INTRODUCTION

Various financial incentives to gross investment by private firms have been given by the U.K. government in the post-war period. In particular, firms have been able to claim against tax varying amounts of initial and investment allowances as well as annual depreciation allowances. (For a time investment grants - a cash gift - were also given). The focus of this paper is on some of the implications of the use of such instruments for one aspect of farm machinery investment decision-making, namely the optimal timing of replacement using farm tractors as a case study. Since any changes in the planned life of equipment influence the replacement rate (the ratio of replacement investment to capital stock) such implications are also relevant to the study of replacement investment in farm machinery.

Our study is based on a present value cost minimising simulation model incorporating a sensitivity analysis with respect to certain key variables. Tax adjusted replacement models have been presented in the agricultural economics literature by Chisholm (1974) and Kay and Rister (1976). Our framework introduces certain innovations into such models. Firstly, tax elements are embodied within a continuous time framework whereas the previous contributions have utilised discrete time models. The former type of model has, we feel, certain advantages over the latter type of model: it finds the optimum replacement age exactly and it gives a precise shape for the present value cost curve, a feature of some importance as discussed later. Secondly, we extend the tax adjusted replacement model to embrace the influence of inflation when historic cost accounting is used for taxation purposes.

* P.R. Custance acknowledges the support of the S.S.R.C. whilst a postgraduate student at the Economics Department, University of Nottingham.

1 For a discussion of this relationship, see Feldstein and Rothschild (1974) Sections 5 and 6.
2. A CONTINUOUS TIME REPLACEMENT MODEL

Replacement is defined here as the acquisition of a machine to perform a specific function, simultaneously scrapping (selling) or transferring to another use the asset which has hitherto fulfilled that function. The conventional replacement model assumes that the firm chooses the replacement age so as "to minimise the present value cost of obtaining a constant flow of machine services over an infinite planning horizon" (Chisholm, op. cit., p 776)\(^2\) The replacement age is measured in years denoted by \(n\) (note that \(n\) is not necessarily an integer value). The elements entering the cost equation may be examined under the following headings:

(i) Inflation, Taxation and the Continuous Rate of Discount.

Let \(I\) and \(F\) denote the constant annual monetary rates of opportunity cost interest and inflation respectively.

Let \(z\) denote the constant marginal rate of income tax. Since interest charges can be set against tax, the real after tax discount rate (\(R\)) is generally given by

\[
(1+R) = (1 + (1-z)I) / (1+F) \tag{1}
\]

However, the tax relief on interest charges is lagged one year; moreover, the benefits are in depreciated money. Consequently, the effective real after tax discount rate (\(R_e\)) is higher than that implied by equation (1). In particular, let \(W\) be the appropriate correction factor, then\(^3\)

\[
(1+R_e) = (1 + (1-z)I + W) / (1+F) \tag{2}
\]

where \(W = \frac{1}{2}(1 + 2I - 4zI + I^2) + zI - \frac{1}{2}(1 + I)\)

Finally, the continuous rates of inflation (\(f\)), money interest (\(i\)) and real after tax interest (\(r\)) are given by:

\[
\begin{align*}
\text{\(e^f = 1 + f\)} & \\
\text{\(e^i = 1 + i\)} & \\
\text{\(e^r = 1 + R_e\)} & \\
\end{align*}
\]

(ii) Capital Costs and Resale Values

Let \(C_o\) and \(C_n\) denote respectively the initial cost of the machine and its secondhand value at the time of replacement. These money prices are assumed to increase over time at the general rate of inflation.

Then the real present value costs (allowing for the tax offset of interest charges) - of the purchase of the first machine plus an infinite stream of identical replacements less their resale values is:

\[
PV(C) = (C_o - C_n e^{-rn})/(1 - e^{-rn}) \tag{3}
\]

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\(^2\) Stationary technology and certainty are subsumed.

\(^3\) A full derivation of the correction factor can be supplied on request.
(iii) Maintenance and Repair Costs

Maintenance costs can be assumed to increase with the age of the machine. (They also increase pari passu with prices in general). Such costs can be offset against tax, but the benefits are lagged, typically by one year. In addition, such benefits are in depreciated money in inflationary periods. Denoting the repair costs in year $t$ by $M_t$, the real present value maintenance costs of all machines in the chain is:

$$PV(M) = \int_{0}^{\infty} (1 - e^{-rt}) M_t e^{-rt} dt / (1 - e^{-rt})$$

(iv) Annual Depreciation Allowances, Initial Allowances and Balancing Charges

In this section we consider depreciation and initial allowances as the only fiscal instruments affecting the optimal age. These allowances can be set against tax with an assumed lag of one year to allow for the normal 'preceding year' basis of tax assessment used in agriculture. In times of inflation, the use of historic cost accounting procedures mean that the receipts from such allowances are in depreciated money. In addition, when the equipment is sold the difference between the re-sale price and the unexpired depreciation allowances is subject to tax as a balancing charge. In inflationary times, re-sale prices for any given age of machinery are likely to be increasing and may well exceed the unexpired depreciation allowances which are based on historic costs.

Denote the discrete rate of allowance given in the first year of the machine's life by $\nu (0 \leq \nu \leq 1)$. We note that this may be a combination of annual and initial allowances or an initial allowance only or solely an annual allowance.

Denote by $\gamma$ the discrete rate of annual allowances given in the second and subsequent years of the machine's life. ($0 \leq \gamma \leq 1$)

Then the value of the first year allowance may be written as:

$$C_0 - C_0 (1 - \nu) = C_0 - C_0 e^{-\nu} = C_0 (1 - e^{-\nu})$$

where $(1 - e^{-\nu})$ is the rate of the first year allowance adjusted onto a continuous time basis. The value of the second year allowance may be written as:

$$C_0 (1 - \gamma) - C_0 (1 - \nu) (1 - \gamma) = C_0 e^{-\nu} - C_0 e^{-\nu} e^{-\gamma} = C_0 e^{-\nu} (1 - e^{-\gamma})$$

where $(1 - e^{-\gamma})$ is the rate of second year allowance adjusted onto a continuous time basis. Similarly, the value of the third year allowance may be written as:

$$C_0 (1 - \gamma) (1 - \gamma) - C_0 (1 - \nu) (1 - \gamma) (1 - \gamma) = C_0 e^{-\nu} (1 - e^{-\gamma}) (1 - e^{-\gamma})$$
Consequently, the present value of tax benefits accruing from the
allowances for the first machine is:

\[ PV(T_1) = zC_0 (1 - e^{-k}) e^{-(f+r)} + zC_0 e^{-k(1 - e^{-g})} e^{-2(f+r)} \]
\[ + zC_0 e^{-(k+g)(1 - e^{-g})} e^{-3(f+r)} + \text{etc.} \]  

(5)

This can be written as:

\[ PV(T_1) = zC_0 (1 - e^{-k}) e^{-(f+r)} + \{ zC_0 e^{-k(1 - e^{-g})} e^{-2(f+r)} \} \frac{1 + e^{-(g+r)}}{1 - e^{-(g+r)}} \]

\[ + e^{-2(g+r)} + \cdots + e^{-(n-2)(g+r)} \]

(6)

Next, tax is levied on the balancing charge - the difference between the
re-sale price of the machine and its written down value (purchase price less
the sum of expired depreciation allowances). Money re-sale prices are assumed
to keep pace with inflation. However, the (money) written down value is based
on historic costs and loses real value according to the rate of inflation over
the lifetime of the machine. Finally, there is an assumed one year lag for
the payment of tax in depreciated money. Consequently, the real present value
of the tax paid on the balancing charge for the first machine is

\[ PV(T_2) = z(C - C_0 e^{-(n-1)(g+r)}) e^{-(n+1)(f+r)} \]  

(7)

Finally, the total real present value costs of tax allowances and charges
for all machines in the chain is given by:

\[ PV(T) = \frac{-PV(T_1) + PV(T_2)}{1 - e^{-TR}} \]  

(8)

\( v \) Total Present Value Cost

The total real present value cost of replacing each item of equipment
after time period \( n \) of its life is equal to capital costs less re-sale values
plus maintenance costs plus tax costs:

\[ TPV = PV(C) + PV(M) + PV(T) \]  

(9)

3. DATA AND BASE CASE

As far as possible the data used for the base case are relevant to the
conditions appertaining to the early 1970's. The initial cost \( C_0 \) of a
tractor is taken as £2000 for a medium sized tractor (51 - 80 b.h.p.). A re-
sale price function (in real terms) was derived from data on four popular
tractor models over the period 1964 to 1975. Re-sale price as a proportion
of new price was represented as a modified exponential function of re-sale age,
the function being estimated by non-linear least squares. The estimated function
is:
\[ \frac{C_n}{C_0} = (0.0975 + 0.7225(0.38)^n) \]  

(10)

and a graphical depiction is given in figure 1.

**FIGURE 1**
RESALE PRICE FUNCTION

The time path of maintenance and repair costs is crucial to the optimal timing of replacement. Unfortunately, however, comprehensive survey data on maintenance costs under UK conditions are unavailable: the reported surveys (Crozier and Talks (1969) and Gill (1971) and James et al (1972)) are limited in both sample size and age of tractor covered. In particular, they give insufficient or no information on the crucial pattern of maintenance costs in the later years of a tractor's working life. Nevertheless, it was concluded from these surveys that 900 hours per annum was a reasonable estimate of the average annual use of a tractor. This figure is similar to that used by Kay and Rister (1976) for a study of replacement under American conditions. The American Society of Agricultural Engineers (ASAE (1975)) suggest that 12000 hours is a reasonable figure for tractor life which gives a maximum age of 13 1/3 years under 900 hours per annum utilisation. This American publication also posits a maintenance cost function (based on work by Larson and Bowers (1965)) which with the above information is represented by: 

\[ M_t = C_0 0.04068 t^{0.5} \]  

(11)

In our view, this function, hereafter called the ASAE function, is unlikely to adequately represent reality for the reason that it embodies cost increasing at a declining rate. More realistically, we would expect costs to increase at an increasing rate. However, in the absence of fundamental data we suggest the simplest possible alternative: namely a linear maintenance cost function (costs increasing at a constant rate) which gives the same cumulated total cost
as (11) over the lifetime of the tractor. This function is represented by:

$$M_t = C_0 0.0135 t$$  \hspace{1cm} (12)

We note that both functions (11) and (12), are in real terms.

Figure 2 below graphs these alternative functions, (11) and (12), together with the available UK survey data, all related to a £2000 new tractor.
Movements in the retail price index were chosen as an indicator of the rate of inflation whilst the money interest rate was defined as bank rate (minimum lending rate) plus 12%. Since short term movements in the latter can be constrained by considerable political interference leading to capital rationing, it was felt that medium period averages of inflation and money interest rates would be a better indicator of the equilibrium relationship between the two monetary indices. In particular, averages for the period 1966 to 1973 inclusive were chosen as the base data yielding a rate of inflation of 6.5% per annum and an annual monetary discount rate of 19.5%. The interest paid is, of course, affected by the marginal tax rate of the tractor owner. For illustrative purposes, alternative marginal tax rates of 30%, 50% and 70% are used in calculating the real effective after tax interest rate.

The last pieces of data required relate to initial and depreciation allowances. For the base case the allowances given during 1970 were chosen: these are a first year initial allowance of 30% and an annual allowance (year 1 onwards) of 28%. The base data relating to inflation, interest rates, tax rates and depreciation allowances may be summarised in terms of the notation of Section 2 as follows:

\[ I = 0.195 ; F = 0.065 ; Z = 0.30 \text{ or } 0.50 \text{ or } 0.70 \]
\[ \pi = 0.58125 ; \gamma = 0.28125 \]

This information was adjusted onto a continuous time basis as explained in Section 2.

Table 1 records the optimum replacement age at which total present value cost (TVP) is minimised for the base data applied to the two alternative maintenance cost functions and the three alternative tax rates. 5

<table>
<thead>
<tr>
<th>Tax Rate</th>
<th>Maintenance Cost Function</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ASAE</td>
</tr>
<tr>
<td>0.3 (0.074%)(^4)</td>
<td>19.8</td>
</tr>
<tr>
<td>0.5 (0.0393%)(^4)</td>
<td>16.9</td>
</tr>
<tr>
<td>0.7 (0.0020%)(^4)</td>
<td>14.3</td>
</tr>
</tbody>
</table>

\(^*\) The figure in parentheses is the annual effective real after tax discount rate (Re) associated with each tax rate.

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\(^4\) The rate chosen is an estimate of the hire purchase rate (see Allard (1974)) Such a rate overstates the borrowing cost of a bank overdraft. However, the magnitude of bank overdrafts frequently reflects capital rationing by banks and typically the overdraft rate is not the marginal rate. Moreover, the opportunity cost of funds retained from farm profits is likely to be considerably higher than the bank overdraft rate.

\(^5\) Total present value and marginal present value costs were printed out for 0.1 year intervals. The equality of marginal cost to zero was used to pinpoint optimum replacement age.
Clearly, the ASAE maintenance cost function gives rise to results that are unrealistic and uninformative since the lifetime of the tractor is assumed $13^{1/3}$ years. In contrast, the results derived from the analysis employing the linear maintenance cost function are within the bounds of realism and are of interest. In particular, it may be noticed that the lower rates of effective discount associated with higher marginal tax rates induce shorter optimal replacement intervals. Nevertheless, the optimal replacement ages may seem high in relation to practices followed by commercial farmers. One explanation for any inconsistency lies in the shape of the curve relating Total Present Value Cost to replacement age. The curve for the linear maintenance cost function and the 30% tax-payer is depicted below in Figure 3.

**FIGURE 3**

TOTAL PRESENT VALUE COSTS AND REPLACEMENT AGE (BASE CASE)
Initially, costs fall very sharply as replacement age increases so that replacing after three years is half as costly as replacing after 1 year. However, present value cost declines rather slowly as replacement age lengthens from 3 years onwards. Thus replacement at 4 years involves present value cost some 13% higher than that given by optimal replacement (10.4 years) whilst replacement at 6 years involves a present value cost only 4% higher than that associated with the optimum. Thus there is only a small present value cost saving from the optimal strategy rather than replacement several years earlier. This factor combined with an increasing probability of breakdown or loss in reliability leading to downtime costs (costs associated with a loss of timeliness) as a tractor ages would suggest an earlier replacement strategy in practice than those calculated here.

4. REPLACEMENT, TAX ALLOWANCES AND THE RATE OF INFLATION

This section reports results on optimal age and associated real present value costs under various tax allowance schemes with different inflation rates. Particular attention is given to a comparison of results under the allowances chosen for the base case (30% initial and 28½% annual) and those under the 100% initial allowance scheme which operates currently. Two other schemes which were in force in the 1960's are considered in less detail: firstly, 30% investment allowances combined with 28½% annual depreciation allowances and, secondly, a 10% investment grant combined with 28½% annual allowance. In all cases, the linear maintenance cost function is used in the present value cost minimisation model.

Tables 2 and 3 present the results of cost minimisation under the base and 100% initial allowance policies respectively. In each case, four inflation rates are combined with each of the three illustrative tax rates (and associated real effective after tax interest rates). Information is given on present value capital costs less resale prices (C), present value maintenance costs (M), present value costs of tax allowances less balancing charges (T) and total present value costs (TPV), all as defined in Section 2.

Both tables clearly show that inflation raises TPV replacement costs, ceteris paribus under the historic cost accounting principles built into the model. However, TPV costs increase at a declining rate as the rate of inflation increases. It is also apparent that the increase in TPV costs is associated with higher inflation rates and is proportionately larger for the tractor owner paying tax at higher rates (and borrowing at lower effective interest rates). Thus inflation affects optimal age and real replacement costs because tax benefits and payments are made in depreciated money. In particular, for any given replacement age, after tax maintenance costs, M, are
Table 2. 30\% Initial Allowance and 23\% Annual Allowance
Real Present Value Costs at the Optimal Replacement Age for Different tax Rates and Different Inflation Rates

<table>
<thead>
<tr>
<th>Tax Rate</th>
<th>Inflation Rate</th>
<th>£</th>
<th>£</th>
<th>£</th>
<th>£</th>
<th>(years)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0%</td>
<td>3303</td>
<td>1227</td>
<td>630</td>
<td>3700</td>
<td>10.2</td>
</tr>
<tr>
<td>0.3</td>
<td>6.5%</td>
<td>3277</td>
<td>1277</td>
<td>719</td>
<td>3834</td>
<td>10.4</td>
</tr>
<tr>
<td>(Re=0.0741)</td>
<td>13.0%</td>
<td>3251</td>
<td>1325</td>
<td>637</td>
<td>3939</td>
<td>10.6</td>
</tr>
<tr>
<td></td>
<td>19.5%</td>
<td>3238</td>
<td>1359</td>
<td>575</td>
<td>4023</td>
<td>10.7</td>
</tr>
<tr>
<td>0.5</td>
<td>0%</td>
<td>5221</td>
<td>1554</td>
<td>-2361</td>
<td>4425</td>
<td>9.0</td>
</tr>
<tr>
<td>(Re=0.0393)</td>
<td>13.0%</td>
<td>4933</td>
<td>1913</td>
<td>-183</td>
<td>5153</td>
<td>10.1</td>
</tr>
<tr>
<td></td>
<td>19.5%</td>
<td>4884</td>
<td>2027</td>
<td>-136</td>
<td>5415</td>
<td>10.3</td>
</tr>
<tr>
<td>0.7</td>
<td>0%</td>
<td>85,427</td>
<td>15,016</td>
<td>-59,422</td>
<td>41,020</td>
<td>7.3</td>
</tr>
<tr>
<td>(Re=0.0020)</td>
<td>13.0%</td>
<td>71,878</td>
<td>25,424</td>
<td>-36,085</td>
<td>61,216</td>
<td>9.8</td>
</tr>
<tr>
<td></td>
<td>19.5%</td>
<td>70,548</td>
<td>28,498</td>
<td>-31,300</td>
<td>67,744</td>
<td>10.1</td>
</tr>
</tbody>
</table>
Table 3. 100% Initial Allowance

Real Present Value Costs at the Optimal Replacement Age for Different Tax Rates and Different Inflation Rates

<table>
<thead>
<tr>
<th>Tax Rate</th>
<th>Inflation Rate</th>
<th>C (£)</th>
<th>M (£)</th>
<th>T (£)</th>
<th>TPV (£)</th>
<th>n (years)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0</td>
<td>0.0</td>
<td>3372</td>
<td>1175</td>
<td>-241</td>
<td>3605</td>
<td>9.7</td>
</tr>
<tr>
<td>0.3</td>
<td>6.5</td>
<td>3372</td>
<td>1203</td>
<td>-683</td>
<td>3631</td>
<td>9.7</td>
</tr>
<tr>
<td>(Re=0.0741)</td>
<td>13.0</td>
<td>3372</td>
<td>1229</td>
<td>-833</td>
<td>3767</td>
<td>9.7</td>
</tr>
<tr>
<td></td>
<td>19.5</td>
<td>3372</td>
<td>1250</td>
<td>-787</td>
<td>3834</td>
<td>9.7</td>
</tr>
<tr>
<td>0.5</td>
<td>0.0</td>
<td>5398</td>
<td>1458</td>
<td>-2596</td>
<td>4259</td>
<td>8.4</td>
</tr>
<tr>
<td></td>
<td>0.3</td>
<td>5398</td>
<td>1540</td>
<td>-2438</td>
<td>4500</td>
<td>8.4</td>
</tr>
<tr>
<td>(Re=0.0383)</td>
<td>13.0</td>
<td>5398</td>
<td>1613</td>
<td>-2298</td>
<td>4713</td>
<td>8.4</td>
</tr>
<tr>
<td></td>
<td>19.5</td>
<td>5398</td>
<td>1678</td>
<td>-2173</td>
<td>4902</td>
<td>8.4</td>
</tr>
<tr>
<td>0.7</td>
<td>0.0</td>
<td>85,437</td>
<td>15,016</td>
<td>-59,678</td>
<td>40,765</td>
<td>7.3</td>
</tr>
<tr>
<td></td>
<td>6.5</td>
<td>85,437</td>
<td>17,140</td>
<td>-56,004</td>
<td>46,586</td>
<td>7.3</td>
</tr>
<tr>
<td>(Re=0.0020)</td>
<td>13.0</td>
<td>85,437</td>
<td>19,020</td>
<td>-52,765</td>
<td>51,678</td>
<td>7.3</td>
</tr>
<tr>
<td></td>
<td>19.5</td>
<td>85,437</td>
<td>20,695</td>
<td>-48,885</td>
<td>56,232</td>
<td>7.3</td>
</tr>
</tbody>
</table>
increased with increasing inflation because of the reduction in the real value of the offset against tax of such costs. Similarly, the real value of fiscal allowances (net of tax paid on balancing charges), T, are reduced with higher inflation rates.

Ceteris paribus, the increase in real PV maintenance costs with inflation tends to reduce optimal age whilst the reduction in real PV fiscal benefits tends to increase optimal age. In the 100% initial allowance model the magnitude of the two effects are similar and optimal age is insensitive to the inflation rate. On the other hand, in the base model, the fiscal effect outweighs the maintenance cost effect and optimal age increases with increasing inflation. This increase in optimal age directly reduces C, increases M and reduces the absolute value of T.

A comparison of the results under the base and 100% initial allowance systems show that the 100% system gives the lower TPV due to the increasing tax benefits. Furthermore, TPV costs are reduced by a proportionately greater amount, the higher the rate of inflation, and the higher the tax rate paid, ceteris paribus.

Results for two other types of policy instruments - investment allowances and investment grants - combined with annual allowances are presented in tables 4 and 5. Investment allowances permit a firm to set against tax a proportion of the initial cost of the asset at the end of the first year. However, unlike the case of an initial allowance, the firm is not required to depreciate the asset by this amount when computing annual allowances for the second and subsequent years. Thus the investment allowance can be viewed as a cash benefit rising with the marginal tax rate, and is denoted by G for grant in Table 4. Compared to an initial allowance at the same % rate, the investment allowance leads to a larger direct tax benefit and much smaller balancing charge, particularly at higher tax rates. As a result, optimal replacement occurs earlier and TPV cost is reduced as can be seen by comparing Tables 2 and 4. These effects are much more pronounced the higher the tax rate and the lower the inflation rate because the tax benefit in real terms is larger. Indeed at the highest tax rate considered, net present value cost becomes negative for 0.0% and 6.5% inflation rates\(^1\). The reader is left to reflect on the resulting implications.

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1 The partial equilibrium basis of the model should be recalled here: if substantial numbers of tractors were replaced immediately, then the resale price function would probably shift in response and second hand prices would need to be treated as an endogenous rather than an exogenous variable.
### Table 4. 30% Investment Allowance and 28% Annual Allowance

Real present value costs at the optimal replacement age for different tax rates and different inflation rates.

<table>
<thead>
<tr>
<th>Tax Rate</th>
<th>Inflation Rate</th>
<th>C</th>
<th>M</th>
<th>T</th>
<th>G</th>
<th>TPV</th>
<th>n</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.0%</td>
<td>3576</td>
<td>1037</td>
<td>-211</td>
<td>-349</td>
<td>3443</td>
<td>8.4</td>
</tr>
<tr>
<td>0.3</td>
<td>6.5%</td>
<td>3431</td>
<td>1160</td>
<td>-642</td>
<td>-291</td>
<td>3557</td>
<td>9.3</td>
</tr>
<tr>
<td>(Re=0.0741)</td>
<td>13.0%</td>
<td>3344</td>
<td>1249</td>
<td>-528</td>
<td>-252</td>
<td>3813</td>
<td>9.9</td>
</tr>
<tr>
<td></td>
<td>19.5%</td>
<td>3303</td>
<td>1305</td>
<td>-469</td>
<td>-225</td>
<td>3933</td>
<td>10.2</td>
</tr>
<tr>
<td>0.5</td>
<td>0.0%</td>
<td>6357</td>
<td>1106</td>
<td>-2072</td>
<td>-1218</td>
<td>4174</td>
<td>5.9</td>
</tr>
<tr>
<td>(Re=0.093)</td>
<td>6.5%</td>
<td>6357</td>
<td>1106</td>
<td>-2072</td>
<td>-1218</td>
<td>4174</td>
<td>5.9</td>
</tr>
<tr>
<td></td>
<td>13.0%</td>
<td>5461</td>
<td>1577</td>
<td>-1484</td>
<td>-830</td>
<td>4724</td>
<td>8.2</td>
</tr>
<tr>
<td></td>
<td>19.5%</td>
<td>5293</td>
<td>1606</td>
<td>-1201</td>
<td>-692</td>
<td>5108</td>
<td>9.1</td>
</tr>
<tr>
<td>0.7</td>
<td>0.0%</td>
<td>86,88</td>
<td>20,416</td>
<td>-26,995</td>
<td>-21,230</td>
<td>58,277</td>
<td>7.2</td>
</tr>
<tr>
<td>(Re=0.0020)</td>
<td>6.5%</td>
<td>86,88</td>
<td>20,416</td>
<td>-26,995</td>
<td>-21,230</td>
<td>58,277</td>
<td>7.2</td>
</tr>
<tr>
<td></td>
<td>13.0%</td>
<td>86,88</td>
<td>20,416</td>
<td>-26,995</td>
<td>-21,230</td>
<td>58,277</td>
<td>7.2</td>
</tr>
<tr>
<td></td>
<td>19.5%</td>
<td>86,88</td>
<td>20,416</td>
<td>-26,995</td>
<td>-21,230</td>
<td>58,277</td>
<td>7.2</td>
</tr>
</tbody>
</table>

*Negative TPV for age < 1 year
*Negative TPV for age < 5 years
*Negative TPV for age < 3 years
*Negative TPV for age < 2 years

*Immediate replacement is optimal.
Table 5. 10% Cash Grant and 28% Annual Allowance

Note: Present Value Costs at the Optimal Replacement Age for Different Tax Rates and Different Inflation Rates.

<table>
<thead>
<tr>
<th>Tax Rate</th>
<th>Inflation Rate</th>
<th>C</th>
<th>N</th>
<th>T</th>
<th>G</th>
<th>TPV</th>
<th>n</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.3</td>
<td>0.0%</td>
<td>3492</td>
<td>1091</td>
<td>-704</td>
<td>-372</td>
<td>3508</td>
<td>8.9</td>
</tr>
<tr>
<td>(Re=0.0741)</td>
<td>6.5%</td>
<td>3386</td>
<td>1192</td>
<td>-556</td>
<td>-317</td>
<td>3705</td>
<td>9.6</td>
</tr>
<tr>
<td></td>
<td>13.0%</td>
<td>3317</td>
<td>1271</td>
<td>-456</td>
<td>-277</td>
<td>3852</td>
<td>10.1</td>
</tr>
<tr>
<td></td>
<td>19.5%</td>
<td>3277</td>
<td>1327</td>
<td>-390</td>
<td>-247</td>
<td>3966</td>
<td>10.4</td>
</tr>
<tr>
<td>0.5</td>
<td>0.0%</td>
<td>5558</td>
<td>1377</td>
<td>-2039</td>
<td>-705</td>
<td>4191</td>
<td>7.9</td>
</tr>
<tr>
<td>(Re=0.0393)</td>
<td>6.5%</td>
<td>5111</td>
<td>1710</td>
<td>-1493</td>
<td>-547</td>
<td>4776</td>
<td>9.4</td>
</tr>
<tr>
<td></td>
<td>13.0%</td>
<td>4933</td>
<td>1913</td>
<td>-1194</td>
<td>-446</td>
<td>5186</td>
<td>10.1</td>
</tr>
<tr>
<td></td>
<td>19.5%</td>
<td>4837</td>
<td>2063</td>
<td>-992</td>
<td>-411</td>
<td>5408</td>
<td>10.5</td>
</tr>
<tr>
<td>0.7</td>
<td>0.0%</td>
<td>99,553</td>
<td>11,371</td>
<td>-56,518</td>
<td>-17,895</td>
<td>36,507</td>
<td>5.5</td>
</tr>
<tr>
<td>(Re=0.0020)</td>
<td>6.5%</td>
<td>75,394</td>
<td>21,297</td>
<td>-33,395</td>
<td>-9,796</td>
<td>53,298</td>
<td>9.1</td>
</tr>
<tr>
<td></td>
<td>13.0%</td>
<td>69,265</td>
<td>26,980</td>
<td>-24,665</td>
<td>-7,759</td>
<td>63,799</td>
<td>10.4</td>
</tr>
<tr>
<td></td>
<td>19.5%</td>
<td>66,832</td>
<td>31,003</td>
<td>-19,589</td>
<td>-6,874</td>
<td>71,570</td>
<td>11.0</td>
</tr>
</tbody>
</table>
Investment grants were a cash gift paid by the government equal to a percentage of the purchase price of the tractor. Unlike the investment allowance tax benefit, this grant was deducted from the purchase price in the calculation of annual depreciation allowances. Table 5 records results for a 10% cash grant, (combined with the standard annual allowance). For the 30% tax payer, the direct value of the 10% cash grant exceeds by a small amount the direct tax benefit of a 30% investment allowance. However, because the tax benefits of depreciation allowances (net of balancing charge) are somewhat lower under the cash grant policy, such a policy slightly increases replacement age and increases TPV cost, compared to the investment allowance policy for the 30% tax payer (compare Tables 4 and 5). For tractor owners paying tax at the higher rates of 50% and 70%, investment allowances confer larger reductions in TPV cost than the cash grant because the latter is invariant with respect to the tax rate.

Finally, Tables 4 and 5 indicate that higher rates of inflation increase TPV cost and lengthen optimal replacement age under the operation of both investment allowance and grant schemes. These effects of inflation are more pronounced than under the two schemes discussed earlier. In addition, a comparison between Table 3, (100% initial allowance) and Tables 4 and 5 is of some interest. At inflation rates of 5.5% and above, 100% initial allowances give a lower TPV cost than the 10% cash grant cum annual allowance scheme for all three tax rates. The 30% investment allowance cum annual allowance tends to be more advantageous to the tractor owner than 100% initial allowances at low rates of inflation. However, the situation is reversed under circumstances of medium to high rates of inflation depending upon the tax rate paid by the tractor owner.

5. SUMMARY AND COMMENT

A continuous time present value cost simulation model incorporating relevant tax elements has been used to investigate certain aspects related to the optimal timing of tractor replacement. Particular attention has been paid to the implications of certain fiscal incentive schemes under differing levels of inflation when historic cost accounting principles govern the calculation of tax payments and receipts.

A major problem encountered in the construction of the empirical model was a lack of suitable data on the relationship between maintenance cost and age of machine. In the event, a linear function was chosen as a convenient ad hoc expedient. However, our first conclusion must be that there is a need for the collection of relevant maintenance cost data if the replacement decision is to be studied adequately from a policy viewpoint.
Subject to the caveat concerning maintenance costs, our second conclusion relates to the shape of the curve of real total present value cost (TPV) to replacement age. Under the fiscal incentive scheme chosen as the base for comparison (30% initial allowance plus 28½% annual allowance), the TPV curve falls very sharply at first but then flattens out considerably and becomes almost flat for a number of years either side of the optimal age (see Figure 3). Curves of this shape are also typical for the other schemes considered under most tax and inflation rates. Thus, there is only a small present value cost saving from optimal timing of replacement rather than somewhat earlier replacement. This conclusion explains to a considerable extent our impression that farmers tend to have an earlier replacement strategy in practice than most of those calculated in the paper.

Our third conclusion relates to the impact of inflation on replacement. Higher rates of inflation invariably increase the TPV cost of replacement and usually lengthen optimal replacement age. The reasons for increased costs with high rates of inflation are that at any given replacement age, the real value of fiscal allowances (net of balancing charges) and the real value of the tax offset of maintenance costs are reduced.

The 100% initial allowance policy, introduced during the 'inflationary 1970's' nullifies the cost-increasing effects of inflation to a certain extent. In proportionate terms, costs increase far less with increasing inflation than under any of the alternative policies investigated. Moreover, at high rates of inflation, TPV cost is less under 100% initial allowances than under any of the alternative policies for a given tax rate. Thus the trend in policy in the early 1970's toward higher and higher initial allowances culminating in 100% initial allowances since 1972 can be seen to have given some relief to tractor owners faced with increased replacement costs resulting from the inflationary conditions of the 1970's. In a sense, 100% initial allowances can be viewed as a limited substitute for tax accounting principles based on real rather than historic cost during periods of rapid inflation.

In so far as fiscal incentive schemes are designed to reduce replacement cost, then 100% initial allowances are the most effective at moderate and high rates of inflation. Inevitably, tractor owners paying tax at higher rates benefit more than those paying tax at lower rates. Thus, TPV as a proportion of net capital cost is roughly 60% for the 70% tax payer and roughly 110% for the 30% tax payer.¹ At very low inflation rates, the investment allowance and cash grant schemes provide lower TPV costs at optimal

¹ Recall that a direct comparison of TPV for owners paying tax at different rates cannot be made from the tables because a different discount rate is associated with each tax rate.
replacement ages. Again the relief may be seen to be greater for the owner paying tax at higher marginal rates. Indeed, investment allowances implied a negative TPV for the 70% tax payer with immediate replacement. Such a result suggests that investment allowances on the scale of 30% are not a justifiable policy under conditions of nil or very modest inflation from both efficiency and equity viewpoints.

Finally, the results show that optimal replacement age is lower, the higher the (long term) marginal tax rate faced by the tractor owner. This effect stems from the lower effective interest paid and the higher real tax benefits received from fiscal incentives by the higher tax payer.

REFERENCES


References (continued)

