Optimal Replacement Interval and Depreciation Method for a Grain Combine

Alfons Weersink and Steve Stauber

A stochastic dynamic programming model is developed to determine optimal replacement intervals and depreciation schedules for a combine on a cash grain farm in north central Montana, where the optimal decision is based on the stochastic nature of winter wheat prices. Empirical results indicate that the decision varies widely depending on the states describing the conditions facing the farm firm. Under normal profitable conditions and ERTA81 tax legislation, suggested replacement is after five years of service, the new asset being depreciated under the accelerated cost recovery system and the investment credit option. Changes to the tax law would tend to smooth out and increase this replacement interval.

Key words: depreciation, marginal tax rate, replacement, stochastic dynamic programming.

The basic marginal principle of economic theory can dictate the optimal replacement age by comparing the costs incurred from keeping an asset for another time period with those which would be realized from a new asset during the same interval. The difficulty with using this criterion arises in the proper specification of relevant cost elements. Recent work has included components besides the traditional repair and acquisition costs which account for the impact of income taxes on replacement policy (Chisholm, Kay and Rister) along with parameters to account for inflation (Bates, Rayner, and Custance) and the assets' true remaining market value (Reid and Bradford).

While these are determinants of cost, their impact on the firm's investment decision is influenced by the economic environment surrounding the enterprise. Tax liability is dependent upon the depreciation schedule and investment incentives used on the asset and upon the level of returns experienced by the firm. Because returns in agriculture are inherently unstable, any study on optimal replacement should consider their stochastic nature. The decision maker does not ignore the stochastic environment nor the time dimensions involved; and thus, neither should any model used in the analysis of replacement slight these factors. These elements of the decision-making process must be included if the previous work on replacement is to be extended. Thus, the objective of this paper is to account for the costs involved in the replacement decision within a stochastic framework.

To incorporate this uncertainty, a stochastic dynamic programming model is used to determine optimal replacement intervals and depreciation schedules for a major farm asset in the midst of fluctuating commodity prices. After the general decision model is developed, it is applied to a typical cash grain farm in north central Montana where the asset of concern is a wheat combine and the optimal decision policy based on the stochastic nature of winter wheat prices. The results, which have applications for similar farms throughout the Great Plains wheat region, are then presented and discussed including the possible impact of the 1986 federal tax reform.

The authors are a graduate student, Department of Agricultural Economics, Cornell University, and a professor of agricultural economics, Montana State University, respectively.

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Decision Model

The replacement analysis involves determining the sequence of decision which minimizes the expected present value of costs associated with each asset during the firm's planning horizon. Rather than being a once-and-for-all decision, the problem is properly formulated as a multistage decision process. The owner must decide whether to replace an asset or keep it another time period subject to the uncertainty surrounding income. It has been assumed that output remains relatively constant, so the stochastic nature of returns is represented solely by commodity prices. The owner is unsure about these price levels for the next period, but current conditions are a useful indication if returns are assumed to be correlated over time. Current information can then determine the relative value of tax deductions which the owner must weigh against purchase costs and increasing repairs when making the replacement decision.

All costs attributed to the asset and relevant to this replacement decision must be reflected in the model by certain state variables. At any point in time the state variables are comprised of asset age, stochastic price level, and existing depreciation method. Together they describe the condition of the system at the time the decision is made plus contain additional information with which the future behavior of the system can be more precisely predicted in response to those decisions. These state variables thus summarize the multistage decision process and form the basis on which the decision rule is made. The optimal replacement policy is then determined by solving the sequence of decisions which minimizes the expected present value of all cash flows associated with each asset. Under the specification described, the proper objective is expected cost-minimization rather than maximizing net returns of the asset because the decision maker has direct control of expenses of the asset through his replacement decision but has no impact on total revenues as output is fixed and prices random. Also note that it is assumed that the machine provides the same quality of services over its life; only maintenance and operating costs change.

The preceding description is formulated in terms of a general dynamic programming (DP) model with the following notation and definitions. As is traditional in DP, the end of the planning horizon becomes the point of reference with the stage of the decision process measured by the number of discrete time periods remaining in the firm's planning horizon. They are denoted by subscripts and the index n, where $n = 0, 1, \ldots, N$. Because the major factors that influence the replacement decision in agriculture occur on an annual basis, a year is an appropriate choice for the time interval between stages. All other variables are on an annual basis and are defined as follows: K is the set of all possible decision alternatives at a given stage and consists of all asset ages and tax alternatives; k is the particular decision selected from the set K; s is the set of state variables which designate the status of the presently owned asset at the current stage in terms of age and depreciation schedule; and p is the set of lagged product prices which comprise the remaining state variables.

The transition of the asset is deterministic and does not involve the price state variable. It is given by

$$s(n-1) = h[k, s(n)],$$

which states that the present status of the asset in stage $n-1$ is a function of asset age and depreciation schedule of the asset in the preceding stage (n) along with the decision alternative selected (k).

The movement of the price vector $\vec{p}$ is stochastic and does not involve the decision variable nor the status of the asset. It is described mathematically as follows:

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

where $\vec{v}$ is the vector of random variables such that there is an element of $\vec{v}$ associated with each element of $\vec{p}$; and $\vec{g}$ is the vector function associated with the elements of $\vec{p}$ and $\vec{v}$. Thus, present price is related to price last period but with a random component included to capture inherent price instability in agriculture.

With these definitions, the recurrence equation to the dynamic programming formulation for the replacement problem is as follows:

$$(1) \qquad f_n(s, \vec{p}) = \min(R(k, s, \vec{p}) + \beta E f_{n-1}[h(k, s), \vec{g}(\vec{p}, \vec{v})]),$$

where $f_n(s, \vec{p})$ is the expected value of discounted costs from an n-stage process under an optimal replacement policy when the initial state is described by the age of the asset (s) and the vector of price state variables (P); $R(k, s, \vec{p})$ is the expected immediate costs in stage n which are a function of the state variables s and p and the decision alternative selected; β is the appropriate discount factor $1/[1 + (1 - t)r]$, where t is the marginal tax rate and r is the real rate of interest; and E is the expectation operator.

The solution procedure iterates backward, stage by stage, through the use of the recurrence equation. It identifies the optimal policy for each state at a given stage where the optimal policy for each state and stage in the future time period is available. If these optimal returns are known, one would make the decision that minimizes the sum of expected immediate costs and the optimal costs from the process starting in the next time period.

Empirical Problem

This dynamic programming model was applied to a representative cash grain farm in north central Montana, where the asset of concern is a grain combine and the optimal decision policy encompasses the stochastic nature of winter wheat prices. Each combine, of which the farmer is the sole owner, is replaced by an identical machine based on the current technology. Each combine has a new purchase price of $80,000 and has a 160-horsepower engine that will handle a 24-foot grain header.

For purposes of determining the marginal tax bracket, the owner is assumed to be married, with two children, and the family's sole means of support is derived from growing grain on 2,400 acres of cropland. Each year, winter wheat will be sown on 1,000 acres, barley on 500 acres; the remaining ground left as summer fallow. The cropping sequence is fixed, as are the crop yields, with wheat presumed to average 35 bushels per acre and barley 50 bushels per acre. The stochastic nature of returns is thus accounted for exclusively by the random price level for grain crops. In order to simplify the computations, barley is expressed in terms of wheat price equivalents. The high positive correlation between these two prices implies that little information is lost by this procedure.

Yields could also be included as another stochastic state variable, but any serial dependence in crop yields is too weak to provide much useful information in the decision process. Since the firm operates in a perfectly competitive market with output and price 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.

The machinery complement and its usage per acre along with the corresponding enterprise costs for a farm this size are summarized in Weersink. These costs are assumed to be deterministic, the only expenses that can change on the farm are those attributable to the combine. Combine costs are directly linked to the replacement decision, and it is the owner's objective in making that decision to determine the age which minimizes the expected value of those costs incurred in obtaining a constant flow of services from a sequence of combines over his planning horizon. The replacement decision is made annually on 31 December so the information concerning the current tax rate is known. The length of the planning horizon is 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 an effort to minimize costs associated with the combine, the owner is interested in the variables that will affect current and future expenses. 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 claimed and the remaining loan balance to be paid. Fifteen possible ages are assumed in this study; and, 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. The cost recovery deductions for property placed in service under the ERTA81 law are calculated with ACRS, the accelerated cost recovery system. Farm equipment, such as combines, are classified as five-year property items under the system and are depreciated as such over that time period. The deductions are calculated by multiplying the measure of investment in the asset by the annual percentages given for five-year property items which are 15%, 22%, and then 21% a year for the last three years. Under ACRS, the owner may alternatively choose to use a straight-line system of depreciation with a recovery period of five, twelve, or twenty-five years. This leaves the owner of a new combine with four depreciation schedules, including the three alternatives under straight line, from which to choose.

A certain part of the cost of the combine can be treated as an expense rather than as a capital expenditure. A decision must be made for each item of qualifying property whether to deduct or capitalize and depreciate the asset's cost. This study assumes that the owner elects to expense the allowable limit of $5,000 which is deductible in the year the property is placed in service 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 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 cost of a depreciable asset directly from their tax liabilities in the year the asset is first purchased. The reduction is 10% 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. If investment credit is taken, then the basis from which depreciation deductions are calculated must be reduced by 50% of the credit. The owner may elect to take a percentage reduction in the regular investment credit down to 8% rather than make the basis adjustment, but this option is not considered here. The tax credit along with the expensing option may be used together or separately, resulting in four possible investment incentives which in turn may be used with any of the four depreciation schedules.

The advantages to any of the options depend upon the returns received from the crops grown. The stochastic nature of returns emanates entirely from the random behavior of grain prices. Though some of the ripple effect on income will be missing without random yields, the six random price levels used in the model should adequately represent the changing economic environment surrounding the farm. The prices range from $1.50 to $6.50, 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 resulting in a model consisting of 1,440 (6 × 15 × 16) states. Two other states would be necessary to incorporate the carryback/carryforward provisions of investment tax credit and net operating losses. The value of the additional information provided in very low income states was not sufficient to warrant its inclusion.

Decision Alternatives

In addition to the basic replacement decision, this study also seeks to find jointly the optimal depreciation schedule and investment incentives to be employed on the new asset available under ERTA81. The attainment of this goal forces the expansion of the replace decision to include the sixteen possible tax options which are summarized in table 1 along with the keep alternative ($k = 17$).

Discount Factor

It is assumed that the owner faces a perfect capital market with the lending and borrowing rate in equilibrium. If this were not the case, the model would direct the owner to borrow all his funds or none at all. As Perrin noted, the appropriate discount rate is represented by the cost of capital since it is the rate at which the owner has the opportunitiy to trade present for future dollars. The interest rate of 6% chosen as the cost of capital contains components to reflect time preference and a risk premium but not inflation, which is held at zero in the model. The real after-tax discount factor used to put the expected costs from each n-stage process in present dollars is $1/[1 + (1 - t)r]$, where r is the real rate of interest and t is the marginal tax rate. Income taxes are determined in the computational process for the expected immediate costs where grain prices are an important determinant of marginal tax rates.

Expected Immediate Costs

The costs associated with the combine are a function of the decision alternative selected and the state variables. As the asset grows older, repair costs are presumed to increase due to wear and tear through operation. The actual

Table 1. Decision Alternatives Available in DP Replacement Model

	Decision Alternative		
k	Options	Depreciation Method	Decision
1	No options		
2	Expensing	5-year ACRS	
3	Investment credit		
4	Expensing and ITC		
5	No options		
6	Expensing	5-year straight line	
7	Investment credit		
8	Expensing and ITC		Replace
9	No options		
10	Expensing	12-year straight line	
11	Investment credit		
12	Expensing and ITC		
13	No options		
14	Expensing	25-year straight line	
15	Investment credit		
16	Expensing and ITC		
17	Maintain present tax conditions		Keep

expenses to fix a down self-propelled combine are calculated from an equation given in the *Agricultural Engineers Yearbook*. Because 1,500 acres of grain are to be harvested each year at an assumed 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 amount of down time estimated by the *Agricultural Engineers Yearbook* is multiplied by the marginal value product of an hour during harvest, which has been assumed to be $20.

There is also an opportunity cost associated with a major breakdown which may force replacement. The probability of such an event is estimated based on the cumulative logistic probability function:

$$P = 1/[1 + e^{(-\alpha+\beta(Age))}], \qquad (2)$$

where P represents the probability of a major breakdown given the age of the combine. Assuming there is a 1% chance of a major failure in the first year and a 50% chance by age nine, the resulting parameters of $\alpha = -4.59512$ and $\beta = .510569$ were calculated based on those two coordinates. The probabilities provided indicate that the chance of a major breakdown occurring in a particular year, given that one has not previously occurred, are continually rising. These unconditional probabilities of involuntary replacement are dependent only on age. Because the chance of a major breakdown might drop after one has happened due to the failure item being repaired, the use of conditional probabilities would mean the addition of another state variable describing the age of the asset when the breakdown happened and/or the overhaul required.

The annual probabilities of a major breakdown are multiplied by the cost of 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 at 750 acres. Multiplying this value by the custom rate of $14 per acre provides an estimate of $10,500 for a major breakdown. An arbitrarily high penalty is 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. A similar relationship describing remaining value to state variable age is necessary so that all relevant costs and returns can be incorporated. To obtain a similar function for combines, time-series data were gathered from the same source (National Farm and Power Equipment Dealers Association) on present used-prices for five combine makes up to six years old with comparable features to the assumed model. The market value for each age of the manufactured models was converted to percentage of present new price for easy comparison and calculation. Because the market value declined at a decreasing rate with age, an exponential functional form was chosen with the following equation as the result, where RV is the remaining value of the combine:

$$(3)\ \ln RV = \underset{(.0265)}{4.4994} - \underset{(.00975)}{.13023}(Age) \quad \bar{R}^2 = .87.$$

Equation (3) is used in determining the property tax associated with the combine and the amount the owner will receive upon the sale of his asset. It is assumed to be sold privately rather than as a trade-in with a dealer which allows him to receive cash on the sale and provides a consistent investment basis throughout the planning horizon. However, the actual amount the farmer gets 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 the asset is disposed of before the end of its fifth year, the investment tax credit is also subject to recapture. The credit is recomputed to reflect its actual life by recapturing a certain percentage which forms a direct addition to the tax liability.

The money received on the sale is used as a down payment in the purchase of a new machine. Typical financing arrangements require that one-third of the new price be put down, which in this case is always $26,400. If the actual amount received on the sold combine is greater than this value, the difference is assumed to be placed in a savings account to earn interest, which is added to income. However, if the market price is less than the required down payment, 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 annual 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 that the owner's equity is such that he has to borrow all the remaining funds necessary to acquire the combine. If the combine were a small capital item on the farm, its replacement would not affect gross receipts and the financing arrangements would be inconsequential. However, because the combine purchase represents a significant capital expenditure to the firm, the fixed costs are important in the analysis. This would be true unless the owner had a cash fund to pay for the asset completely. With the assumption of a perfect capital market, such an ability to completely generate the money internally would mean the cost of borrowing, should he decide to do so, would be offset by the interest earned on a savings account and the effects of financing negated as a result.

Without sufficient equity to cover the purchase price, the interest paid on borrowed funds is greater than the interest earned on savings. The resulting increased tax deductions influence the marginal tax rate, which in turn affects the other parameters in the decision model. It is assumed here that the operator has to borrow all funds necessary to purchase a new combine except for those provided by the sale of the current one. Financing decisions are thus predetermined, placing the emphasis on investment decision making. It should be noted, though, that without the assumption of optimal capital structure, the resulting investment decision may not be optimal.

The final element comprising immediate cash costs is 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 for both federal and state taxes. It also permits the calculation of net farm profit on which a self-employment tax was paid at a rate of 9.35% up to $35,700 in 1983.

Each of the components of the expected immediate costs occurs at different points during the year and thus must be discounted accordingly. If the decision is to replace, a down payment is required immediately, so this value is not discounted. All other expenses are incurred after the 31 December decision period regardless of the decision. Income taxes are paid in April, repairs are made six months later during harvest, and property tax and loan repayments are made at year end. The discussion is summarized with the following equation:

Table 2. Optimal Replacement Age and Depreciation Schedule for Asset Presently Depreciated Under ACRS for Various Discount Rates

Price	Discount Rate	ACRS Depreciation Method			
		No Options	Expensing	ITC	Expensing and ITC
<$3.00	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)
$3.00–$4.00	6	6 (4)*[a]	6 (4)*	6 (4)*	6 (4)*
	9	6 (4)**	6 (4)**	6 (4)**	6 (4)**
	12	6 (4)**	6 (4)**	6 (4)**	6 (4)**
$4.00–$5.00	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)
>$5.00	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)

Note: First number indicates age at which to replace the current asset; bracketed number indicates the optimal depreciation schedule for the new asset based on the decision alternatives in table 1.

[a] Single asterisk indicates replacement policy changes to 3 (ACRS with ITC) in later years; double asterisk indicates keep decision recommended again in later years.

(4) $$R(k, s, \vec{p}) = \textit{downpayment} + [FT + ST + SET]/[1 + r]^{1/3} + [Repair + Brkdn]/[1 + r]^{1/2} + [Paymnt + Proptax]/[1 + r],$$

where $R(k, sp, \vec{p})$ is the expected immediate costs in stage n; downpayment, the amount required to meet mandatory downpayment stipulations; *FT*, federal income tax liability; ST, state of Montana income tax liability; *SET*, self-employment tax payable; *Repair*, the costs of parts and labor to fix a down combine; *Brkn*, the opportunity cost of a major breakdown times the probability of such an event; *Paymnt*, loan repayment including both principal and interest; *Proptax*, property tax associated with the combine; and *r*, real rate of interest.

Transitional Probabilities

The state of the stochastic replacement decision process is controlled at any stage by the transitional probability density function. The state transitions for age and tax conditions are deterministic, so all uncertainty is accounted for by random prices. Prices are assumed to change annually according to a probability distribution based on the following regression that predicts current price as a function of the price in the previous year:

(5) $$P_t = \underset{(1.076)}{1.602} + \underset{(.228)}{.643}P_{t-1} + u_t \quad \bar{R}^2 = .6328.$$

Annual winter wheat prices for the state of Montana were converted to 1983 dollars and then used in the regression analysis. "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 was 1.125" (Yager, Greer, and Burt, p. 463). The transitional probabilities associated with wheat prices were then calculated using the standardized normal variate. Without inflation, the predicted relationships are presumed to continue through the firm's planning horizon.

Terminal Values

Value at the end of the decision process 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 salvage value is represented after that time by the remaining market value. Note that the remaining value is a statistical estimate and that it may have different risks than wheat prices.

Table 3. 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 and ITC
<$3.00	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)
$3.00–$4.00	6	6 (4)*[a]	6 (4)*	6 (4)*	6 (4)*
	9	6 (4)**	6 (4)**	6 (4)**	6 (4)**
	12	6 (4)**	6 (4)**	6 (4)**	6 (4)**
$4.00–$5.00	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)
>$5.00	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)

Note: First number indicates age at which to replace the current asset; bracketed number indicates the optimal depreciation schedule for the new asset based on the decision alternatives in table 1.
[a] Single asterisk indicates replacement policy changes to 3 (ACRS with ITC) in later years; double asterisk indicates keep decision recommended again in later years.

Results

Optimal policies and the expected net present value of costs were obtained by solving the recursive equation (1) for all relevant states and stages. The solution of the model, given in tables 2 through 5, specifies the age at which to replace the existing combine and the tax options to be used on the new asset. They are presented for planning horizons of thirty years in length; however, by stage twenty, the optimal policy had converged into one which was a function of the state only.

The policies are presented for only four different price levels. Both the $1.50 and $2.50 states 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 this price range. The decision rules are nearly identical as well in the two highest price levels, so they have also been grouped together in order to reduce the volume of output.

The results show that, together, the marginal tax rate experienced (price of wheat) and the depreciation method previously used have a large impact on optimal replacement age. If the asset is presently being depreciated under the twenty-five-year straight-line method, then the same schedule will be used on a new combine which is purchased every thirteen years during periods of low returns (see table 5). The ability to deduct depreciation expenses is thus maintained if higher wheat prices, and thus higher marginal tax brackets, prevail. Thus, even though tax policy does not significantly affect the replacement decision during the present periods of such low returns, it is advisable for the owner to choose the proper depreciation schedule which will benefit him when returns increase. This is not the case with other depreciation systems, so replacement generally takes place around age six because of this factor and a combination of increasing repair costs and the avoidance of investment credit recapture.

As wheat price increases, replacement is postponed until the combine has been in service for five full years under depreciation schedules with recovery periods of the same length. This is done to escape any direct addition to tax liability in the form of investment credit recapture, but the significance of this factor declines for longer depreciation methods as income level rises (see tables 4, 5). With these methods, replacement is suggested as early as age one if neither of the investment incentives was previously used and up to age three if both options were utilized. In these instances, the recapture of investment credit and the cost of acquisition are offset by the higher deduction levels available, the negative depreciation recapture, and the new tax credit.

Table 4. 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 and ITC
<$3.00	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)
$3.00–$4.00	6	6 (3)**[a]	6 (3)**	6 (3)**	6 (3)**
	9	6 (3)**	6 (3)**	6 (3)**	6 (3)**
	12	6 (4)**	6 (4)**	6 (4)**	6 (4)**
$4.00–$5.00	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)
>$5.00	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)

Note: First number indicates age at which to replace the current asset; bracketed number indicates the optimal depreciation schedule for the new asset based on the decision alternatives in table 1.
[a] Single asterisk indicates replacement policy changes to 3 (ACRS with ITC) in later years; double asterisk indicates keep decision recommended again in later years.

Even under ACRS, which represents the most rapid rate of deductions, replacement is recommended after three full years of use if the marginal tax rate is 50% (wheat prices above $5) and the investment tax credit has not been employed. It is after five full years of service otherwise (see table 2).

The inverse relationship between investment credit and replacement age supports the results obtained by recent studies, but its real value to farmers 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 in the $3.50 price range if the asset is completely or nearly written off. This gain can be offset by the expensing option, which reduces net farm profit and in turn the amount of self-employment tax payable. However, beyond the age of nine, recapture is lowered as used price falls; and so the ability to reduce taxable income through expensing in the year of purchase does not offset the reduction in future depreciation deductions and in investment tax credit. Because the book and market value do not have this divergence in the longer recovery periods, the desire for immediate deductions is not as great and the investment credit option is used in the replace decision. The same policy is suggested for prices above $3.50 since the expensing deduction does not significantly reduce income below the maximum level on which the self-employment tax is paid.

As a consequence, the apparently attractive expensing option is employed only in particular situations such as described above since the extra value of an early deduction does not generally offset the reduced value of the investment credit base and, therefore, of the credit itself. The impact of expensing could be wider ranging if the allowable limit to expense were increased and/or if the maximum level of net farm profit on which self-employment tax is paid were also increased.

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 when the value of deductible expenses are magnified. However, as Musser, Tew, and White note, the advantages of accelerated depreciation methods are firm specific when the tax rates and the after-tax discount rates are

Table 5. Optimal Replacement Age and Depreciation Schedule for Asset Presently Depreciated Under 25-Year Straight Line for Various Discount Rates

Price	Discount Rate	25-Year Straight-Line Depreciation Method: No Options	Expensing	ITC	Expensing and ITC
<$3.00	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)
$3.00–$4.00	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)
$4.00–$5.00	6	1 (4)**[a]	1 (3)**	2 (3)**	3 (3)**
	9	1 (3)	1 (3)	2 (3)	3 (3)
	12	1 (4)	1 (4)	1 (4)	2 (4)
>$5.00	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)

Note: First number indicates age at which to replace the current asset; bracketed number indicates the optimal depreciation schedule for the new asset based on the decision alternatives in table 1.
[a] Double asterisks, same as in previous tables.

endogenized within the model, as has been done here. The impact of these factors imply that ACRS is not always appropriate during periods of low income, which is consistent with the obtained results. When returns are negative, the new asset should be depreciated under the twenty-five-year straight-line method with no options so that the deductions may be preserved for a time when positive income levels return.

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 9% and 12%. By increasing the discount rate, the present value of tax benefits to be received 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. Rates lower than the original 6% were also used, but the results were not significantly different from those presented earlier.

While the hypothesized effect of the discount rate is true in general, it very much depends upon the state of the process. The keep decision is prolonged in the lower income levels for the longer depreciation schedules. There are still tax deductions available under these methods, and the relative benefits to having them versus the costs involved in purchasing a new machine increase as the interest rate does.

In the $3.50 price level, the keep decision is suggested for increasing periods of time as the interest rises, compared to the minimum age of six years under the 6% discount rate. The optimal replacement interval increases with the interest rate as the criterion optimized is a present value measure which determines implicitly the intertemporal opportunity costs. This effect does not change the replacement age in the higher income levels because of the dampening effect the larger returns have on the after-tax discount rate. However, it does result in the addition of the expensing option with the replacement policy. Even though the basis for computing investment credit and other depreciation deductions are reduced by a value equal to the expenses amount, the deduction occurs in the year of purchase, and, consequently, its relative value will rise with the discount rate.

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 will be greatest at that time. However, only in the lowest income brackets do both the keep and replace decisions occur as optimal choices for this age group. For higher income levels, the decision to purchase a new combine has already been made well before the asset reaches this age. As a result, the obvious impetus to replace as opportunity cost rises and keep if it declines takes place only for a limited number of years in those particular price levels. It has no effect on the depreciation schedule to be used with the new asset.

Impact of 1986 Federal Tax Reform

Two changes especially relevant to such farm assets as a combine have resulted from the new tax legislation. One proposal increases the initial deduction percentages under ACRS but extends the recovery period from five to seven years. In most situations, replacement is delayed until the asset has been completely depreciated regardless of the price level. As a result, a longer time period over which an asset may be depreciated will induce a longer time interval between replacements.

The other modification calls for the elimination of the investment tax credit. As this study has shown, ITC provides a major stimulus for replacement during normal profitable periods. However, during years of low returns and under either of the five-year depreciation methods, replacement is delayed until the asset is fully depreciated in order to avoid investment credit recapture. Thus, replacement interval will tend to be smoothed without the availability of ITC and increased on average. The combined effect of the legislation will be to slow investment in major farm assets and enhance the use of the expensing option as an alternative to investment tax credit.

Concluding Remarks

If a general rule of thumb could be drawn from this study, it would be to replace after five full years of service and depreciate under the accelerated cost recovery system with the investment credit option. The new tax law, with its longer recovery periods and elimination of ITC, would increase this replacement interval to seven years. Under present low prices, replacement age will remain relatively constant, but the method of depreciation suggested is twenty-five-year straight-line with no options. However, these are only generalizations, and the optimal decision rule is very dependent on the specific financial and physical status of the combine and the economic environment surrounding the firm. Because 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.

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