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A COMPARATIVE ANALYSIS OF AGRICULTURAL TRACTOR INVESTMENT MODELS

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An implicit rental price approach is used to analyse the determinants of farm tractor investment at the aggregate level. Three models, based on different assumed factor substitutabilities, are compared. Variations in the rental price of tractors appear to have less effect on demand than variations in factors affecting the profitability of the cropping enterprise as a whole. The implications for forecasting and for policy instruments, such as the investment allowance, are discussed.

There has been a profusion of economic analysis of both investment behaviour and of the determinants of investment decisions. Most of this analysis has dealt with aggregate investment for the entire economy or for particular sectors, rather than with decisions relating to individual types of capital equipment.

In this paper, the focus is on investment determinants at the firm level. Three distinct approaches to investment analysis are identified. These are developed at the microeconomic level, by considering the basis of individual decisions, and tested empirically at the aggregate level. Tractors are of interest because of the size of the capital outlay required and the range of different investment theories that have been used to model this decision. In addition, data pertaining to tractors are superior to those relating to other durable farm inputs.

Tractors are a significant component of the capital cost of farm machinery (about 40 per cent), which in turn account for about 10 per cent to 15 per cent of total farm costs. Normally, about 12 000 to 14 000 tractor units are sold annually. The average size has trended upward over time. The aggregate investment expenditure in farm tractors was about \$400m in 1983–84.

Tractor sales have been analysed *inter alia* by Penson, Hughes, and Nelson (1977), Penson, Romain, and Hughes (1981), Rayner and Cowling (1967, 1968), Griliches (1960), and by Filmer and Ferris (1976). Although a range of approaches has been used, the majority of recent studies have adopted the rental price approach, as expounded by Jorgensen and Stephenson (1967) and Coen (1975). This approach has also been used to model aggregate rural sector investment (Fisher 1974).

In this paper, a putty-putty model is compared to putty-clay and clay-clay models. In the first model, it is assumed that factor proportions are flexible and responsive to relative price movements both before and after the installation of the capital item. The putty-clay model implies fixed factor proportions once the capital has been installed, while the clay-clay alternative is based on the premise that factor proportions are determined by the nature of the production process and are not responsive to relative prices either before or after installation.

The putty-putty and putty-clay models are examined using the rental price approach. The explanatory power of these models is mediocre and it is apparent that the rental price variable *per se* has a relatively minor effect on the variations in net tractor investment. The clay-clay model, in which investment is related to area sown, is more satisfactory.

In the next section, the background to the study, including the pattern of gross and net investment, is discussed. The following sections contain discussion of the three basic models, specification of the rental price series, results and a discussion of the implications for investment policy and forecasting.

Background

Annual sales of tractors fluctuate considerably. Over the period 1957–58 to 1982–83, annual sales, expressed in units of power, ranged from 427 000 kW to 978 000 kW, with a mean of 671 000 kW and a coefficient of variation of 0.247. However, sales were less stable in the 1970s, with the coefficient of variation rising to 0.266 from 0.158 in the previous decade. The sales series displays considerable volatility, there being 14 turning points in the period under consideration (see Figure 1).

In 1959–60, the number of wheeled tractors on rural holdings amounted to 221 785 (ABS 1983*a,b*), equivalent to around 3.75 million kW. By 1982–83, tractor stock amounted to 8.3 million kW. The growth of stock levels is shown in Figure 1 together with sales. (For the derivation of the stock series see the Appendix). The reversal of growth in the early 1970s occurred when wheat quotas were in force and farmers were shifting into the beef cattle enterprise.

Net investment is equal to gross investment minus depreciation of the previous period's capital stock. As depreciation is a constant proportion of stock, the net investment series has a similar pattern to gross investment. The mean annual net investment is about half that of gross investment. Although it is common in studies of agricultural investment to use gross investment as the dependent variable, the interpretation of the coefficients is conceptually difficult. For this reason net investment is used as the dependent variable in this study. Although the explanatory power appears lower in comparison to the gross investment model, forecasting ability is not diminished.

Models of Capital Investment

The central feature of the neoclassical theory of capital is the response of the demand for capital to changes in the relative factor prices, and to the ratio of factor prices to the price of output. Where factor ratios are responsive to prices both before and after the investment takes place, a putty-putty model is relevant. Because factor ratios can be changed at any time in response to a price change, the investor need not take into account expected prices over the life of the machine. Current prices are the relevant decision variables, although their effect may be lagged.

The durable nature of capital means that the relevant cost of capital is the implicit rental price, rather than the initial market price of the capital item. This is because investment in a capital good (or stock) provides a flow of services, and it is the periodic cost of providing this flow of services that determines, with other input prices, the relative factor ratios. The implicit rental price, as a measure of the cost of a flow of services, is akin to the price at which a machine might be hired in a smoothly operating rental market.

As in most studies of this kind, the rental price was taken to be exogenous, and the supply side of the tractor market was not modelled. There are two main reasons for this. First, many of the elements of the rental price (for example fuel costs) are clearly exogenous. If tractor

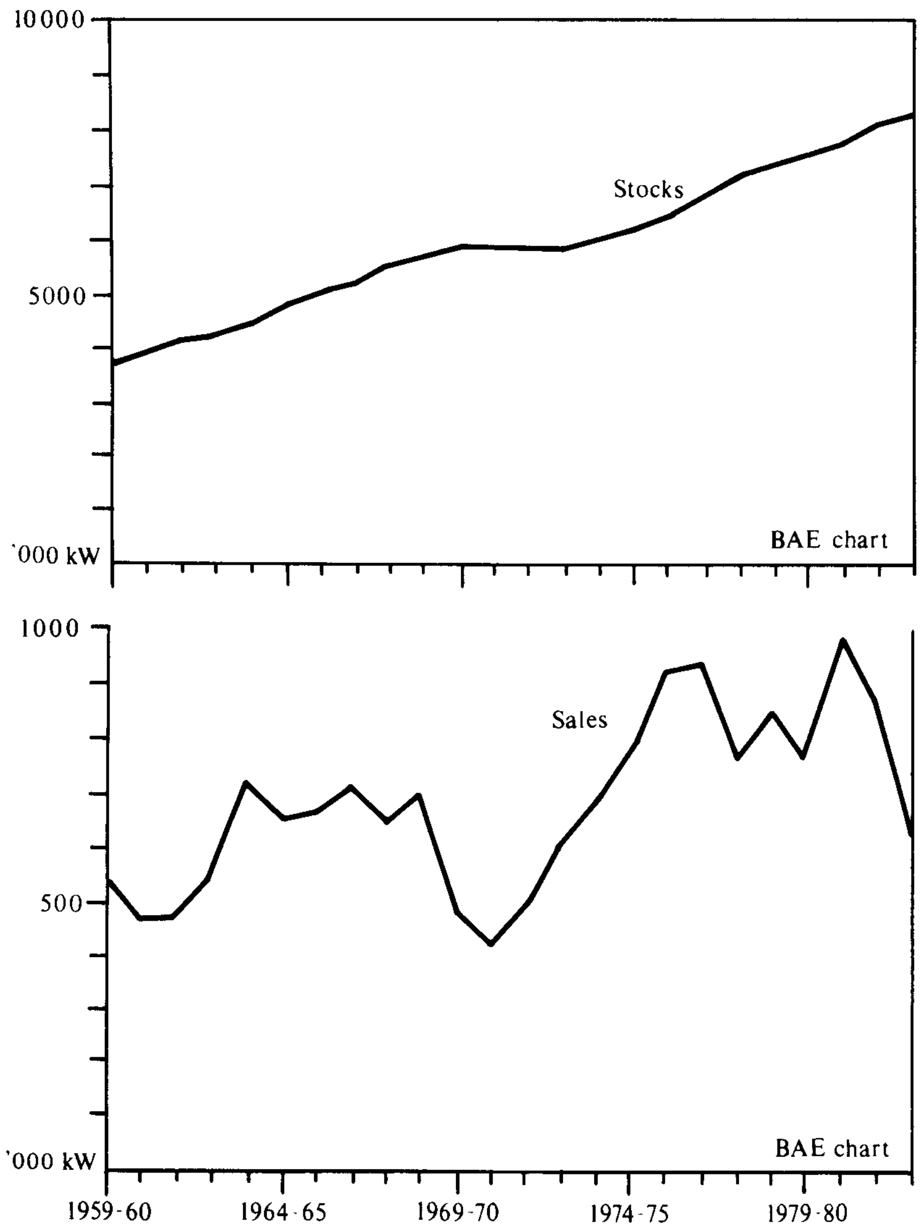

FIGURE 1—Tractor Sales and Stocks.

prices are determined by a combination of world prices and tariff/bounty arrangements, they will also be largely unaffected by variations in Australian demand. Second, the estimation and data difficulties involved in including a useful supply equation are very severe.

The rental price approach, as outlined by Jorgensen and Stephenson (1967), Fisher (1974), Coen (1975), and applied to tractor investment by Penson et al. (1977, 1981) and Filmer and Ferris (1976), is based on the Cobb-Douglas production function. Let:

$$Y = A\, X_1^{\alpha_1} X_2^{\alpha_2} \ldots X_n^{\alpha_n} \tag{1}$$

where $\sum_{i=1}^{n} \alpha_i = 1$, Y is the level of output and $X_1, \ldots, X_n$ are factor inputs. Profit maximisation implies that the input level of factor i will be chosen to equate marginal cost and marginal value product

$$p\, \partial Y/\partial X_i = c_i \tag{2}$$

where p is the output price and c_i the rental price of factor i. For the Cobb-Douglas production function, this implies that the optimal input level is given by:

$$X_i^* = \alpha_i p Y/c_i \tag{3}$$

Typically, a lagged adjustment process is imposed so that

$$X_i = X_i^* + (1-\lambda)X_{i-1} \tag{4}$$

This implies that the actual level of input used takes time (more than one period) to adjust to changes in the optimal level. This is particularly applicable to durable capital items (due to high transaction costs).

A common framework with which to examine durable input use is the partial stock adjustment model. The rental price approach, plus alternatives not based on a Cobb-Douglas production function, can be applied within this framework. The model is suitable where investment depends on the speed of adjustment from the previous period's actual stock to the current desired level of stock. Given actual stock can be observed, it is necessary to estimate (a) the desired (optimal) capital stock; and (b) the speed of adjustment. The model can be represented as follows:

$$I_t = \lambda(K_t^* - K_{t-1}) \tag{5}$$

where I_t = investment in period t;
λ = adjustment coefficient;
K_t^* = desired capital stock; and
K_t = actual capital stock.

The determinants of K_t^* can be substituted into the equation, and the adjustment coefficient estimated. From equation (3), it can be postulated that desired capital stock is some function of the output price-to-rental price ratio. Assuming a linear functional form:

$$K_t^* = a_0 + a_1(p_t Y_t/c_t) \tag{6}$$

Substituting, an estimating equation is obtained:

(7) $$I_t = b_0 + b_1(p_t Y_t / c_t) - b_2 K_{t-1} + e_t$$

where $b_0 = \lambda a_0$, $b_1 = \lambda a_1$, $b_2 = \lambda$.

Some refinements can be made to this model. First, the prices of substitutable or complementary inputs can be introduced into the model. These are expressed as ratios of the rental price c. Second, additional variables, such as those which influence the ability of the investor to adjust actual to desired stock, can be included. Even though already installed, capital is instantly malleable and thus factor proportions are free to adjust to relative prices. However, the adjustment process may not be costless or instantaneous.

Whereas the putty-putty model assumes factor ratios are responsive to relative price changes even after the investment has occurred, the transaction costs of trading-in a tractor for one of a different size suggests that this model may not adequately reflect actual tractor investment behaviour. In addition, tractors have a low salvage value outside agriculture, and thus the downward flexibility of the stock of tractors in aggregate is limited. An alternative approach is the putty-clay model, which assumes that factor proportions are fixed over the economic life of the machine once it has been acquired.

This implies that the relevant factor prices impinging on the decision-making process are not current prices, as in the putty-putty model, but expected prices of all factors and output over the life of the machine. A putty-clay model can be derived in a similar fashion to a putty-putty model, with an autoregressive process, for example, used to estimate expected output and prices.

Putty models imply that inputs are substitutes. An obvious alternative is to suppose that all or some inputs are complements. Factor proportions would then be fixed both before and after installation, and not directly responsive to factor prices. This is commonly referred to as a clay-clay model.

The implications of a clay-clay model for input demands can be seen by considering the following fixed-proportions production function:

(8) $$Y = \min\,(B_1 X_1, B_2 X_2, \ldots, B_n X_n)$$

In this case, profit maximisation implies

(9) $$X_i^* = Y/B_i$$

Since there is no possibility of substitution between inputs, the rental price of factor i has no effect on input demand except through output levels. Thus, a fixed-proportions production function yields an 'accelerator' model.

A completely fixed-proportions production function is somewhat implausible. However, it is equally implausible to suppose that all factors of production are substitutes rather than complements, especially at high levels of disaggregation. For example, rental price studies (such as that of Filmer and Ferris 1976) of the demand for tractors typically, and correctly, include fuel costs as a component of the rental price of tractors. This procedure would not be valid if fuel and tractors combined in a Cobb-Douglas fashion. It could, similarly, be argued that the production relationship between tractors and arable land is much closer to fixed proportions than to Cobb-Douglas.

In both the fuel-tractor and the tractor-land cases there are substitution possibilities. Nonetheless, in both cases, fixed proportions may be a reasonable approximation. Thus, a two-level production function can be considered:

$$Y = AZ_1^{\alpha_1} \ldots Z_m^{\alpha_m} \tag{10}$$

where

$$Z_i = \min (B_{i1}X_{i1}, \ldots, B_{ik}X_{ik}) \tag{11}$$

This yields:

$$X^*_{ij} = Z_i/B_{ij} \tag{12}$$

$$= \alpha_i p Y/c_i B_{ij}$$

The cost, c_i, of the composite factor, Z_i, is given by:

$$c_i = \sum_{j=1}^{k} c_{ij}/B_{ij} \tag{13}$$

where the c_{ij} are the prices of the factors X_{ij}.

In some cases, these costs will be measurable as market prices. In the case of land, however, there is the further difficulty that an opportunity cost measure is appropriate, and this will depend upon the returns available from alternative production activities.

It follows that the responsiveness, or otherwise, of tractor demand to rental prices will depend on two factors. The first is the relative importance of tractor costs in the total cost of the group of complementary factors of which it is a member. The second is the degree to which substitution between the factors is technically possible. (In fact, the own-price elasticity of demand for any input is a weighted average of the elasticity of demand for the output and the elasticity of substitution, where the weights are the relative factor proportions.) If the fixed-proportions assumption is a good approximation, then the rental price of tractors will be fairly unimportant as a determinant of tractor demand. The first of these points, relating to the relative importance of tractor costs, can be determined by an examination of crop preparation costs. Bailey and Buffier (1982) suggest that the tractor costs of preparing a hectare of wheat on the North West Slopes of New South Wales was \$13.80 in 1982. This compares with a total variable cost figure of \$53.80/ha, and harvesting costs of \$21.65/ha. Overhead costs amount to 30 per cent to 50 per cent of variable tractor costs, depending on use. Labour costs are about \$14/ha. These figures illustrate that tractor costs account for a relatively small proportion of crop preparation and harvesting costs for dryland wheat enterprises.

The remaining question is the degree of substitutability between the tractor input and the associated group consisting of land, harvesting inputs, seed and fertilisers. The main possibility which is intuitively apparent is that of adopting 'minimum tillage' technology, in which the amount of ploughing is reduced, and an increased amount of herbicide used to alleviate the resulting weed problems. It is not clear at this stage whether moves to minimum tillage are motivated primarily by a desire to reduce short-term cultivation costs or by a concern for soil conservation. In any case, the relatively recent advent of this technology means that it did not have a major impact during the period examined in this study.

A number of studies of substitution possibilities in agriculture have been made in recent years. However, these must be interpreted with caution, for a number of reasons. First, these studies necessarily involve a fairly high degree of factor aggregation. As was noted above, a production function displaying substitution between aggregated factors can be quite consistent with a high degree of complementarity between factors at a disaggregated level. Second, most of these studies treat output as a homogeneous quantity. Substantial changes in input mix may be achieved by shifting the output mix between cropping and livestock activities. If the input substitution estimates obtained in this way are interpreted as applying to particular production activities, the degree of substitutability will generally be overestimated.

Two of the most recent studies are those of Vincent (1977) and McKay, Lawrence, and Vlastuin (1980). Vincent found an almost zero substitution elasticity between land and capital, noting that 'it is reasonable to postulate a degree of complementarity between capital and land' (p. 127). By contrast, McKay et al. found an elasticity of substitution greater than one. Similar results to this were obtained by Watts and Quiggin (1984) who recalculated the McKay et al. estimates using a different specification of the time trend.

The reason for this difference may lie in the different levels of aggregation employed in the two studies. Vincent (1977) used three factors—land, labour and capital. McKay et al. (1980) disaggregated the capital input into livestock and 'materials and services' as well as a general capital input. The 'materials and services' input, of which fuel is a major component, was found to be complementary with land. As has been noted above, fuel costs are a major part of the rental price of tractors. Thus, the results of McKay et al. are consistent with the notion that the tractor input and the associated inputs of cropping land, seed, fertiliser and harvesting services are complementary. This group of inputs may be substituted for labour by varying the intensity of cultivation.

Thus far, three models of investment have been postulated. These vary in factor substitutability from fully flexible to fully fixed. Examination of the price responsive putty-putty and putty-clay models requires specification of the implicit rental price of capital. This is the subject of the next section.

Specification of the Rental Price

There are a variety of ways of measuring the rental price, but components common to all are the price of the capital item, a measure of replacement investment and the cost of capital. Coen (1975, p. 63) notes that the usual expression for the rental price, c, is:

$$c = q\,(r + \delta) \qquad (14)$$

where q = market price of capital item;
r = interest rates; and
δ = rate of economic depreciation.

To this it is usual to add the influence of tax deductibility and operating costs, tax allowances, and the marginal tax rate. Such costs are usually included if they are both significant and variable. (Penson et al. 1981, p. 630, for example, excluded operating costs, as they were estimating opportunity rather than user costs. Once sunk, operating costs have no opportunity cost). Thus:

$$c = q(r + \delta)(1 - m) + qf(1 - m) \tag{15}$$

where m = marginal tax rate; and
f = operating costs as proportion of market price of capital.
A discount rate is used to estimate the present value of future costs and benefits.

The implicit rental price equation used in this study includes the factors mentioned above. It takes account of Australian tax arrangements (including the deductibility of interest costs) and inflation. It differs from the Filmer and Ferris approach in the way in which tax, interest, depreciation and investment allowance effects are handled. The final equation with the capital recovery allowances is as follows:

$$c = q(1 - im)(r + \delta)(1 - m) + qf(1 - m) + \theta \tag{16}$$

where i = investment allowance; and
θ = annuitised value of difference between tax depreciation and true depreciation rates.

There are four main differences between equations (14) and (16). First, operating costs have been included. Second, the tax deductibility of interest, operating costs and depreciation has been taken into account. Third, the effects of the investment allowance, which effectively reduce the initial cost of the tractor have been captured in the term $(1 - im)$. This is added in a multiplicative fashion because the value of the allowance is amortised over the life of the machine. Finally, the term θ represents the difference between the depreciation allowed for tax purposes and the true rate of depreciation.

The market price, q, is measured by the BAE index of prices paid for tractors. The index is based on list prices, without accounting for variations in discounts. Of those tractors included in the index, all are given equal weight, although more of the better selling tractors are included in the regimen. In this manner, high-powered, high-quality machines are introduced into the index at the expense of outdated models. Quality change is estimated at this point. The index may be biased downward by the tendency to attribute all of a price change to quality changes when a new model is introduced. However, the index is not dissimilar from the hedonic price index constructed by Ferris (1976) for the period 1959 to 1975. It is important to note that movements in prices of new tractors also influence the second-hand market. As most farmers trade-in when they buy new machines, variations in new tractor prices are effectively smoothed by the existence of the second-hand market.

The interest rate, r, is that rate which applies to first-ranking two-year debentures issued by finance companies. The nominal rate, k, is deflated by the expected rate of inflation, π, proxied by an exponentially smoothed tractor price index (using an alpha value of 0.4), and adjusted for non-neutral effects of taxation on nominal rates of interest and inflation:

$$r = [k(1 - m) - \pi] / (1 - m) \tag{17}$$

The choice of a deflator is important, and, as Ando, Modigliani, Rasche and Turnovsky (1974, p. 383) have noted, real interest rates can be expressed in terms of output, of capital goods, or of labour. They have shown that the real rate of interest relevant to the putty-putty model is measured in terms of capital goods. By contrast, for a putty-clay model, the interest rate measured in terms of output is applicable. However, this is a special case based on a constant mark-up from cost, and is therefore relevant to oligopolistic market structures. For agriculture, where output prices are not closely related to input prices, expected consumer prices were used to deflate interest rates for the putty-clay model. This assumption is important, and the movement in the rental price series is critically dependent upon the choice of deflator.

Using the measures outlined, estimated real interest rates were negative for a number of years in the mid-1970s, but their effect on the rental price was swamped by depreciation and operating costs, preventing the present value of the investment from becoming infinite.

The marginal tax rate, m, is assumed to be constant at 22 per cent. Given the existence of tax averaging provisions available to farmers, this appears reasonable. The constancy of the rate does understate changes in the rental price somewhat, although such movements are not sensitive to the level of the marginal tax rate. (Changing the value of m from 0.15 to 0.22 and 0.30 alters the mean of the rental price series from 18.51 to 17.43 and 16.20, respectively.) Given the lack of sensitivity and paucity of reliable marginal tax rate data, it seems unlikely that the refinement of calculating a varying series would improve results. The inclusion of the tax component in this term reflects the tax deductibility of debt capital costs.

Operating costs, f, are expressed as a proportion of initial price. The most crucial assumption here is that fuel use is approximately 0.222 litres per kilowatt per hour (Blomfield 1981). It has been assumed that the technical relationships between fuel, lubricants, tyres, repairs and maintenance and output have remained constant over the period under study.

The rental price series is shown in the Appendix and depicted in Figure 2. This series, in which nominal interest rates are deflated by tractor price movements, shows how the real post-tax periodic cost of owning and operating a tractor has moved over time. In 1981 the rental price series was 21.99, composed mainly of operating costs and depreciation. The real price index for tractors was 95.44, so that the rental price was about 23 per cent of the current market price. For an average-size tractor priced at around \$20 000, the implicit rental cost was about \$4600 in that year.

The index rose initially, as real interest rates rose, then trended down until 1975, at which point rising operating costs and market prices combined to cause a reversal of the long-term trend. This is a significant

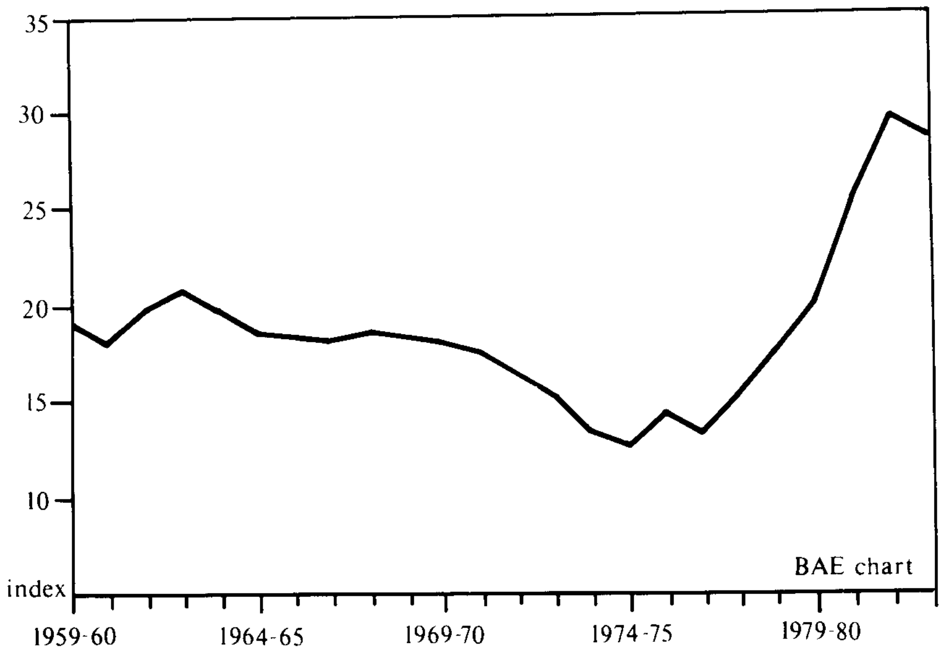

FIGURE 2—Rental Price of Tractors.

development in the industry. In spite of it, tractor sales (in kilowatts) expanded, breaking the nexus between sales and rental prices.

This result does not appear to be attributable to any peculiarities in the method used to calculate rental prices in the present study. Indeed, had nominal rather than real interest rates been used, as in the Filmer and Ferris (1976) rental price index, the increase would have been even more pronounced.

The rental price approach was tested more formally by relating net investment to the current crop returns-to-rental price ratio. This follows the Jorgensen model, developed above, and is in contrast to the approach used by Filmer and Ferris (1976), and Fisher (1974) in his aggregate level study. These authors used crop prices rather than crop returns as the numerator of the rental price ratio variable. Given the 'perverse' relationship between rental prices and tractor sales, described above, this alternative approach yields poor results.

Results

In order to compare the three models, it is necessary first to select appropriate specifications for each model. The main problem is the selection of appropriate variables for inclusion in addition to those required by the basic model specification. The approach used was to specify a set of variables for consideration and eliminate those which proved to be insignificant. The variables considered reflected (lagged) real gross returns, returns from complementary and substitute activities and a wheat quota dummy.

TABLE 1

Parameter Estimates for Alternative Net Investment Models[a]

Variable[b]	Putty-putty			Putty-clay		Clay-clay	
	1	2	3	4	5	6	7
$K(-1)$	0.01	0.01	−0.19	−0.019	0.01	−0.137	−0.107
	(0.37)	(0.37)	(−1.25)	(−0.78)	(0.71)	(−3.38)	(−2.14)
DVQ	−112.14	−153.51	(−128.04)	−144.46	−141.76	−148.37	196.51
	(−1.75)	(−2.99)	(−2.06)	(−2.23)	(−2.39)	(−2.51)	(−2.82)
CR^c	112.18	95.74	114.98	9.26	28.51		
	(2.77)	(3.28)	(3.27)	(0.86)	(3.63)		
SR^c	91.43			2.47		−28.19	
	(1.17)			(1.54)		(−1.95)	
BR^c	−121.15			−2.24		244.39	
	(−1.17)			(−0.47)		(2.38)	
$Y(-1)$		0.179		0.14		0.27	
		(1.72)		(1.13)		(2.47)	
$Y(-2)$		0.351		0.35		0.37	
		(3.31)		(2.55)		(2.93)	
A						48.76	56.23
						(2.34)	(2.22)
Intercept	−20.53	157.49	172.34	−241.47	−156.01	256.77	188.15
	(−0.10)	(2.33)	(2.08)	(−1.17)	(−1.19)	(2.81)	(2.09)
DW	1.38	1.84	1.49	1.79	1.65	1.97	1.46
R^2	0.36	0.58	0.37	0.50	0.41	0.56	0.23

[a] The numbers shown in parentheses are t-values.
[b] A full description and listing of the data can be found in the Appendix.
[c] CR, SR and BR are defined differently for each model type. See text for details.

Putty-putty model

The full version of this model (not reported) proved highly unsatisfactory. Many of the coefficients were statistically insignificant. In the absence of clear guidance from formal significance tests, two sets of restrictions were considered.

Equation 1 in Table 1 includes current crop returns-to-rental price ratio (CR), and two variables reflecting complementary and substitution possibilities for cereal growers, but excludes real gross returns.

The real gross returns to sheep enterprises were expressed as a ratio of the rental price (SR), as were the real gross returns to beef (BR). An increase in sheep returns relative to the rental price is likely to lead to increased demand for tractors (implies the output effect is greater than the substitution effect), while an increase in beef returns is expected to lead to a fall in tractor demand.

There was evidence both of autocorrelation and multicollinearity in this equation. The lagged capital coefficient is insignificant. The coefficient on CR appears relatively important, although this result may be spurious, due to the unsatisfactory nature of the model.

An alternative version of the putty-putty model is one in which real gross returns (to wheat, barley and oats), the numerator in the CR variable, are substituted for SR and BR, the variables representing real returns to sheep and beef enterprises. This model (equation 2) contains virtually no multicollinearity or autocorrelation and is statistically satisfactory with the exception of the low, although significant, lagged stock coefficient. A cusum test revealed the coefficients to be stable at the 5 per cent level.

The responsiveness of net investment to change in prices and incomes is indicated by the elasticities derived from this equation; $CR=0.609$, $Y(-1)=0.530$ and $Y(-2)=1.040$. (These are calculated at the mean values of the data). The implication is that a change in CR of 1 per cent will have a less than proportionate effect on net investment. The effect of a change in income is clearly dependent on the time horizon. A two year lag suggests that machinery requirements may backlog while funds are used for more immediate priorities. This lagged capital coefficient is unexpectedly low, implying that the speed of adjustment is very slow.

The income from cereals variable (Y) is superior to the sheep and beef income variables, SR and BR (which are expressed as ratios of the rental price). To examine the effect of the level of income on net investment, equation 3 was estimated without $Y(-1)$ and $Y(-2)$. In this case, the coefficient on the lagged capital stock variable is closer to what might be expected. However, the remaining coefficients did not change greatly. An F test for the inclusion of additional variables indicates that income contributes significantly to the explanatory power of the equation ($F=4.78$).

Putty-clay model

The putty-clay model is similar to the putty-putty version except that expected rather than current values of prices and returns are used. The crop returns-rental price variable (CR) comprises a three year moving average of real prices multiplied by a five year moving average of yield, divided by an exponentially smoothed rental price series. Nominal output prices are deflated by a prices paid index in which each input is weighted according to its importance in the production process. In addition, the rate of interest is deflated by changes in the consumer price index, rather than using the tractor price index.

Equation 4 in Table 1 represents the full version of the putty-clay model which includes the variables real income from cereals (lagged one and two years) and expected returns from the sheep and beef enterprises (each expressed as a ratio of the rental price). In this case, all the coefficients on the rental price variables are insignificant.

When the income and sheep and beef returns variables are deleted, (equation 5) the expected crop returns-to-rental price variable has a significant coefficient, although the coefficient on the lagged capital stock variable is still insignificant. The F test for additional variables suggests that equation 5 is superior to equation 4.

It is not possible to discriminate adequately between the putty-putty and putty-clay models. However, elaborate specification of the rental price variable has not resulted in the development of a satisfactory explanatory model.

Clay-clay model

The full version of the clay-clay model (equation 6 in Table 1) includes real gross income from cereals (Y) lagged one and two periods (as in equation 1), and the ratios of expected returns to wheat and sheep, and wheat and beef. An area cropped variable is included instead of the crop returns-to-rental price ratio.

The coefficient on the lagged capital variable (the adjustment coefficient) is consistent with only 13 per cent of the difference between desired and actual stock being made up in the current period. This is consistent with estimates made by Filmer and Ferris (1976) who found the partial adjustment coefficient ranged from 0.10 to 0.15. They point out that a relatively low value is to be expected (p. 20) because the purchase of a tractor may necessitate the investment in additional machinery, such as more compatible cultivating implements.

The area coefficient implies that an increase of one million hectares would lead to an increase in net investment of 47 460 kW, equivalent to 790 tractors of average size. Similarly, a 10 per cent increase in income from the mean value of 584 would lead to increases in net investment of 260 units the succeeding year and 360 the following year. Whereas a 10 per cent increase in sheep prices from the mean would increase net investment by 30 500 kW or 508 units, a similar increase in beef prices would result in reduced net investment (210 units). These ratios capture the output and substitution effects much more satisfactorily than the sheep and beef income variables in the previous models.

Equation 7 shows the restricted version of the clay-clay model. Although the explanatory power is severely reduced, all variables are significant and have the appropriate sign. An F test for the inclusion of additional variables indicates that the full version of the model is to be preferred ($F = 5.05$). The presence of autocorrelation in the restricted clay-clay model makes comparison with the putty-putty and putty-clay models difficult. In spite of the lower explanatory power, parameter values in equation 7 conform more closely to a priori expectations. However, it is more meaningful to compare model types by examining the unrestricted versions, represented by equations 2, 4 and 6.

The models do not differ greatly in terms of explanatory power, as measured by $\bar{R}^2$. More sophisticated statistical tests of the explanatory power of non-nested models have been proposed by Cox (1962) and Pesaran (1974). However, it was felt that, given the absence of sharp variations in $\bar{R}^2$, it would be more useful to compare the models on the basis of consistency with the underlying economic theory. The three versions of the model (putty-putty, putty-clay and clay-clay) can be compared on the basis of correctness of specification, acceptability of estimated coefficients and stability of coefficients.

While equation 2 does not suffer from the more obvious specification problems, the capital coefficient is below the hypothesised magnitude. The putty-clay equation 4 contains some multicollinearity, although this does not affect the goodness of fit. Again, the capital coefficient is not significant. By contrast, the clay-clay model reveals no autocorrelation, and the capital coefficient is in the hypothesised range. However, some multicollinearity is present.

The inclusion of additional variables affects the crop returns-to-rental price coefficient in both the putty-putty and putty-clay models. By contrast, the area coefficient in the clay-clay model is hardly affected at all, falling from 54 to 47. However, the area coefficient is more affected by deleting the final period, the drought year 1982–83. In that year, crops were planted but lack of follow-up rains led to reduced income expectations, and falling tractor sales.

Equations 2, 4 and 6 were tested for stability (Brown, Durbin and Evans 1975) using the cusum test. All models where stable. The rental price coefficients (in equations 2 and 4) and the area coefficient (in equation 6) were tested for stability with the Farley-Hinnich test (Farley, Hinnich and McGuire 1975). Values of FH were 0.014, 0.00018 and 0.026 respectively. These are insignificant, suggesting at least that the coefficients do not change linearly over time.

In assessing these models, the clay-clay approach would seem to provide estimates that are stable, within a model that is not obviously misspecified. This approach is preferred to the alternatives, which fail to satisfy the stated model selection criterion. In particular, they show signs of autocorrelation and, in addition, the coefficient on the lagged capital variable is implausibly low.

The clay-clay model is easier to use for forecasting purposes because there is no requirement to predict each component of the rental series. To forecast tractor sales in terms of power, estimates of area cropped and the relative returns to cropping, sheep and beef are required. Revenue estimates are required if forecasts are to be made more than one year ahead. Once net investment has been forecast, replacement investment must be added to obtain an estimate of sales. The percentage of explained variation in total sales is about 80 per cent. In this study, tractor stocks and sales are measured in terms of power. However, forecasts can be made in terms of tractor units, perhaps by size categories, by predicting the size distribution of sales.

Implications for Investment Allowances

The investment allowance is a policy which effectively reduces the initial purchase price, and hence the implicit rental price, of capital goods. The analysis presented so far provides two grounds for questioning whether the investment allowance has had a major impact on sales of tractors. First, the investment allowance makes only a fairly small difference to the implicit rental price of tractors and, second, it appears that the rental price is not the main factor in determining tractor demand.

An investment allowance of 20 per cent is worth \$1000 to a farmer with a 25 per cent marginal tax rate who buys a \$20 000 machine. When this is amortised over the life of the machine, its value is not of great significance, especially in comparison to operating, depreciation and interest costs, which amount to perhaps 30 per cent per year of the initial price. Thus, the investment allowance may amount to 1.5 per cent of the rental price. Given the coefficient on the *CR* variable in equation 1 of 95.74, an increase in the investment allowance from 0.2 to 0.4 would increase investment by 1800kW, or 30 average-size tractors.

There is, nonetheless, a widespread belief that the investment allowance has had a significant impact on investment decisions. Certainly, sales rose following the introduction of the allowance. On an aggregate level, the level of investment allowance is correlated with agricultural investment in general and with tractor sales in particular. In effect this correlation reflects variability over only three years' data because the investment allowance has been at or very near 20 per cent except for the period August 1973 to January 1976 when it was not applied, and for the period January 1976 to June 1978 when it was 40 per cent. However, it is not difficult to find alternative explanations for the fluctuations in investment in these years. These include extensive shifts between beef and cropping industries, resulting from changes in relative profitability, the energy crisis and the onset of recession in Australia and overseas. Any one of these factors could be used as a plausible explanation for the fall and rise of tractor demand. For example, during 1973–74 and 1975–76, all forms of investment were constrained by the 'credit squeeze', and this would explain a subsequent 'catch-up'.

There are, however, some avenues through which investment allowances could have a significant impact on tractor sales, in addition to those mentioned above. The first possibility is applicable to the period 1976 to 1978 when a 40 per cent rate was known initially to be available for a limited period only. This would certainly affect the timing of tractor purchases even if it did not change the long-run desired stock levels. A converse effect would have occurred in 1973 if farmers had expected (correctly) the removal of the investment allowance to be temporary.

A second possibility arises from the fact that the investment allowance affects the rental price of capital goods other than tractors, such as headers and other harvesting equipment. If the cropping activity is more capital intensive than competing land uses, then it will tend to expand in response to higher investment allowances, thus increasing the demand for tractors. This effect will be additional to the input-substitution effects estimated above. Thus, the present study cannot give a final determination of the effects of investment allowances on tractor sales.

Concluding Comments

The analysis has revealed difficulties with all of the competing approaches to the empirical application of investment theory to the analysis of farm tractor investment decisions. While the prior belief of most economists would tend to favour the standard (putty-putty) rental price model, the clay-clay model performed somewhat better in econometric testing and is also more useful for forecasting purposes. In this model, sales depend primarily on the stock of tractors on farms in relation to that required to sow the area that farmers expect to crop. Relative input price levels are not particularly important and policies which operate through changes in the price of capital goods are unlikely to have much impact on investment.

Some of the conclusions drawn here are fairly robust with respect to the choice of model. In particular, whichever model is used, the direct substitution effects of the investment allowance on sales are found to be quite small. As indicated above, however, the allowance may affect tractor sales in other ways. Given the importance currently attached to policies affecting private investment decisions, this is clearly an area where further analysis and debate is required.

APPENDIX

Derivation of θ

θ represents the annuitised flow of the difference between tax and real depreciation. This difference is discounted back to a present value (using an expected nominal rate of inflation) and then annuitised over the life of the machine. This can be expressed as follows:

$$\theta = \sum_{j=1}^{n} \left\{ d_i(1+k)^{-j} - \delta(1-mi)\,[1+(1-m)]^{-j} \right\} / \sum_{j=1}^{n} [1+r(1-m)]^{-j}$$

where d_i = rate of tax depreciation;
k = expected nominal rate of inflation;
δ = rate of real depreciation;
m = marginal tax rate;
i = investment allowance;
r = real pre-tax rate of interest; and
n = life of machine.

The first term refers to the present value of the tax depreciation benefits. The second term accounts for real depreciation, after adjustments for the investment allowance. This is discounted by the post-tax real rate of interest. The difference is summed over the life of the machine, and annuitised with a real post-tax rate of interest by dividing through by the third term. For ease of calculation, the annuity can be approximated by $1/n+r$, given that $(1+r)^n$ is close to $1+rn$.

TABLE A.1

Description of Variables

Label	Title	Unit	Description
K	Capital stock	'000 kW	Stock of tractors on farms. See Appendix for derivation.
KS	Sales	'000 kW	Sales of agricultural wheeled tractors.
NI	Net investment	'000 kW	Gross investment less depreciation.
A	Area	million hectares	Area cropped of wheat, barley and oats.
Y	Income	index	Gross returns from wheat barley and oats (1961 $m) at principal wholesale markets, deflated by consumer price index.
C	Rental price	index	See text for derivation.
Q	Real tractor prices	index	Tractor prices deflated by consumer price index.
RFP	Real fuel prices	index	Fuel prices deflated by consumer price index.
WB	Expected returns to crops and beef	ratio	Three year moving average of expected returns, deflated by prices paid index representative of particular industry. Returns to crops expressed as a ratio of returns to beef.
WS	Expected returns to crops and sheep	ratio	Three year moving average of expected returns, deflated by prices paid index representative of particular industry. Returns to crops expressed as ratio of returns to sheep.
SR[a]	Sheep returns to rental price	ratio	Real gross returns to sheep enterprises deflated by rental price.
BR[a]	Beef returns to rental price	ratio	Real gross returns to beef enterprises deflated by rental price.
CR[a]	Crop returns to rental price	ratio	Real gross returns to wheat barley and oat enterprises deflated by rental price.
DVQ	Quota dummy variable		1 = 1969–70 to 1971–72; 0 = other years.

[a] In the putty-clay models, *SR*, *BR* and *CR* are based on expected rather than current returns.

TABLE A.2

Data

Year ending June	Stock of tractors on farms K	Sales of wheeled tractors KS	Net investment NI	Area cropped wheat, barley and oats A	Real gross value, wheat barley and oats Y	Rental price C	Real tractor price Q	Real fuel price RFP	Expected returns to crops and beef WB	Expected returns to crops and sheep WS
	'000 kW	'000 kW	'000 kW	million ha	index	index	index	index	ratio	ratio
1958	3496	400.36	121.72	5.70	218.26	11.08	85.87	115.22	0.69	8.81
1959	3606	450.86	159.60	6.80	448.06	15.48	88.17	112.90	0.60	8.73
1960	3755	536.73	236.39	7.10	359.90	18.05	84.37	108.33	0.56	10.81
1961	3979	466.47	153.59	8.10	504.60	18.14	83.00	102.00	0.51	11.20
1962	4114	467.63	136.11	8.30	456.20	19.37	84.00	100.00	0.51	11.09
1963	4239	538.90	196.14	8.80	543.10	19.92	85.00	100.00	0.56	11.36
1964	4425	711.64	358.48	8.90	559.01	19.32	85.14	98.01	0.66	11.38
1965	4768	650.06	281.42	9.50	594.95	18.88	83.80	93.33	0.66	11.25
1966	5021	664.29	267.08	9.50	445.96	19.26	82.56	98.16	0.63	11.39
1967	5267	704.19	285.92	11.10	756.25	18.98	82.14	96.42	0.55	11.63
1968	5532	647.44	208.69	11.60	445.04	18.40	83.47	98.26	0.54	12.91
1969	5719	696.28	235.41	13.70	729.32	18.84	82.20	95.76	0.50	12.70
1970	5939	479.09	2.67	12.40	516.80	18.90	81.14	92.62	0.45	12.78
1971	5923	426.83	−67.90	10.10	444.30	18.84	79.68	91.40	0.38	12.27
1972	5856	485.11	−8.31	10.80	455.62	16.58	80.29	86.86	0.39	14.04
1973	5854	635.61	147.71	10.70	330.34	14.88	81.37	82.75	0.37	10.57
1974	6002	687.40	199.75	12.00	956.83	16.22	76.21	76.82	0.40	8.41
1975	6189	777.38	277.41	11.00	819.22	11.58	80.72	78.64	0.61	10.91
1976	6451	923.93	408.35	11.90	759.68	14.10	88.42	91.20	1.01	16.04
1977	6837	931.45	394.05	12.27	577.52	10.03	88.61	88.21	1.85	22.16
1978	7199	755.37	185.78	13.83	449.44	12.20	90.70	95.91	1.49	17.28
1979	7355	849.54	249.81	14.39	940.00	15.61	90.72	111.68	0.87	13.07
1980	7592	775.95	163.25	14.75	942.87	19.10	90.34	141.74	0.63	12.43
1981	7735	977.69	345.26	14.82	628.06	21.99	95.44	162.96	0.57	13.17
1982	8069	875.61	231.23	15.94	842.27	26.97	97.12	174.60	0.60	13.47
1983	8272	623.60	−48.55	15.37	459.37	25.75	97.82	181.93	0.69	14.72

Derivation of Tractor Stock Series

The tractor stock series used in this study takes as its starting point the 1960 Australian Bureau of Statistics census of tractors on rural holdings (ABS 1983*a,b*). The figure is adjusted for the age distribution of tractors, based on a probability of survival function estimated by Filmer and Ferris (1976).

$$K\,(1960) = \sum_{i=-25}^{1} K_{t-1}\,(1-\delta)^{i}/\exp\,[-0.038(t-i)^{.98}]$$

where $(t-i)$ refers to the age of the tractor. The denominator is the probability of survival function. This estimate of stocks in 1960 serves as a useful reference point from which to construct a series. (These censuses were discontinued as from 1969). The data are published in several horsepower categories, and are converted from annual unit sales to kilowatts. To convert to power the mid-points of each category were assumed to represent the mean. Kilowatt sales was added to the depreciated capital stock figure each year. Thus, given an initial stock level, the series is calculated from yearly sales and a constant depreciation term.

By using power rather than units as a measure, tractors of different size can be aggregated and treated as homogeneous. Although this conceals a trend towards larger and four-wheel-drive machines, it is assumed here that all kilowatts provide identical service regardless of the size of tractor from which they emanate. In addition, technical change is implicitly incorporated into the series, as Ferris (1976) has shown that other technological attributes are closely correlated with power.

In this study, it is assumed that depreciation is a constant proportion of stock. (This implies that the mortality distribution—the product of service life and capacity depreciation—is geometric and, as Jorgenson notes (1971, p.1113), capital stock is a weighted sum of previous gross investments with geometrically declining weights.) On the basis that tractors operate for 1000 hours per year on average and last for twelve years (Blomfield 1981), the depreciation rate is assumed to be 8.3 per cent.

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