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Optimum replacement of farm machinery under conditions of capital rationing - Preliminary results.

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ABSTRACT

Australian farmers invest over two thirds of their capital expenditure on farm machinery and equipment. Clearly investment decisions of this magnitude have a big impact on the viability of the farm. Complicating the situation is the erosion of the capital base which has occurred on Australian farms over the last fifteen years, due to high interest rates, low world commodity prices, droughts and the tightening of requirements by financial institutions. This paper presents some background on machinery investment in Australia and reviews what has historically been seen as the key decision variables. Results are then presented from a spreadsheet analysis undertaken as part of a larger project to investigate optimal machinery replacement for Australian conditions.

INTRODUCTION

Over the last fifteen years annual expenditure on plant and equipment has fallen from an average of $50,000 down to $10,000 per farm (see Figure 1). Similarly the ratio of capital additions to total farm expenditure has fallen from 23% to 11% (ABARE,1994). Further evidence of the situation was provided by Powell and Milham (1990) who showed that capital stocks declined by an estimated 3% per year for the 10 years prior to 1989-90. This clearly implies that capital equipment on Australian farms is becoming run down.

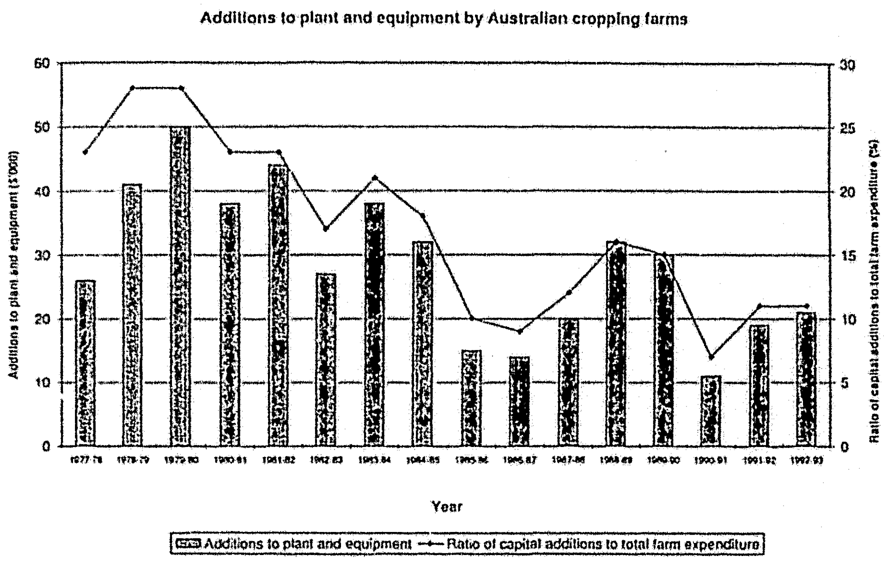

Figure 1. Additions to plant and equipment on Australian farms. Source: ABARE, 1994.

It has been suggested that this trend is due to the combination of a number of factors. In the late 1970s and early 1980s machinery prices increased relative to the cost of all other farm inputs (Knopke and Harris 1991), and in the early 1980s the government removed the investment allowance on farm machinery purchases. The rise in interest rates from the late '70s to the late '80s was around 7% (6% -14%), with some farmers charged up to 22%. Low commodity prices and drought conditions brought about further credit rationing by banks in the late 1980s. The adoption of minimum tillage production techniques all combined to extend this reduction in machinery investment by farmers into the 1990s (Nicholas and Horton 1991).

Debt over the last decade has increased sharply. With increased levels of borrowing and interest rates the total cost of financing this debt has risen (Tucken, Berenger and Backhouse 1990). Farmers generally owe around two thirds of their debt to banks, around 10% to pastoral and insurance companies, 3% to financing leasing and 3% to high purchase loans (ABS 1994).

The result of all these pressures has meant that much of the plant and equipment on Australian farms has now aged far beyond its normal economic life. Only one quarter of Australian cropping farms have a main tractor under six years old (ABARE, 1994). The average age of the main tractor is eleven years old. The situation is worse on livestock farms with only a quarter of farmers owning a tractor under nine years old and an average main tractor age of sixteen years (see Table 1).

With the developments over the last decade as described above, not only is the concern that farmers cannot take advantage of technological developments, but also that they are exposing themselves to potentially large timeliness costs due to increasing breakdown chances.

Table 1. Distribution of farms, by age of main tractor (average per farm).

Percentage of farms with age of main tractor at or below value shown	Cropping farms		Livestock farms	
	1988-89	1992-93	1988-89	1992-93
25 per cent	4	6	5	9
50 per cent	7	10	11	15
75 per cent	10	14	20	23
Average age	8	11	13	16

Note: Where farms have more than one tractor, the main tractor is defined as the tractor that has the highest replacement value. Source: ABARE, 1994.

The average age of headers has risen two years over the last decade to be fifteen years old (see Table 2). The developments in technology in headers is possibly more dramatic than those in the tractor industry. This situation compounds the losses to the industry of not being able to take advantage of these advances.

Table 2. Distribution of farms, by age of header (average per farm).

Percentage of farms with age of header at or below value shown	Cropping farms	
	1988-89	1992-93
25 per cent	7	9
50 per cent	11	14
75 per cent	18	19
Average age	13	15

Source: ABARE, 1994.

Shortage of funds and restrictive bank lending policies have meant that capital rationing is an important concern for farmers at the moment. Whether the optimal replacement decision for Australian farmers should be made on an ad hoc or planned basis, the identification of influencing factors will assist in better decision making. Of the money Australian farmers spend on capital assets approximately three quarters is on farm machinery. With a new tractor costing in the vicinity of $100,000 investment decisions of this magnitude clearly have a big impact on the farm's viability.

This paper reviews what has historically been seen as the key decision variables and their influence on optimal machinery replacement. Preliminary results are then presented from an analysis of optimal replacement undertaken as part of a larger project to investigate the decision for Australian conditions.

FACTORS INFLUENCING THE REPLACEMENT DECISION

The main prompt for a farmer to replace a tractor is when the costs involved in running a tractor appear to be higher than the costs of acquiring a newer one. These costs can be grouped into operating costs, breakdown repair costs and timeliness costs.

The probability of tractor breakdown is conditional on the age and service history of the tractor. The costs can be dependent on when the breakdown occurs and the availability of the repair parts required. The hidden cost of tractor or header breakdown is the timeliness cost involved particularly if the breakdown occurs during a crucial farming stage (planting or harvest). Timeliness costs are also incurred when farmers do not take advantage of technological advancements in the industry.

Once it appears clear to the farmer that the cost of retaining the tractor is higher than acquiring a better tractor, the financing hurdle must be cleared. Restrictions on borrowing methods due to individual farm's financial situation as well as the general farming sector financial situation are central to both whether another tractor will be acquired and what financing method can be used. With capital rationing (both internal and external to the farm) many farmers have been forced to continually delay their replacement decisions. This has the disadvantage that farmers are placed in a weak bargaining position while their situation is made worse due to increased breakdown and timeliness costs.

The literature addressing the optimal replacement problem is approached from a number of different angles. These have included maximising the net present value of asset returns: minimising the net present cost of the asset and determining: the influence of discount rates, inflation, tax, opportunity costs, breakdown risk, and capital rationing.

Initially the solution was described as the time period which maximised revenue (Hirschleifer, 1958; Farris, 1960). This assumed the physical inputs and their related costs were fixed while total revenue varied. A range of authors then further refined the analysis method and emphasised the importance of discount rate and interest costs (Chisolm 1966, Perrin, 1972).

A general model of asset replacement was used by Perrin (1972) to argue that for durable equipment maximising present value of residual earnings was equivalent to minimising present value of the cost of the machine. This was because the flow of services was by definition constant, except in the case of replacement of technologically improved assets.

Tax, as one of these component costs has been considered in terms of investment incentives (tax credits) depreciation methods, and marginal tax rates.

Chisolm, (1974), found that a 20% investment allowance substantially decreased the optimal tractor replacement age for high tax bracket farmers in Australia. Whereas an accelerated depreciation allowance for the same had little influence. The small effect of various tax depreciation methods on optimal replacement age was confirmed by Kay and Rister (1976), and subsequently by Reid and Bradford (1983).

Lewis et al (1988) showed that the cost of capital for the farm firm was determined by their marginal tax rate, and that it was the fall in the cost of capital which was important in determining plant and machinery investments.

The fact that optimal replacement intervals were reduced as marginal tax rates rose effectively suggests that low income farmers will ignore the tax law (Chisolm,1974; Lynne, 1988). In this situation profit maximising reinvestment occurs significantly later in the life of the machine. The importance of this increases as the number of farmers in the low income bracket increases.

Smith (1990) showed that the optimal replacement time was inversely related to the size of the investment tax credits and the present value of the depreciation allowances. Further, it was directly related to marginal tax rates. He found the effect of the TRA was to increase the replacement age for short depreciation lives (tractors) and decrease it for items with long depreciation lives (farm structures).

Kay and Rister argued that improved technology had a major effect on reducing the optimal replacement age. Chisolm (1976) also indicated that loss in reliability as a machine ages was a more important factor in the replacement decision. This was also confirmed by Lynne, 1988; VanTassell and Nixon, 1989 and Perry and Nixon, 1989.

The influence of capital rationing on the optimal replacement time was explored by Lorie and Savage (1955) initially and then Weingarten (1977). They both treated the decision as a financial management decision. Weingarten defined capital rationing as "a market-imposed limitation on the expenditures a firm may make". He distinguished between whether the focus of the capital rationing was that of the firm or that of the manager.

The feasibility of investment conclusions is often questioned when the debt profile of farmers is considered (Bright, 1987). Lynne argued that as there were multiple optimal replacement ages farmer objectives must be known to distinguish between them.

PROBLEM SOLVING APPROACHES TO THE OPTIMAL REPLACEMENT DECISION

Solution methods

A variety of operations research tools are available to solve the asset replacément problem. Small problems can be solved using budgeting methods to enumerate all reasonable replacement intervals. This method now lends itself to spreadsheet solution, especially when macros are employed to automate tedious data entry. It is relatively easy to add simple simulation to components of spreadsheets to model probabilistic elements of the environment.

Linear programming, provides a method of solving the replacement problem. The usual objection to linear programming in the modelling of risk responses can be overcome to some extent by combining simulation methods with LP, and/or using non-linear programming methods. In problems of replacement under capital rationing, integer programming methods can be useful.

Dynamic programming can also be used to solve machinery replacement problems (Kennedy 1986 p. 136-41, Pagoulatos and Blackwell 1992). DP can provide a very efficient solution method and the dimensionality problem that plagued it in the past has diminished with the advent of computers with large amounts of memory. However, model specification still remains difficult when compared to budgeting and linear programming methods.

The Spreadsheet model

A spreadsheet was used to model the decision for replacing the main tractor on a typical cropping farm in the wheat-sheep belt of New South Wales. The loan purchase of a new $100,000 tractor over a range of replacement periods (2-25 years) was modelled for a 50 year planning horizon.

The spreadsheet was structured to separately calculate the costs associated with operating costs, repair costs, residual value decline, interest and capital repayments, and the taxation benefits associated with the depreciation rate and marginal tax rate. A series of macros were written to enable the net present cost to be calculated for alternative replacement periods and collated into a linked spreadsheet.

The key assumptions used within the spreadsheet are documented in Table 3. The purchase price of $100,000 approximates the list price of a new 140 h.p. standard broad acre cropping tractor. The scenario was analysed for a typical loan purchase situation. The spreadsheet model is based on six month intervals to enable the inclusion of tax effects.

It was assumed that the tractor would decline in value at approximately 10% of its value per year. However, it has been shown by Cross and Perry (1994) that the depreciation rate of farm machinery is not accurately described by straight line depreciation, costs of diminishing value or the American Society of Agricultural Engineers depreciation functions.

Table 3. Assumption used within the spreadsheet analysis.

ASSUMPTION	VALUE
Purchase Price	$100,000
Marginal Tax Rate	5%
Depreciation Rate	20% over 5 Years
Discount Rate	7% per annum
Interest Rate	12%
Months until June	1 Month
Operating Costs	$32 per Hour @ 1000 Hrs/yrs
Residual Value Decline	10% per annum
Interest Rate	12% calculated and paid Yearly
Repair Costs	Year 5 = $5000 Year 10 = $10,000. Year 15 = $10,000. Year 20 = $10,000

The repair costs used in this model were derived from a survey undertaken by the Konindin Group (Konindin Group, 1992). It is difficult to get accurate estimates for repair costs on tractors with over 10,000 hours as this becomes highly dependent on the service history of the machinery. Operating costs are those estimated for the NSW crop production budgets for the central cropping region (Fraser et al., 1993).

The marginal tax rate used for this example was 5%. However, the average marginal tax rate for Australian farmers is closer to 25%. In this preliminary analysis no account was taken of technological innovations or timeliness costs associated with breakdowns.

RESULTS

With the above assumptions the lowest net present value was at 14 years for the optimal tractor replacement age (see Figure 2). The net present value of costs declined steeply as the replacement intervals increased from 2 to 8 years. The costs then flattened out between 8 and 20 years replacement age at which point costs then rose again up to 25 years. There is little difference in the net present costs of replacing the tractor between the ages of 8 years or 20 years. Within this time span there tends to be multiple optima as identified by Lynne (1988).

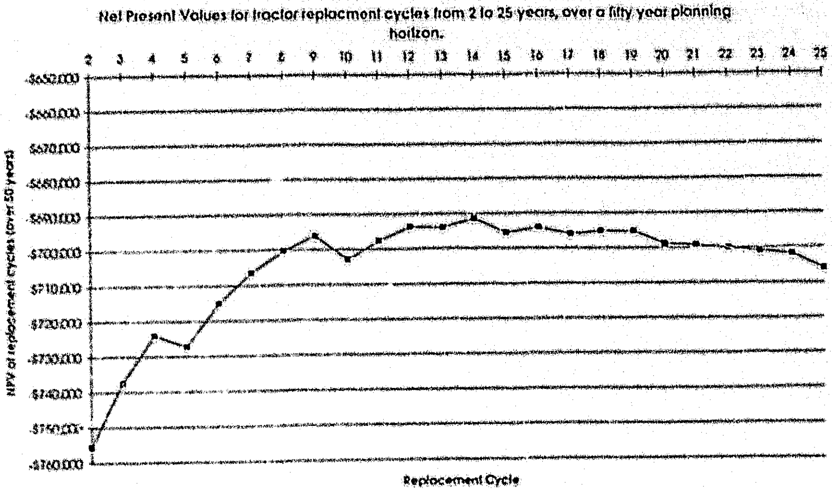

Figure 2. The Net Present Value for Replacement Cycles from 2 to 25 years.

It is important to remember that no account was taken of the value of technological innovations or timeliness costs associated with breakdown. The optimal replacement age, identified as 14 years is close to the average age of the main tractor on Australian cropping farms which is 11 years. The difference here is thought to be due to the above mentioned timeliness costs. Within the literature reviewed the optimal replacement age varies from every 3 to every 12 years. The difference between this and the Australian situation is thought to be due to credit rationing brought about by the poor financial position Australian cropping farmers are in at the moment, and credit rationing by lending institutions.

The aim of this research is to develop both rules of thumb and paper or computer based decision support systems for farmers' machinery replacement decisions. It is hoped that the spreadsheet model will better define the problem on which to base future LP or DP models. Ideally probabilistic information on repair costs and depreciation costs would assist in making these models more realistic. Although this information has proven difficult to retrieve for Australian conditions it is hoped that interviews with farmers and banks will assist. Sensitivity analysis will also assist in identifying the more important factors in the replacement decision. The model will be run to take into account variations in available finance, tax rates, discount rates, purchase dates, finance method, hours of use, breakdown risk, breakdown costs and timeliness costs.

Within the spreadsheet analysis the influence of capital rationing is proposed to be modelled on a case by case situation. By identifying the critical levels farm economic indicators required by banks and financing companies, the available financing methods can be identified for each scenario. Similarly, the expected cash flows estimated for the future, determine payments which are possible for the farmer, and the financing methods which can be accommodated.

CONCLUSIONS

After fifteen years of pressures against capital replacement, the Australian farmer is now working with tractors eleven to sixteen years old and headers thirteen years old. The cost to the industry due high breakdown and timeliness costs and lost productivity from missing out on technological advances is, no doubt, high. Many farmers are now being forced to decide how to finance replacement machinery under the conditions of capital rationing they now find themselves in.

The literature identifies key factors influencing the replacement decision economically, as usage and repair costs; probability and pattern of breakdown; taxation structures and marginal tax rates, capital rationing and farmers objectives. Previous analysis of the replacement problem for a variety of other situations identified an optimum replacement age for tractors anywhere between 2 years to 12 years. The results presented here from a spreadsheet analysis using Australian conditions indicated 14 years was the optimal time. It was established that this replacement age could be over estimated as no account for technological advances and opportunity costs were included. Further research on this topic will yield information on more profitable ways for farmers to make their machinery replacement decisions.

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