant. In addition, used prices are likely to be increasing and may well exceed the book value resulting in depreciation recapture. The net effect is a longer replacement interval than that predicted without inflation.

This may be offset by technological improvements which are likely to contribute to a shorter replacement policy. The advancements may be in the form of convenience and personal comfort which the owner may wish to experience. On the other hand, if the improvements result in increased productivity and efficiency, he may be foreced into early replacement. All farmers seek profit through such new technology but the resulting downward pressure on prices and profit margins allows only the early adopters to do so and forces the laggards into a similar policy in order to prevent financial loss.

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APPENDIX

Computer Program Used to Generate
Expected Immediate Costs

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C ****************************************************
C *** FARM TAX PROGRAM - SUTA/STAUBER/WEERSINK  ****************
C ****************************************************
C      VARIABLE DEFINITION
C      ACRS: ACCELERATED COST RECOVERY SYSTEM
C      ACRS3: ANNUAL DEPRECIATION DEDUCTIONS UNDER ACRS FOR 3 YEAR ASSETS
C      ACRS5: ANNUAL DEPRECIATION DEDUCTIONS UNDER ACRS FOR 5 YEAR ASSETS
C      ACRS15: ANNUAL DEPRECIATION DEDUCTIONS UNDER ACRS FOR 15 YEAR ASSETS
C      ACRS5SL5: ANNUAL DEPRECIATION DEDUCTIONS UNDER 5 YEAR STRAIGHT LINE
C      ACRS5SL12: ANNUAL DEPRECIATION DEDUCTIONS UNDER 12 YEAR STRAIGHT LINE
C      ACRS5SL25: ANNUAL DEPRECIATION DEDUCTIONS UNDER 25 YEAR STRAIGHT LINE
C      ADEP=ACCUMULATED DEPRECIATION ON PRESENT COMBINE
C      ADJFIC: FEDERAL INVESTMENT TAX CREDIT CLAIMED ON COMBINE
C      ADJTI=ADJUSTMENTS TO TAXABLE INCOME DUE TO COMBINE
C      ANFP: NET FARM PROFIT ADJUSTED FOR COMBINE EXPENSES
C      APTAX: PROPERTY TAX ASSESSED TO COMBINE
C      ASVLND=ASSESSED VALUE OF LAND PER ACRE
C      ATI: TAXABLE INCOME ADJUSTED FOR REPLACEMENT EFFECTS
C      AUPRICE: ACTUAL MONEY RECEIVED ON SALE AFTER LOAN BALANCE PAID
C      B: BARLEY EXPRESSED IN WHEAT EQUIVALENTS
C      BASESET: MAXIMUM NET FARM PROFIT WHICH IS SUBJECT TO SELF EMPLOYMENT TAX
C      BETA: DISCOUNT FACTOR
C      BINS: BUILDING INSURANCE
C      BREPS: BUILDING REPAIRS
C      BRKDN: COST OF A MAJOR BREAKDOWN
C      BVA: BOOK VALUE OF PRESENT COMBINE
C      CACRES: NUMBER OF ACRES FOR EACH CROP
C      CAPGAIN: CAPITAL GAIN OR LOSS
C      CAPGNS: CAPITAL GAINS OR LOSS ON DISPOSED ASSET
C      CI: INCOME FROM CROPS
C      CILAND:INTEREST CHARAGE ON LAND AND BUILDINGS
C      CIMACH: INTEREST CHARGE ON MACHINERY AND EQUIPMENT
C      CLINS: LIABILITY AND COMP. INSURANCE
C      CNAME: CROP NAME
C      CONT: CHARITABLE CONTRIBUTIONS
C      CPRICE: PRICE PER BUSHEL FOR EACH CROP
C      CVC: VARIABLE ASSOCIATED WITH EACH CROP EXCLUDING COMBINE REPAIRIR
C      CYIELD: YIELD FOR EACH CROP
C      DEP=DEPRECIATION DEDUCTIONS ON COMBINE
C      DEP5=DEPRECIATION SCHEDULE CHOSEN FOR 5 YEAR ASSET(COMBINE)
C      DEPRCPT: DEPRECIATION RECAPTURE OF DISPOSED ASSET
C      DFPTAX: DISCOUNT FACTOR FOR PROPERTY TAX AND LOAN REPAYMENTS
C      DFREPC: DISCOUNT FACTOR FOR REPAIR COSTS
C      DFTAX: DISCOUNT FACTOR FOR INCOME TAXES
C      DIF: INTEREST ON DIFFERENCE BETWEEN ACTUAL USED PRICE AND REQUIRED DOWNPAYMEN
C      DPMT: DOWNPAYMENT REQUIRED ON LOAN TO BUY COMBINE
C      EIMACH: INTEREST EXPENSE ON MACHINERY
C      EMED: DEDUCTIONS FOR MEDICAL EXPENSES
C      FMISC: MISCELLANEOUS EXPENSES
C      EXP=EXPENSED AMOUNT WHICH IS DEDUCTED FROM NEW PRICE
C      FINVCR: FEDERAL INVESTMENT CREDIT EXCLUDING COMBINE
C      FMTR: MARGINAL FEDERAL INCOME TAX RATE
C      FT:  ESTIMATE OF FEDERAL TAX LIABILITY
C      FTAIC: FEDERAL TAX LIABILITY AFTER INVESTMENT CREDIT
C      FTAX: FEDERAL INCOME TAX TABLES
C      FTBIC: FEDERAL TAX LIABILITY BEFORE INVESTMENT CREDIT
C      FTI: FEDERAL TAXABLE INCOME
C      GAIN=GAIN FROM DISPOSITION OF ASSET
C      HILAB: WAGES FOR HIRED LABOR
C      IAGE: AGE OF CURRENT ASSET (END OF PERIOD)
```

```
C      ICRI=INVESTMENT CREDIT OPTION USED ON CURRENT ASSET-YES OR NO
C      IDEPI=DEPRECIATION SCHEDULE PRESENTLY USED ON CURRENT ASSET-4 CHOICES
C      IEXPI: EXPENSING OPTION USED ON CURRENT ASSET-YES OR NO
C      INTEXP: INTEREST EXPENSE ON FUNDS USED TO BUY ASSET
C      ISTATE: PRESENT PHYSICAL AND FINANCIAL STATUS OF COMBINE AND PRICE OF WINTER
EAT
C      K: DECISION ALTERNATIVE CHOSEN
C      JAGE: AGE OF ASSET IN NEXT STATE
C      JDEPJ: DEPRECIATION SDCHEDULE USED ON ASSET IN NEXT STATE-4 CHOICES
C      JCRJ: INVESTMENT CREDIT OPTION USED ON ASSET IN NEXT STATE-YES OR NO
C      JEXPJ: EXPENSING OPTION USED ON ASSET IN NEXT STATE-YES OR NO
C      MILEVY: MILL LEVY
C      MKTVLD: MARKET VALUE OF LAND PER ACRE
C      NEXEMPT: NUMBER OF EXEMPTIONS CLAIMED
C      NFP: NET FARM PROFIT
C      NP=NEW PRICE
C      OACRS(N): AGE OF ASSET N FOR DEPRECIATIONS DEDUCTIONS UNDER ACRS
C      OAGE(N): AGE OF ASSET N
C      OFFNI: OFF-FARM NET INCOME
C      OINC: ADDITION OR LOSS TO ORDINARY INCOME FROM SALE OF ASSET
C      OINT: OTHER INTEREST EXPENSES
C      OMONTH(N): MONTH THAT 15 YEAR ASSET WAS PURCHASED
C      ONAME(N): ASSET NAME
C      OP(N): PURCHASE PRICE OF ASSET N
C      PAYMT: LOAN REPAYMENT  ON FUNDS BORROWED TO BUY ASSET
C      PBLDG: TAXABLE RATE ON BUILDINGS
C      PCTEQLD: PERCENT EQUITY ON LAND AND BUILDINGS
C      PCTEQMY: PERCENT EQUITY OF MACHINERY AND EQUIPMENT
C      PEXFED: FEDERAL EXEMPTION ON DEPENDENTS
C      PEXST: STATE EXEMPTION ON DEPENDENTS
C      PLAND: TAXABLE RATE ON LAND
C      PMACH: TAXABLE RATE ON MACHINERY
C      PRBREP:PROBABILITY OF MAJOR BREAKDOWN
C      PRINT: INTEREST EXPENSE ON PERSONAL RESIDENCE
C      Q(ISTATE,K): EXPECTED IMMEDIATE COSTS IN PRESENT STATE GIVEN K-TH DECISION
C      RCPTIC=RECAPTURE OF INVESTMENT TAX CREDIT ON DISPOSED ASSET
C      REMCST: REMAINING LOAN BALANCE YET TO BE PAID ON COMBINE
C      REP=REPAIR FUNCTION WHICH IS DEPENDENT ON AGE
C      REPCST=REPAIR COST
C      REPLBAL=REPLACEMENT COST
C      RILAND: AVERAGE RATE ON BORROWED FUNDS FOR LADND AND BUILDINGS
C      RIMACH: AVERAGE RATE ON BORROWED FUNDS FOR MACHINERY AND EQUIPMENT
C      RSET: SELF EMPLOYMENT TAX RATE
C      SACRS3: ACCUMULATIVE DEPRECIATION PERCENTAGES FOR 3 YEAR ASSETS UNDER ACRS
C      SACRS5: ACCUMULATIVE DEPRECIATION PERCENTAGES FOR 5 YEAR ASSETS UNDER ACRS
C      SACRS15: ACCUMULATIVE DEPRECIATION PERCENTAGES FOR 15 YEAR ASSETS UNDER ACRS
C      S5SL5: ACCUMULATIVE DEPRECIATION PERCENTAGES  UNDER 5 YEAR STRAIGHT LINE
C      S5SL12: ACCUMULATIVE DEPRECIATION PERCENTAGES  UNDER 12 YEAR STRAIGHT LINE
C      S5SL25: ACCUMULATIVE DEPRECIATION PERCENTAGES  UNDER 25 YEAR STRAIGHT LINE
C      SBV3: BOOK VALUE OF 3 YEAR ASSETS
C      SBV5: BOOK VALUE OF 5 YEAR ASSETS EXCLUDING COMBINE
C      SBV15 BOOK VALUE OF 15 YEAR ASSETS
C      SIC: EFFECT OF REPLACEMENT ON STATE TAX CREDIT
C      SMTR: MARGINAL STATE INCOME TAX RATE
C      ST:  ESTIMATE OF STATE TAX LIABILITY
C      STAIC: STATE TAX LIABILITY AFTER INVESTMENT CREDIT
C      STAX: STATE INCOME TAX TABLES
C      SUM3DEP: SUM OF DEPRECIATION ON 3 YEAR CLASS ASSETS
C      SUM5DEP; SUM OF DEPRECIATION ON 5 YEAR CLASS ASSETS EXCLUDING COMBINE
C      SUM15DEP: SUM OF DEPRECIATION ON 15 YEAR CLASS ASSETS
C      SUMBV: SUM OF BOOK VALUES FOR FARM ASSETS EXCLUDING COMBINE
C      SUMDEP: SUM OF ANNUAL DEPRECIATION DEDUCTIONS FOR FARM ASSETS EXCLUDING COMBINE
```

```
C       SUMCGR: GROSS RETURNS FROM ALL CROPS ON FARM
C       SUMCI: SUM OF INCOME FROM CROPS
C       SUMCVC: SUM OF ALL CROP VARIABLE COSTS EXCLUDING REPAIRS ON COMBINE
C       SUMDEP: SUM OF DEPRECIATION EXPENSES EXCLUDING COMBINE
C       SUMPTAX: SUM OF PROPERTY TAXES EXCLUDING COMBINE
C       TACRES: TOTAL ACRES
C       TAXDEF: TAX DEFERMENT
C       TBETA: AFTER-TAX DISCOUNT RATE
C       THEFT: THEFT OR CASUALTY LOSSES
C       TI: TAXABLE INCOME PRIOR TO REPLACEMENT EFFECTS
C       TT: TOTAL TAX PAYABLE
C       UPRICE=USED PRICE OF ASSET
C       UTILS: ANNUAL UTILITY BILL
C       VBLDG: ASSESSED VALUE OF BUILDINGS
C       VLAND: MARKET VALUE OF LAND BASE
C       VMACH: ASSESSED VALUE OF MACHINERY
C       W: PRICE PER BUSHEL OF WINTER WHEAT
C       ZBA: ZERO BRACKET AMOUNT (DEPENDS ON FILING STATUS)
C       0=NO
C       1=YES
C ****************************************************
        DIMENSION Q(1500,20),BETA(1500,20)
        DIMENSION CNAME(10,10),CACRES(10),CYIELD(10),
       &CPRICE(10),CVC(10),FTAX(15,4),STAX(10,4)
        DIMENSION ONAME(20,10),OP(20),UPRICE(26),PRBREP(15)
        DIMENSION REPCST(26),SACRS15(15,12),S5SL12(13),S5SL25(26)
        DIMENSION DEP5(4,26),ADEP5(4,26),ACRS5SL5(6),ACRS5SL12(13),ACRS5SL
       $25(26)
        REAL NP,MKTVLD,NFP,INTEXP
        COMMON TI,ATI,SUMCGR,SUMCVC,OFFNI,CAPGAIN,TAXDEF,SUMDEP,SUMPTAX,
       $APTAX,HILAB,BINS,BREPS,CLINS,UTILS,CILAND,CIMACH,EMED,PRINT,OINT
       $,CONT,EMISC,THEFT,ZBA,ADJTI,REPCST,DEP,DEPRCPT,FT,ST,PEXFED,PEXST
       $,BVA,ADEP,EXP,TBETA,RATE,CAPGNS,OINC,DIF,INTEXP
       $,FTAX,STAX,FINVCR,ADJFIC,RCPTFIC,IAGE,JAGE,M,JEXPJ
        INTEGER ACRS3(3),ACRS5(5),ACRS15(15,12)
        INTEGER SACRS3(3),SACRS5(5),S5SL5(6)
        INTEGER OAGE(20),OACRS(20),OMONTH(20)
        RATE=.06
        DFREPC=1.0/(1.0+RATE)**.5
        DFPTAX=1.0/(1.0+RATE)
        DFTAX=1.0/(1.0+RATE)**(4/3)
C       ENTER NEW PRICE OF ASSET,MAXIMUM AMOUNT EXPENSED,ASSESSED VALUE OF LAND.
C       ENTER THE SELF-EMPLOYMENT TAX RATE,AND THE MAXIMUM NET FARM PROFIT WHICH ,
C       IS SUBJECT TO SE TAX.
        DATA NP,EXP,ASVLND,RSET,BASESET/80000.,7500.,61.37,0.0935,35700./
C -- ACRS ANNUAL PERCENTAGES FOR 3, 5, & 15 YEAR ASSETS --
        DATA ACRS3/25,38,37/
        DATA ACRS5/15,22,21,21,21/
        DATA SACRS3/75,37,0/
        DATA SACRS5/85,63,42,21,0/
        DATA S5SL5/90,70,50,30,10,0/
        DATA ACRS5SL5/.10,4*.20,.10/
        DATA ACRS5SL12/.0417,11*.0833,.0417/
        DATA ACRS5SL25/.02,24*.04,.02/
C       READ ANNUAL DEPRECIATION PERCENTAGES FOR 15 YEAR ASSETS
        DO 31 I=1,15
 31     READ(105,110)(ACRS15(I,J),J=1,12)
C       READ ACCUMULATIVE DEPRECIATION PERCENTAGES FOR 15 YEAR ASSETS
        DO 32 I=1,15
 32     READ(105,110)(SACRS15(I,J),J=1,12)
C       READ ACCUMULATIVE DEPRECIATION PERCENTAGES FOR 5 YEAR ASSETS
C       12 YEAR STRAIGHT LINE
```

```
      READ(105,112)S5SL12
C     READ ACCUMULATIVE DEPRECIATION PERCENTAGES FOR 5 YEAR ASSETS
C     25 YEAR STRAIGHT LINE
      READ(105,112)S5SL25
 110  FORMAT(12I4)
 112  FORMAT(10F10.0)
 113  FORMAT(2F10.0,F5.0,F10.0)
C     READ REPAIR COST
      READ(105,112)REPCST
C     READ PROBABILITY OF A MAJOR BREAKDOWN
      READ(105,112)PRBREP
C     READ USED PRICES OF ASSET
      READ(105,112)UPRICE
C     READ IN THE FEDERAL TAX TABLE
      DO 33 I=1,15
 33   READ(105,113)(FTAX(I,J),J=1,4)
C33   WRITE(108,114)(FTAX(I,J),J=1,4)
C114  FORMAT(4F20.4)
C     READ IN THE STATE TAX TABLE
      DO 34 I=1,10
 34   READ(105,113)(STAX(I,J),J=1,4)
C34   WRITE(108,114)(STAX(I,J),J=1,4)
      DO 49 I=1,4
      DO 49 J=1,26
      DEP5(I,J)=ADEP5(I,J)=0.0
 49   CONTINUE
      DO 50 J=1,26
      IF(J.GT.5)GO TO 51
      DEP5(1,J)=ACRS5(J)/100.0
      ADEP5(1,J)=SACRS5(J)/100.
 51   IF(J.GT.6)GO TO 52
      DEP5(2,J)=ACRS5SL5(J)
      ADEP5(2,J)=S5SL5(J)/100.0
 52   IF(J.GT.13)GO TO 53
      DEP5(3,J)=ACRS5SL12(J)
      ADEP5(3,J)=S5SL12(J)/100.
 53   DEP5(4,J)=ACRS5SL25(J)
      ADEP5(4,J)=S5SL25(J)/100.
 50   CONTINUE
C     DO 71 I=1,4
C     WRITE(108,446)(DEP5(I,J),J=1,26)
C71   CONTINUE
C     DO 72 I=1,4
C     WRITE(108,446)(ADEP5(I,J),J=1,26)
C72   CONTINUE
C446  FORMAT(5X,13F8.4)
C -------- INITIALIZE --
      SUM3DEP=SUM5DEP=SUM15DEP=SUMCI=SUMCVC=0.0
      SUMDEP=SBV3=SBV5=SBV15=SUMBV=TACRES=0.0
C -- INCOME FROM CROPS SECTION --
C     CROP VARIABLE COST SHOULD EXCLUDE REPAIR COST ON THE ASSET TO BE REPLACED
C     COMPUTE CROP VARIABLE COSTS
C     AGE REFERS TO THE AGE OF THE ASSET AT THE END OF THE ACCOUNTING YEAR.
      DO 80 I=1,10
      READ(105,100)(CNAME(I,J),J=1,10),CACRES(I),CYIELD(I),
     &CPRICE(I),CVC(I)
 100  FORMAT(10A4,4F12.0)
      IF(CNAME(I,1).EQ.4HLIVE)GOTO 81
      SUMCVC=SUMCVC + CVC(I)*CACRES(I)
      TACRES=TACRES+CACRES(I)
 80   CONTINUE
C     PRINT*,'SUMCVC',SUMCVC
```

```
C -------------------------
C -- LIVESTOCK SECTION OMITTED FOR NOW --
C ---------------------------------
C -- READ OFF-FARM NET INCOME --
 81    CONTINUE
       READ(105,200)OFFNI
 200   FORMAT(T41,F12.0)
C -- CAPITAL GAIN OR LOSS --
       READ(105,200)CAPGAIN
C -- ADJUSTMENTS  TO INCOME --
C --         IRA PAYMENTS, KEOUGH, ETC. --
       READ(105,200)TAXDEF
C -- DEDUCTIONS FROM INCOME -- DEPRECIATION
C -- READ  ASSET NAME, PRICE, AGE, ACRS YRS, & MONTH IF 15-YR ASSET --
C      *** SCHEME FOR LABELLING AGE--1,2,......
C      DO NOT READ THE ASSET TO BE REPLACED
       READ(105,202)NDEPI
       DO 82 I=1,NDEPI
       READ(105,101)(ONAME(I,J),J=1,10),OP(I),OAGE(I),
      &OACRS(I),OMONTH(I)
 101   FORMAT(10A4,F12.0,3I4)
C -- CHECK END-OF-ASSET LIST. --
 82    CONTINUE
C - COMPUTE SUM OF CURRENT YEARS DEPRECIATION --
C      ALSO COMPUTE BOOK VALUE OF DEPRECIABLE ASSETS
       DO 95 N=1,NDEPI
       IF(OACRS(N).EQ.3)GOTO 340
       IF(OACRS(N).EQ.5)GOTO 341
       IF(OACRS(N).EQ.15)GOTO 342
 340   SUM3DEP=SUM3DEP+ACRS3(OAGE(N))*OP(N)/100.0
       SBV3=SBV3+SACRS3(OAGE(N))*OP(N)/100.0
C      COMPUTE BOOK VALUE OF DEPRECIABLE ASSETS
       GO TO 95
 341   SUM5DEP=SUM5DEP+ACRS5(OAGE(N))*OP(N)/100.0
       SBV5=SBV5+SACRS5(OAGE(N))*OP(N)/100.0
       GO TO 95
 342   SUM15DEP=SUM15DEP+ACRS15(OAGE(N),OMONTH(N))*OP(N)/100.0
       SBV15=SBV15+SACRS15(OAGE(N),OMONTH(N))*OP(N)/100.0
 95    CONTINUE
C      PRINT*,'SUM3DEP',SUM3DEP,'SUM5DEP',SUM5DEP,SUM15DEP
       SUMDEP=SUM3DEP+SUM5DEP+SUM15DEP
C      PRINT*,'SBV3',SBV3,'SBV5',SBV5,'SBV15',SBV15
C      SUMBV=SBV3+SBV5+SBV15
C -- PROPERTY TAX INFO --
C -- READ THE MILL LEVY & MKT VALUE FOR MACH., BLDGS., &LAND
C -- COMPUTE SUMTAX = SUM OF PROP. TAXES
       READ(105,202)MILEVY
 202   FORMAT(I4)
       READ(105,205)VMACH,PMACH
       IF(VMACH.LT.1.0)VMACH=SBV3+SBV5
       READ(105,205)VBLDG,PBLDG
       IF(VBLDG.LT.1.0)VBLDG=SBV15
       READ(105,205)MKTVLD,PLAND
       VLAND=MKTVLD*TACRES
 205   FORMAT(2F12.3)
C -- COMPUTE PROPERTY TAXES --
C      CHECK FORMULA FROM PROPERTY TAX MANUAL & FOGLE'S BULLETIN
       SUMPTAX=(MILEVY/1000.00)*(VMACH*PMACH+VBLDG*PBLDG+ASVLND*PLAND*TAC
      $RES)
C      PRINT*,'TAX',SUMPTAX
C -- HIRED LABOR - EXCL. OF CROP VC --
       READ(105,200)HILAB
```

```
C -- BLDG. INSURANCE --
      READ(105,200)BINS
C -- BLDG. REPAIRS --
      READ(105,200)BREPS
C -- LIABILITY $ COMP. INSURANCE --
      READ(105,200)CLINS
      READ(105,200)UTILS
C -- INTEREST EXP. ON LAND, BLDGS., & MACH. --
C     COMPUTE CASH INTEREST PAYMENT ON DEP ASSETS AND LAND
C     READ PERCENT EQUITY AND AVERAGE RATE ON BORROWED FUNDS FOR
C         1.)LAND AND BUILDINGD
C         2.)MACHINERY AND EQUIPMENT
      READ(105,201)PCTEQLD,RILAND
      READ(105,201)PCTEQMY,RIMACH
 201  FORMAT(T41,2F10.0)
      CILAND=(VLAND+SBV15)*(1.0-PCTEQLD)*RILAND
      CIMACH=(SBV3+SBV5)*(1.0-PCTEQMY)*RIMACH
C     PRINT*,'INTEREST',CILAND,CIMACH
C     OUTPUT CILAND,CIMACH
C -- PERSONAL DEDUCTIONS --
      READ(105,200)EMED
      READ(105,200)PRINT
      READ(105,200)OINT
      READ(105,200)CONT
      READ(105,200)EMISC
      READ(105,200)THEFT
      READ(105,200)FINVCR
C     EXCLUDE INVESTMENT CREDIT ON THE ASSET TO BE REPLACED
C ---------------------------------
C -- ADJUSTMENTS TO PERSONAL INCOME --
C ---------------------------------
C -- ZERO BRACKET AMOUNT (INFLATION ADJ.?) --
      ZBA=3400.00
C OR WILL THE TABLE ACCOUNT FOR THIS ?
C -- PERSONAL EXEMPTIONS --
      READ(105,203)NEXEMPT
 203  FORMAT(T41,I4)
      PEXFED=NEXEMPT*1000.00
      PEXST=NEXEMPT*960.00
C ************************************************
C*****ESTABLISH THE I-STATE CONDITIONS
      ISTATE=0
      ADJFIC=0.0
      DO 10 W=1.50,6.51,1.00
C ********* COMPUTE CROP GROSS REVENUE
      B=.727364 + .47322*W
C     COMPUTE CROP GROSS REVENUE
      SUMCGR=CACRES(1)*CYIELD(1)*W+CACRES(2)*CYIELD(2)*B
C     COMPUTE NET FARM PROFIT BEFORE ADJUSTMENTS ASSOCIATED WITH REPLACEMENT
C     THIS IS THE BASE FOR SELF-EMPLOYMENT TAX.
      NFP=SUMCGR-SUMCVC-SUMDEP-SUMPTAX-HILAB-BINS-BREPS-CLINS
     $-UTILS-CILAND-CIMACH
C     PRINT*,'GROSS INCOME',SUMCGR,'FARM PROFIT',NFP,SUMCVC
      DO 10 IAGE=1,15
      DO 10 IDEPI=1,4
      DO 10 ICRI=0,1
      DO 10 IEXPI=0,1
      ISTATE=ISTATE+1
C     EXAMINE ALL DECISIONS FOR EACH I-STATE
C     REFER TO RESULTS OF DECISIONS WITH J NOTATION
C     THE FIRST 16 DECISIONS ARE TO REPLACE
      JAGE=1
```

```
      K=0
      DO 20 JDEPJ=1,4
      DO 20 JCRJ=0,1
      DO 20 JEXPJ=0,1
      K=K+1
C     COMPUTE ADJUSTMENTS ASSOCIATED WITH THE NEW ASSET
C     COMPUTE TAXABLE INCOME ADJUSTMENTS
C      AMOUNT EXPENSED
      ADJFIC=.10*(NP-JEXPJ*EXP)*JCRJ
      DEP=DEP5(JDEPJ,JAGE)*(NP-JEXPJ*EXP-JCRJ*0.5*ADJFIC)
C     ADJUSTMENT TO TAXABLE INCOME
C     DEPRECIATION CANNOT BE CLAIMED IN THE YEAR OF ASSET DISPOSAL
C     COMPUTE DEPRECIATION RECAPTURE
C     COMPUTE ACCUMULATED DEPRECIATION ON PRESENT ASSET
      ADEP=(1.-ADEP5(IDEPI,IAGE))*(NP-IEXPI*EXP-ICRI*0.5*ADJFIC)+IEXPI*E
     $XP
C     COMPUTE BOOK VALUE OF PRESENT ASSET
      BVA=NP-ADEP
C     COMPUTE PROPERTY TAX OF PRESENT ASSET
      APTAX=NP*(MILEVY/1000.)*PMACH
C     REPLACEMENT COST
C     REPLBAL=NP-UPRICE(IAGE)
C     FINANCING COST
      INTEXP=NP*.667*RATE
      PAYMT=INTEXP+(NP*.667/7.)
      REMCST=0.667*(NP*(1.0-IAGE/7.0))
      IF (REMCST.LT.0.) REMCST=0.0
      AUPRICE=UPRICE(IAGE)-REMCST
      DIF=(AUPRICE-NP*.333)*RATE
      DPMT=NP*.333-AUPRICE
      IF(DPMT.LT.0.)DPMT=0.0
C     COST OF A MAJOR BREAKDOWN
      BRKDN=PRBREP(JAGE)*10500.
C     ADJUST NET FARM PROFIT
      ANFP=NFP-DEP-APTAX-REPCST(JAGE)-JEXPJ*EXP-INTEXP+DIF-BRKDN
C ******        COMPUTE SELF-EMPLOYMENT TAX
      IF(ANFP.LT.400.)SET=0.0;GO TO 79
      SET=RSET*(AMIN(ANFP,BASESET))
 79   CONTINUE
C     COMPUTE CAPITAL GAINS OR LOSSES  OF DISPOSED ASSET
      GAIN=UPRICE(IAGE)-(NP-ADEP)
      OINC=AMIN(GAIN,ADEP)
      CAPGNS=GAIN-ADEP
      CAPGNS=AMAX(CAPGNS,0.)
      IF(CAPGNS.GT.0)CAPGNS=0.40*CAPGNS
      IF(GAIN.LT.0.0)CAPGNS=0.5*GAIN
C     COMPUTE DEPRECIATION RECAPTURE OF DISPOSED ASSET
      DEPRCPT=CAPGNS+OINC
C     COMPUTE INVESTMENT CREDIT RECAPTURE
      IF(IAGE.GT.5)GO TO 36
      RCPTFIC=(.10-(IAGE-1)*.02)*ICRI*(NP-IEXPI*EXP)
 36    CONTINUE
      M=K
C     PRINT*,GAIN,OINC,CAPGNS,DEPRCPT,RCPTFIC,REPLBAL
C     **************** TAX SUBROUTINE
      CALL TAXC
C     *********************
      BETA(ISTATE,K)=TBETA
      Q(ISTATE,K)=(REPCST(JAGE)+BRKDN)*DFREPC+DPMT
     &+(SET+FT+ST)*DFTAX+(APTAX+PAYMT)*DFPTAX
C      IF((K.EQ.3).OR.(K.EQ.4).OR.(K.EQ.17))
C    $PRINT*,ISTATE,W,IAGE,IDEPI,ICRI,IEXPI,K,REPCST(JAGE),SET,
```

```
C     $FT,ST,APTAX,Q(ISTATE,K),ADJTI,ATI,INTEXP,PAYMT,DIF,DPMT,
C     &DEP,DEPRCPT,EXP,JEXPJ,AUPRICE,PRBREP(JAGE),BRKDN,BETA(ISTATE,K)
C      PRINT*,REPCST(JAGE),APTAX,DEP,DEPRCPT
C      PRINT*,TI,ADJTI,ATI,FT,ST,ADJFIC,RCPTFIC
 20    CONTINUE
C      ***********    THE LAST DECISION IS TO KEEP THE ASSET **********
       K=17
       IF(IAGE.EQ.15)Q(ISTATE,K)=999999.0;BETA(ISTATE,K)=1.0;GO TO 445
       IF(K.EQ.17)JEXPJ=0
       JAGE=IAGE+1
       ADJFIC=.10*(NP-IEXPI*EXP)*ICRI
       DEP=DEP5(IDEPI,JAGE)*(NP-IEXPI*EXP-ICRI*0.5*ADJFIC)
       ADEP=(1.-ADEP5(IDEPI,IAGE))*(NP-IEXPI*EXP-ICRI*0.5*ADJFIC)+IEXPI*E
      $XP
       BVA=NP-ADEP
C **********          COMPUTE PROPERTY TAX ON ASSET
       APTAX=UPRICE(IAGE)*(MILEVY/1000.)*PMACH
C      COST OF A MAJOR BREAKDOWN
       BRKDN=PRBREP(JAGE)*10500
C      COST OF FINANCING
       IF(K.EQ.17)DIF=0.0;DPMT=0.0
       IF(IAGE.GT.7)INTEXP=0.0;PAYMT=0.0;GO TO 666
       INTEXP=0.667*(NP*(1.0-IAGE/7.0))*RATE
       PAYMT=INTEXP+(NP*.667/7.)
C      ADJUST NET FARM PROFIT
 666   ANFP=NFP-DEP-APTAX-REPCST(JAGE)-INTEXP-BRKDN
C ******        COMPUTE SELF-EMPLOYMENT TAX
       IF(ANFP.LT.400.)SET=0.0;GO TO 35
       SET=RSET*(AMIN(ANFP,BASESET))
 35    CONTINUE
       DEPRCPT=0.
C      REPLBAL=0.0
       ADJFIC=RCPTFIC=0.0
       CAPGNS=0.0
       OINC=0.0
       M=K
C      **************** TAX SUBROUTINE
       CALL TAXC
C      ********************
       BETA(ISTATE,K)=TBETA
       Q(ISTATE,K)=(REPCST(JAGE)+BRKDN)*DFREPC+DPMT
      $+(SET+FT+ST)*DFTAX+(APTAX+PAYMT)*DFPTAX
C      IF((K.EQ.3).OR.(K.EQ.4).OR.(K.EQ.17))
C     $PRINT*,ISTATE,W,IAGE,IDEPI,ICRI,IEXPI,K,REPCST(JAGE),SET,
C     $FT,ST,APTAX,Q(ISTATE,K),ADJTI,ATI,INTEXP,PAYMT,DIF,DPMT,
C     &DEP,DEPRCPT,EXP,JEXPJ,AUPRICE,PRBREP(JAGE),BRKDN,BETA(ISTATE,K)
C      PRINT*,TI,ADJTI,ATI,FT,ST,ADJFIC,RCPTFIC
C      WRITE THE Q(I,K)'S AND BETA'S
 445   WRITE(108,444)ISTATE,W,IAGE,IDEPI,ICRI,IEXPI,(Q(ISTATE,K),K=1,17)
       WRITE(107,447)ISTATE,W,IAGE,IDEPI,ICRI,IEXPI,(BETA(ISTATE,K),K=1,1
      $7)
 444   FORMAT(I5,F5.2,I4,3I2,8F10.2/10X,9F10.2)
 447   FORMAT(I5,F5.2,I4,3I2,8F10.5/10X,9F10.5)
 10    CONTINUE
 570   END
       SUBROUTINE TAXC
       DIMENSION FTAX(15,4),STAX(10,4),REPCST(26)
       REAL INTEXP
       COMMON TI,ATI,SUMCGR,SUMCVC,OFFNI,CAPGAIN,TAXDEF,SUMDEP,SUMPTAX,
      $APTAX,HILAB,BINS,BREPS,CLINS,UTILS,CILAND,CIMACH,EMED,PRINT,OINT
      $,CONT,EMISC,THEFT,ZBA,ADJTI,REPCST,DEP,DEPRCPT,FT,ST,PEXFED,PFXST
      $,BVA,ADEP,EXP,TBETA,RATE,CAPGNS,OINC,DIF,INTEXP
```

```
     $,FTAX,STAX,FINVCR,ADJFIC,RCPTFIC,IAGE,JAGE,M,JEXPJ
C     COMPUTE TAXABLE INCOME PRIOR TO REPLACEMENT EFFECTS
      TI=SUMCGR-SUMCVC+OFFNI+CAPGAIN
     &-TAXDEF-SUMDEP-SUMPTAX-HILAB-BINS-BREPS-CLINS-UTILS
     &-CILAND-CIMACH-EMED-PRINT-OINT-CONT-EMISC-THEFT
     &+ZBA
C     COMPUTE ADJUSTMENTS TO TAXABLE INCOME
      ADJTI=-REPCST(JAGE)-APTAX-DEP+DEPRCPT-EXP*JEXPJ-INTEXP+DIF
C     COMPUTE TAXABLE INCOME ADJUSTED FOR REPLACEMENT EFFECTS
      ATI=TI+ADJTI
C     IF((M.EQ.5).OR.(M.EQ.10).OR.(M.EQ.17)) PRINT*,
C    $M,TI,SUMCGR,SUMCVC,REPCST(JAGE),APTAX,DEP,DEPRCPT,ADJTI,ATI
C MAKE PROVISIONS FOR NEGATIVE TAXABLE INCOME
      FT=ST=0.0
      II=0
 499  FTI=ATI-ST-PEXFED
       IF(FTI.LT.0.0)FTI=0.0
C -- LOOK UP FEDERAL TAX IN TABLES --
      DO 501 K=1,15
      IF(FTI.GE.FTAX(K,1).AND.FTI.LE.FTAX(K,2))
     $FMTR=FTAX(K,3);GO TO 555
 501  CONTINUE
 555  II=II+1
C     WRITE(108,556)II,FTAX(K,1),FTAX(K,2)
C556   FORMAT(' TABLE PASS # ',I2,'  BRACKET IS ',F10.1,' - ',F10.1)
      FTBIC2=FTAX(K,4)+FTAX(K,3)*(FTI-FTAX(K,1))
C     ADJUST FEDERAL INCOME TAX FOR REPLACEMENT EFFECTS
      FTAIC2=FTBIC2-FINVCR-ADJFIC+RCPTFIC
      IF(FTAIC2.LT.0)FTAIC2=0.0
      FDIFF=ABS(FTAIC2-FT)
      FT=FTAIC2
C     WRITE(108,557)FTBIC2,FTAIC2
      STI=ATI-FTAIC2-PEXST
      IF(STI.LT.0.0)STI=0.0
C557  FORMAT(' FED. TAX BFIC= 'F12.2,/,' FED. TAX AFIC= ',F12.2)
C559  FORMAT(' STATE. TAX BFIC= 'F12.2,/,' STATE. TAX AFIC= ',F12.2)
C -- LOOK UP STATE TAX IN TABLES --
      DO 502 J=1,10
      IF(STI.GE.STAX(J,1).AND.STI.LE.STAX(J,2))
     $SMTR=STAX(J,3);GO TO 560
 502  CONTINUE
C560  WRITE(108,556)II,STAX(J,1),STAX(J,2)
 560  STBIC2=STAX(J,4)+STAX(J,3)*(STI-STAX(J,1))
C     ADJUST STATE INCOME TAX FOR REPLACEMENT EFFECTS
      SIC=0.05*(FINVCR+ADJFIC)-.30*RCPTFIC
      IF(SIC.GT.500.)SIC=500.
      STAIC2=STBIC2-SIC
      IF(STAIC2.LT.0) STAIC2=0.0
      SDIFF=ABS(STAIC2-ST)
      ST=STAIC2
C     WRITE(108,559)STBIC2,STAIC2
      TDIFF=SDIFF+FDIFF
C -- CONVERGENCE CRITERIA --
      IF(TDIFF.GT.1.00) GO TO 499
      TMTR=FMTR+SMTR
      TBETA=1.0/(1.0+(1.0-TMTR)*RATE)
C     PRINT*,SMTR,FMTR,TMTR,TBETA
      RETURN
      END
```