A QUARTERLY MODEL OF AGRICULTURAL INVESTMENT IN AUSTRALIA*

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The aims of this study were (a) to attempt to develop a quarterly model to explain aggregate farm investment in Australia, and (b) to examine the concept of the implicit rental price of capital services as a method of taking account of taxation concessions in an investment equation.

Recently, interest in econometric studies of the Australian agricultural sector has increased.[1] However, a fully integrated model of agriculture is yet to be developed. The main objective of this investigation was to construct a quarterly single-equation investment model that could be incorporated into econometric studies of the farm sector.

Writers have suggested a number of related determinants of farm investment. Gruen [6] has claimed that the level and instability of farm income are likely to have a bearing on rural capital formation. Later, Campbell [2] emphasized the role of internal funds. Herr [7] examined Campbell's 'residual funds' hypothesis and concluded that it should be modified to take account of the difference between the short and long-run, but made no attempt to study the structure of the investment process. Glau [4, pp. 210-231] suggested a slightly different role for internal liquidity. He hypothesized that internal liquidity affects the rate of adjustment to changing conditions. Although Glau's model found a role for internal liquidity in a statistical sense, he pointed out that the rate of adjustment of desired to actual capital stock is not particularly sensitive to changes in the level of internal liquidity.

The Commonwealth Statistician's series of annual gross fixed capital expenditure for primary production indicates that there has been a change in the structure of the investment process since the articles by Campbell and Gruen. Until about 1960 the investment series was parallel—with a one year lag—to the series for gross farm product. This may have been a reflection of the effects of accumulated liquidity on investment. Since that year, the investment and output series have been closely synchronized, due possibly to the increasing influence of income tax concessions.

It was argued by Lewis [13], and later by Glau, that the effects of tax concessions on investment operate through an implicit rental price of capital services variable.[2] Lewis suggested that a tax concession effectively lowers the price of a durable good, reducing the implicit rental price to wage rate ratio, and therefore making it profitable to employ

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[1] A number of industry studies, for example see [15] and [18], and some general studies, for example [16] and [19], have been completed recently.

[2] This concept has been developed and extensively used by D. W. Jorgenson. For example, see [9] and [10].

more capital with a given amount of labour and other inputs. The concept of the implicit rental price has often been used in studies of investment in the manufacturing sector.[3] It is a useful way of including the effects of tax concessions in empirical studies because it reduces the number of variables needed in the investment equation.

The concessions that appear to have had the greatest effect on farm investment are the accelerated depreciation allowance and the investment allowance. The investment allowance appears to have been associated with an increase in the volatility of investment. The annual series of gross fixed capital expenditure shows a significant increase in the level of investment expenditure after 1963-64 but sufficient observations are not available to make valid comparisons of the degree of fluctuation in the series before and after that year. However, a quarterly investment series for the period 1958(3) to 1969(4) illustrates increased fluctuations after the introduction of the investment allowance.[4] The increase in standard deviation about trend between the periods 1958(3) to 1963(2) and 1963(3) to 1969(4) was 45·8 per cent. Similar computations for the quarterly gross output series showed an increase in standard deviation about trend of 27·5 per cent for the two periods, suggesting that the investment allowance may induce farmers to consider the timing of investment expenditures more carefully. The inclusion of these effects in a gross investment equation has been attempted by making use of the concept of the implicit rental price.

The Implicit Rental Price

On the basis of the neo-classical theory, a firm should continue to purchase durable goods up to the point where the marginal productivity of capital is equal to the price of the goods. That is, the firm should equate the purchase price of an asset with the present values of all future services flowing from that asset. Included in the returns to the firm will be some amount attributable to taxation concession benefits.[5] The revenue stream, R(t), flowing from a durable good at time (t) can be assumed to decrease at a rate exp (— a.t), and under a system of proportional taxation can be specified as:

$$(1)\quad R(t) = (1-u)(c)\exp(-a.t) + (u.v.q.a)\exp(-a.t) + (u.r.s.q)\exp(-a.t)$$

where,

c = the implicit rental price of capital services;
q = the market price of investment goods;
a = the rate of depreciation;
r = the cost of funds;
u = the aggregate average tax rate;

[3] See for example, Jorgenson [11].

[4] This series was obtained as the difference between total private business investment and the non-farm component of the investment series, deflated by a business investment index. Since the data were supplied in confidence, further details of the series cannot be given. Reference to a member of this series is made by giving the year followed by a number in parentheses referring to a particular quarter.

[5] The specification of the implicit rental price which follows is similar to that used in some investment equations contained in the Reserve Bank of Australia's model RBA1.

s = the proportion of interest charges qualifying as a tax deduction;
v = the proportion of depreciation charges qualifying as a tax deduction;

D(t) = depreciation over time = (a)exp(— a.t)

The investment allowance accrues at time (t_0) resulting in an expression for the present value of the revenue stream such that:

$$(2) \qquad PV = u.x.z.q + \int_0^\infty \exp[-k(1-u)t]R(t)dt$$

where,
x = the proportion of investment expenditure to which the investment allowance refers;
z = the proportion of price of a durable good allowed as the investment allowance;
k = the discount rate, taken as equalling the expected return to capital before tax.

Under the assumptions of the neo-classical theory a firm will invest in new goods up to the point where:

$$(3) \qquad q = PV$$

The implicit rental price of capital services can be obtained by substituting equations (1) and (2) into equation (3) and solving for c.[6] This gives:

$$(4) \qquad c = [q/(1-u)][k(1-u)(1-u.x.z)+a(1-u.x.z-u.v.)-u.r.s]$$

The expression for the implicit rental price can be applied to sectors subject to progressive taxation by substituting the aggregate marginal tax rate for the aggregate average tax rate, u, in equation (4). However, this is not strictly valid in cases where the tax deductions are large enough to shift the aggregate marginal tax rate down more than one step in the tax schedule. To overcome this problem an equation for the implicit rental price that is more applicable under progressive taxation was derived on the assumption that the accelerated depreciation allowance and the investment allowance were the variables which caused the major shifts in the implicit rental price. Using similar assumptions and symbols the revenue stream flowing from a durable good at time (t) will be:

$$(5) \qquad R(t) = (1-u)(c)\exp(-a.t)+(y.u)-[y-(v.q.a)\exp(-a.t)]u'$$

where,
u = the average aggregate tax rate before the deduction of depreciation and investment allowances;
u′ = the average aggregate tax rate after the deduction of depreciation allowance;
y = the taxable income before the deduction of depreciation and investment allowances.

[6] A derivation of equation (4) is given in Appendix 1.

The present value of the revenue stream will then be:

$$(6) \qquad PV = (y'.u') - (y' - x.z.q)(u'') + \int_0^\infty \exp[-k(1-u)t]R(t)dt$$

where,

y′ = the taxable income after the deduction of the depreciation allowance but before deduction of investment allowance;

u″ = the aggregate average tax rate after the deduction of the depreciation and investment allowances.

Setting PV = q, and solving for c gives the expression:[7]

$$(7) \quad c = [q/(1-u)][k(1-u)(1-u''.x.z) + a(1-u''.x.z-u'.v)] \\ -[y'(u'-u'')]\{k+[a/(1-u)]\} - [y(u-u')/(1-u)]\{1+[a/k(1-u)]\}$$

The adjusted implicit rental price based on equation (7) was used in an attempt to explain the quarterly gross capital expenditure series.

The Model

The model employed was a variant of that derived by Mackrell *et al* [14]. The model is based on the Jorgenson theory of gross investment. Part of this theory proposes that a firm will continue to adjust the actual level of capital stock towards the desired level until the desired capital stock is reached. In a dynamic system the actual capital stock can therefore be expressed as a linear combination of desired levels over the period of adjustment. That is:

$$(8) \qquad K_t = \sum_{i=0}^{n} w_i K^*_{t-i}$$

where,

K_t = the actual capital stock;

K_t^* = the desired capital stock.

Taking the difference of both sides of equation (8) gives an expression for net investment:

$$(9) \qquad NI_t = \sum_{i=0}^{n-1} w_i \Delta K^*_{t-i}$$

By adding a term for replacement investment and specifying a relationship for desired capital stock based on the assumptions of profit maximization and a Cobb-Douglas production function, the gross investment equation becomes:[8]

$$(10) \qquad I_t = bK_{t-1} + \sum_{i=0}^{n_1-1} f_i \Delta Y_{t-i} + \sum_{i=0}^{n_2-1} g_i \Delta (p/c)_{t-i}$$

where,

Y = ouput;

p/c = the ratio of prices received to implicit rental price of capital services.

The possible difficulties of estimating the weights, f_i and g_i, by a

[7] The derivation of equation (7) is similar to that for equation (4).

[8] The derivation of equation (10) is similar to that given by Mackrell *et al* [14, pp. 7-9].

simple application of least squares, are well documented.[9] The problem caused by the likely existence of a high degree of multicollinearity between the regressors may be overcome if some *a priori* information about the true weights can be incorporated in the estimation procedure. This usually involves the imposition of some restriction on the distribution of the true weights. A variety of these lag distributions has been formulated.[10] For this study, a polynomial lag distribution was chosen, the weights being estimated using the Almon variable technique [1].

The polynomial lag was preferred because it is capable of representing a 'humped' distribution. Past observations have indicated that there is a substantial lag associated with the effect of price variables on farm investment,[11] and it was expected that a lag distribution with a shape similar to the geometric lag would be inappropriate. Other classes of lag such as the Pascal and the Jorgenson rational lag distributions can exhibit a 'humped' type of distribution but they are much more difficult to estimate than the polynomial lag.[12]

Schmidt and Waud [17] have pointed out a number of dangers associated with the use of the Almon lag, and the importance of specifying the degree of the polynomial and the lag length correctly. As recommended by Schmidt and Waud [17, p. 13] and Mackrell *et al.* [14, p. 10], a number of specifications were tested in an attempt to find the appropriate degree of the polynomial and the correct lag length.

The Data

For the calculation of the implicit rental price series, the index of price of investment goods, q, was taken as being equal to the implicit deflator of the quarterly investment series. The aggregate average tax rates were calculated using data contained in the *Annual Reports of the Commissioner of Taxation* and *Taxation Statistics*. The expected return to capital before tax, k, was estimated as the ratio of the trend in output over the period 1958(3) to 1969(4) to the estimated actual capital stock.[13] The proportion of investment expenditure to which the investment allowance refers, x, was also estimated from tax data. The prices received index was taken as the implicit deflator of the quarterly output series used, namely, farm product at factor cost. All equations were estimated in terms of constant 1966-67 prices. Due to the use of lags the sample period was 1961(4) to 1969(4).

The Results

The results from the regression equations based on the Jorgenson approach were poor. The price variable ($\Delta p/c_t$) was usually insignificant or had the wrong sign. This was partly due to the tendency for the index of prices received to fall in the second quarter of each year when the investment series is rising. To overcome this problem, the variable

[9] See for example, Schmidt and Waud [17, p. 11] and texts such as Kmenta [12, pp. 380-391, 473].

[10] See for example, the survey article by Griliches [5]. For a comprehensive coverage see Dhrymes [3].

[11] See for example, Hooke [8, p. 202].

[12] For a discussion of the rational lag distribution see Dhrymes [3, pp. 236-262].

[13] This series was obtained by cumulating the constant dollar farm investment flow on a base-period fixed farm capital stock figure obtained for 1956 (2), using a constant quarterly depreciation rate.

change in implicit rental price was substituted for the existing price variable. The resulting equations were re-estimated using the Almon variable technique. The distributions of the lag weights for the output and implicit rental price variables were constrained, in various experiments, to follow second, third or fourth degree polynomials of varying lengths. No *a priori* zero constraints were specified for any of the lag distributions. The criteria for selecting a set of preferred equations were (i) R^2 (adjusted for degrees of freedom), (ii) the number of correct signs and (iii) a subjective judgement of the acceptability of the estimated lag weights.

The results for the three preferred equations (equations I, II and III), together with three other sets of results, are given in Table 1. (For comparison, additional results are given in Appendix 2). The table contains the estimated coefficients, their standard errors (in parentheses), the degree of the fitted polynomials and the lag lengths,[14] as well as a number of fit statistics. The most appropriate lag length for the output variable was found to be four quarters. This lag length gave the maximum $\bar{R}^2$ regardless of the polynomial fitted. The sum of the weights was quite stable for lag lengths close to four quarters. It appears that the estimates of the weights on the output variable are slightly more efficient when these weights are constrained to lie along a second degree polynomial. For equation I the sum of the weights was 0·365 with a standard error of 0·063. For the implicit rental price variable the sum of the estimated weights stabilized around a range of values between —8·000 and —10·171 regardless of the degree of the polynomial specified. Stable values of this sum and the maximum value of $\bar{R}^2$ were reached simultaneously at a lag length of five quarters. For equation I the sum of the weights is — 10·171 with a standard error of 1·590. The coefficient on the actual capital stock variable was expected to be close to the assumed rate of depreciation used in the construction of the capital stock series. After a lag of two quarters was reached the addition of extra lagged values of the implicit rental price variable led to a significant increase in the size of the coefficient estimated on the actual capital stock variable. The value of this coefficient stabilized at about 0·049 after the implicit rental price variables were included with lags up to five quarters. The standard error on this coefficient did not increase. These results suggest that the rate of depreciation assumed for the construction of the capital stock series was too low.[15]

Care should be exercised in drawing policy conclusions from these equations. Due to their nature, the data series used in this study are likely to contain a larger percentage of measurement error than many other time series. However, the equations could be used validly to forecast future turning points in the investment series.

Conclusions

The estimation of a reliable expenditure function for aggregate investment in the agricultural sector has been possible within the limits set

[14] If the lag length and the degree of the polynomial are equal then the estimated weights are not constrained to lie along any given polynomial.

[15] There may have been no reason to believe that the rate of replacement was equal to the true rate of depreciation in a sector where the effect of investment incentives was quite strong in the past.

TABLE 1

Investment Functions for Australian Agriculture

Equation Number	I	II	III	IV	V	VI
Constant	—15.094	—14.940		25.714	—0.166	—14.564
	(13.856)	(13.696)		(15.960)	(14.729)	(16.759)
K_{t-1}	0.049	0.049	0.044	0.036	0.044	0.049
	(0.005)	(0.005)	(0.0006)	(0.006)	(0.005)	(0.006)
$\sum_{i=0}^{n_1-1} f_i \Delta Y_{t-i}$						
Degree of Polynomial	2	4	2	2	2	2
Lag Length	4	4	4	4	4	4
f_0	0.043	0.052	0.043	0.046	0.043	0.042
	(0.009)	(0.014)	(0.009)	(0.014)	(0.011)	(0.009)
f_1	0.082	0.072	0.082	0.082	0.087	0.078
	(0.015)	(0.016)	(0.015)	(0.021)	(0.017)	(0.014)
f_2	0.097	0.101	0.097	0.093	0.104	0.091
	(0.017)	(0.017)	(0.017)	(0.024)	(0.019)	(0.016)
f_3	0.088	0.079	0.088	0.081	0.094	0.082
	(0.015)	(0.016)	(0.015)	(0.021)	(0.017)	(0.015)
f_4	0.055	0.049	0.054	0.046	0.056	0.049
	(0.010)	(0.016)	(0.010)	(0.014)	(0.012)	(0.010)
$\sum_{i=0}^{n_2-1} g_i \Delta c_{t-i}$						
Degree of Polynomial	2	2	2	2	4	2
Lag Length	5	5	5	2	4	8
g_0	—1.573	—1.620	—1.281	—1.013	—1.293	—1.672
	(0.566)	(0.572)	(0.450)	(0.937)	(0.770)	(0.463)
g_1	—1.719	—1.743	—1.502	—1.296	—1.481	—1.811
	(0.324)	(0.323)	(0.257)	(0.968)	(0.776)	(0.334)
g_2	—1.792	—1.792	—1.613	—1.851	—1.345	—1.830
	(0.362)	(0.355)	(0.324)	(0.994)	(0.817)	(0.294)
g_3	—1.792	—1.768	—1.616		—2.586	—1.731
	(0.359)	(0.352)	(0.321)		(0.801)	(0.300)
g_4	—1.720	—1.671	—1.509		—1.335	—1.512
	(0.319)	(0.315)	(0.255)		(0.780)	(0.305)
g_5	—1.575	—1.500	—1.292			—1.174
	(0.574)	(0.563)	(0.513)			(0.293)
g_6						—0.717
						(0.280)
g_7						—0.140
						(0.318)
g_8						0.555
						(0.450)
$\bar{R}^2$	0.823	0.830	0.816	0.636	0.769	0.812
F	22.247	18.382	25.587	9.002	12.824	20.747
$D.W.$	2.27	2.24	2.17	1.53	2.16	2.41

(The numbers appearing in parentheses are the standard errors of the coefficients)

by the availability of data. The important implications of the results are as follows:

(i) The neo-classical theory provides a useful framework on which to base empirical studies of aggregate investment and the effects of taxation incentives. The theory is useful in that it provides a set of variables that can be tested in a regression equation and suggests ways in which these variables may be combined.

(ii) The role of the output variable appears to be limited to one of causing seasonal shifts in investment. Lags longer than four quarters and lag distributions following polynomials of degree three and four resulted in unreliable estimates of the lag weights.

(iii) The significance of the implicit rental price variable adjusted for the effects of the special depreciation and investment allowances tends to confirm the earlier contentions of Lewis and Glau. Despite the difficulties associated with the construction of this variable and with the use of basically annual taxation data in a quarterly model the results confirm the usefulness of this approach. The 'humped' lag distribution for this variable is in keeping with results obtained from comparable studies of aggregate investment in the manufacturing sector.

Appendix 1

The equation for the implicit rental price of capital services is derived as follows. The revenue stream, $R(t)$, *is* represented by:

(1) $R(t) = (1-u)(c)\exp(-a.t)+(u.v.q.a)\exp(-a.t)+(u.r.s.q)\exp(-a.t)$

and the present value of the revenue stream is:

$$(2) \qquad PV = (u.x.z.q)+\int_0^\infty \exp[-k(1-u)t]R(t)dt$$

By substituting equation (1) in equation (2) the present value of the revenue stream becomes:

$$(3) \quad PV = (u.x.z.q)+\int_0^\infty [(1-u)(c)\exp(-A.t)+(u.v.q.a)\exp(-A.t) + (u.r.z.q.)\exp(-A.t)]dt$$

where,

$$(4) \qquad A = [a+k(1-u)]$$

Now,

$$PV = (u.x.z.q)+(1-u)(c)\int_0^\infty \exp(-A.t)dt+(u.v.q.a)\int_0^\infty \exp(-A.t)dt + (u.r.s.q)\int_0^\infty \exp(-A.t)dt$$

Completing the integration and finding the definite integrals gives:

(5) $PV = u.x.z.q + (1-u)\ (c)/A + (u.v.q.a)/A + (u.r.s.q)/A$

Under the assumptions of the neo-classical theory a firm will invest in new goods up to the point where:

(6) $q = PV$

Substituting equation (5) in equation (6) and rearranging terms gives:

$(1-u)(c)/A = q - (u.x.z.q) - (u.v.q.a)/A - (u.r.s.q)/A$

and,

(7) $c = [q/(1-u)]\ [A - u.x.z.A - u.v.a. - u.r.s]$

Substituting equation (4) in equation (7) and factorizing gives

$$c = [q/(1-u)]\ [k(1-u)(1-u.x.z.) + a(1-u.x.z - u.v.) - u.r.s]$$

Appendix 2

Equation Number	VII	VII	IX	X	XI
Constant	—14.881	—14.799	—14.767	—14.221	—15.121
	(14.313)	(14.216)	(17.841)	(17.173)	(16.601)
K_{t-1}	0.049	0.049	0.049	0.049	0.049
	(0.005)	(0.005)	(0.006)	(0.006)	(0.005)
$\sum_{i=0}^{n_1-1} f_i \Delta Y_{t-i}$					
Degree of Polynomial	2	4	4	2	4
Lag Length	4	4	8	4	4
f_0	0.043	0.051	0.011	0.042	0.046
	(0.010)	(0.015)	(0.026)	(0.010)	(0.014)
f_1	0.083	0.072	0.087	0.081	0.067
	(0.015)	(0.017)	(0.039)	(0.016)	(0.015)
f_2	0.098	0.102	0.095	0.095	0.098
	(0.018)	(0.018)	(0.044)	(0.019)	(0.016)
f_3	0.089	0.079	0.070	0.086	0.071
	(0.016)	(0.016)	(0.045)	(0.017)	(0.015)
f_4	0.055	0.050	0.041	0.053	0.049
	(0.010)	(0.017)	(0.047)	(0.014)	(0.017)
f_5			0.024		
			(0.050)		
f_6			0.027		
			(0.052)		
f_7			0.048		
			(0.047)		
f_8			0.075		
			(0.027)		
$\sum_{i=0}^{n_2-1} g_i \Delta c_{t-i}$					
Degree of Polynomial	4	4	4	4	2
Lag Length	5	5	5	8	8
g_0	—1.677	—1.774	—2.092	—1.723	—1.681
	(0.677)	(0.686)	(0.877)	(0.689)	(0.473)
g_1	—1.446	—1.436	—1.404	—1.580	—1.810
	(0.637)	(0.629)	(0.818)	(0.479)	(0.332)
g_2	—1.964	—1.888	—1.693	—1.783	—1.824
	(0.505)	(0.499)	(0.632)	(0.431)	(0.287)
g_3	—1.973	—1.965	—1.649	—1.911	—1.723
	(0.504)	(0.496)	(0.619)	(0.370)	(0.293)
g_4	—1.460	—1.535	—1.203	—1.731	—1.507
	(0.635)	(0.626)	(0.794)	(0.408)	(0.299)
g_5	—1.649	—1.494	—1.527	—1.196	—1.175
	(0.680)	(0.676)	(0.852)	(0.373)	(0.286)
g_6				—0.445	—0.729
				(0.421)	(0.273)
g_7				0.199	—0.167
				(0.484)	(0.315)
g_8				0.222	0.510
				(0.605)	(0.460)
$\bar{R}^2$	0.811	0.817	0.712	0.804	0.822
F	16.276	14.009	8.176	15.552	17.430
$D.W.$	2.29	2.25	2.60	2.34	2.22

(The numbers appearing in parentheses are the standard errors of the coefficients)

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