THE NEW ZEALAND PASTORAL LIVESTOCK SECTOR:

AN ECONOMETRIC MODEL (VERSION TWO)

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THE AGRICULTURAL ECONOMICS RESEARCH UNIT

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The AERU, the Department of Agricultural Economics and Marketing, and the Department of Farm Management and Rural Valuation maintain a close working relationship on research and associated matters. The Unit is situated on the 3rd floor of the Burns Wing at the College.

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PREFACE

The following report contains a description of version two of an econometric model of the N.Z. pastoral livestock sector of the N.Z. economy. This description should be viewed as a further development of the 'preliminary' model (or version one) by Laing and Zwart (1981), published as AERU Discussion Paper No. 54.

The current report builds on the earlier paper by refining data and specification aspects as well as extending the scope of the model to include farm income and investment.

Mr Laing carried out the research presented in this report whilst a postgraduate research student working under the supervision of Dr A. Zwart, Senior Lecturer in the Department of Agricultural Economics and Marketing at the College.

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CHAPTER 1

INTRODUCTION

In a previous study, Laing and Zwart (1981), recognising the importance of the pastoral livestock sector to the New Zealand economy, developed a preliminary econometric model of the sector. An econometric model was seen as a valuable aid in describing the sector's structure, predicting the future implications of current trends within the sector, and exploring the effects and consistency of alternative government policies. However, while the preliminary results showed the estimated model to be a valid representation of the pastoral livestock sector's structure, it was recognised that considerable model development and refinement was necessary before the model would be in a form suitable for forecasting and use in policy analysis. The research described in this report is considered to be a positive progression toward these goals.

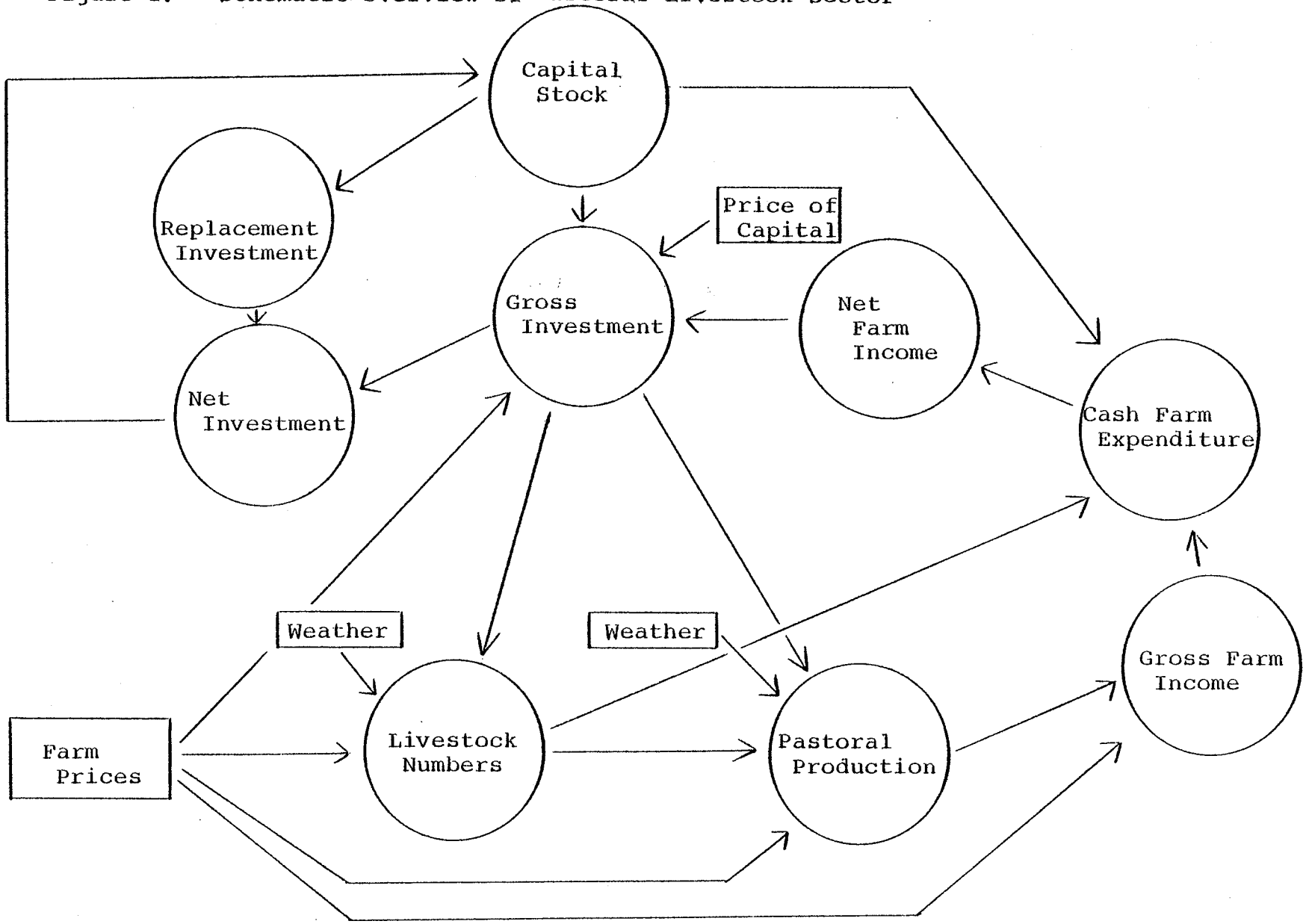
The current research has enhanced the previous model in three ways. Firstly, the data used in estimating the preliminary model have been substantially revised. Secondly, the livestock numbers and production equations have been specified more precisely. Thirdly, and probably most importantly, the model now includes components of farm income and expenditure and farm capital investment. In the preliminary model, investment was treated as an exogenous variable, though it was recognised at the time that causal linkages existed

between livestock numbers, pastoral production, farm incomes, and investment. The chain is completed with the impact farm capital investment has on livestock numbers and animal performance (see Figure 1). A theoretical specification of a model explaining capital investment in land, buildings and transport vehicles, plant and machinery is therefore developed in Chapter 2 while a farm income model is specified in Chapter 4.

Because of the emphasis on establishing the causal linkages between livestock numbers, farm incomes and capital investment, no further work has been undertaken developing the domestic consumption component of the overall model structure. This component was reported in Laing and Zwart (1981; see Figure 1 and Sections 3.4 and 3.5).

In keeping with the report on the preliminary model, the present report is largely technical, in that while the estimation results for individual equations and model validation results are discussed, there is no overall evaluation of the estimated model in terms of its implications for model users and policy makers. Such an evaluation is considered too important to be included in an already lengthy report which has a primary aim of describing the theoretical and estimated structure of an econometric model of the pastoral livestock sector.

Figure 1: Schematic Overview of Pastoral Livestock Sector



Also, a policy orientated evaluation of the model would be incomplete without an analysis of the dynamic properties of the model, especially the consistency of the dynamic elasticities it generates.

Chapter 2 represents a discussion of the farm capital investment component of the model and specifies a theoretical model specification explaining farm capital investment in land, buildings and transport vehicles, plant and machinery. Chapter 3 proceeds with a description of a model specification explaining both changes in the numbers of sheep, beef cattle and dairy cattle, and the level of farm production originating from these livestock populations. Following Chapter 3, a farm income and expenditure model is specified in Chapter 4. The model specification utilises per farm income and expenditure data for both sheep and beef, and dairy farms.

Chapter 5 reports on the estimation of the three model components specified in Chapters 2, 3, and 4. Finally, Chapter 6 discusses the validity of the estimated model in the light of results generated by subjecting the model to a dynamic historical simulation. Chapter 6 concludes with some suggestions as to the direction of future research.

CHAPTER 2

FARM CAPITAL INVESTMENT MODEL SPECIFICATION

2.1 INTRODUCTION

The role of agricultural investment in the New Zealand context has been identified by many writers as an important determinant of both stock numbers and agricultural output[1]. Investment in capital stock influences the carrying capacity of the land, the productivity of the animals which graze the land, and the productivity of the farm labour.

The capital stock of a farm is made up of land, buildings, and plant and machinery. Addiditions to the land capital stock are measured by expenditure on pasture development, irrigation systems, new fencing, and other land improvements such as the planting of shelter belts. The remaining two categories of capital stock can also be identified by expenditure on capital goods such as new farm buildings, tractors, and farm implements.

Not all capital expenditure reflects additions to the capital stock since some capital expenditure occurs in response to the need to replace capital stock which has 'worn out' or become obsolete. It is easy to see why farm investment is considered an important vehicle for the introduction of technological change into agriculture.

Specific government policy recently directed towards farm investment has included tax depreciation allowances,

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[1] See Walsh (1979 and 1980), Taylor (1979), Johnson (1978).

input subsidies, the Livestock Incentive Scheme (LIS), and the Land Development Encouragement Loan Scheme (LDEL). Given that government involvement in the determination of agricultural investment is thought justifiable, then the corrollary of such a conclusion must be the one expressed by Waugh (1977a; p 134): "economic policy embracing new and replacement investment incentives should therefore necessarily consider the relationship between investment behaviour and its underlying determinants." In designing government policy to affect investment, policy-makers need to understand the processes generating both the level and the rate of investment. Only then can effective policy influencing farm investment be instituted, and the indirect effects of other government agricultural policy be anticipated. An important dimension to government investment policy is its timeliness. The production response as a result of agricultural investment is typically delayed. "Consequently, any public measures which are set in motion to offset any threatened decline in the rate of increase of rural production must, if they are to be really effective, be related, in an anticipatory fashion, to investment trends" (Campbell, 1958; p 94).

The objective of this chapter is to develop a theoretical model specification describing the determinants of both the level and the rate of agricultural investment. The economic theories of investment behaviour are first examined, followed by a review of some Australian studies of agricultural investment. A theoretical model specification for New Zealand agricultural investment is then developed.

2.2 THEORIES OF INVESTMENT BEHAVIOUR

The theories of investment behaviour found in the literature provide no unique a priori specification for a model seeking to link the determinants of investment, with actual investment behaviour. In discussing the literature, a convenient starting point is Jorgenson's (1971) survey of econometric studies on investment. While Jorgenson's survey only deals with studies of the manufacturing sector, it provides the theoretical background necessary for the subsequent discussion of studies of agrcicultural investment in Australia.

2.2.1 Components of a Theory of Investment Behaviour

A complete theory of investment behaviour requires three components:

(i) The selection of the determinants of the desired stock of capital. This component of investment theory is the most important, and not surprisingly, the most controversial element in specifying investment models. Given its importance, the determinants of the desired capital stock will be discussed in detail after a brief discussion of the other two components of investment theory.

(ii) A representation of the time structure of the underlying investment process is the second component of an investment theory. For example, actual capital may be represented as a weighted average of all past levels of desired capital, with geometrically declining weights, i.e.

$$K_t = (1 - \beta) \sum_{r=o}^{\infty} \beta^r K^*_{t-r} \qquad (1)$$

where K_t ≡ actual level of capital in period t,

K^*_{t-r} ≡ desired level of capital in period t-r,

β^r ≡ geometrically declining weight.

Equation (1) above is derived from what is called in investment literature as the flexible accelerator mechanism, i.e.

$$K_t - K_{t-1} = \beta (K^*_t - K_{t-1}) \qquad (2)$$

where β ≡ the adjustment coefficient, so that the actual change in capital stock is some fraction of the desired change. Equation (2) is more commonly known as Nerlove's partial adjustment mechanism.

The use of the adjustment mechanism, although widespread, is considered by many to be inconsistent with the various theories of investment. Lucas (1967; p 78) writes about "the incongruity of developing a rigorous economic theory of the determination of X^o (i.e. K*) and then combining this with an ad hoc theory of adjustment ..... adjustment lags ..... are due to the fact that the unit cost of an addition to capital stock is higher the more rapidly the addition takes place ..... a firm attempting to maximise its present value will naturally stagger an adjustment to a new desired stock." Therefore, the imposition of a constraint on the rate at which capital can be accumulated should be done at the same time that decisions about the desired inputs of capital are made. The adjustment process itself must therefore be viewed as an economic decision, concerned with the speed relative to the cost of adjustment.

Not only is the adjustment mechanism claimed to represent the increasing marginal cost of capital as the rate of adjustment increases, but it has also been justified on other

grounds. It is rational that a lag should exist between changes in the determinants of the desired capital stock and the decision to invest, if the decision-maker waits to confirm the long-term presence of changed market conditions. Also, an unavoidable lag exists between the decision to invest and the investment's completion. Another justification for the adjustment mechanism is based on relaxing the usual assumption of perfect foresight by the decision-maker. Instead, a discrepancy between actual and expected values of the determinants of investment is thought to exist, so that adjustments are continually made as the actual values of the determinants are learned (see Jorgenson and Siebert, 1968; p 1124).

(iii) A theory of investment behaviour is completed when replacement investment is accounted for. The usual assumption made is that replacement is proportional to capital stock, i.e.

$$R_t = \delta K_{t-1} \tag{3}$$

where $R_t \equiv$ replacement investment in period t

and $\delta \equiv$ the replacement (or depreciation) rate,

so that the capital stock declines geometrically.

If the capital stock declines geometrically, the capital stock in any one year is equal to a weighted sum of past gross investments with geometrically declining weights, the weight used calculated by taking the replacement rate away from unity. Therefore,

$$K_t = \sum_{r=0}^{\infty} (1 - \delta)^r A_{t-r} \tag{4}$$

where $A_{t-r} \equiv$ gross investment in period t-r.

Equation (4) holds because the change in capital stock is equal to gross investment less a constant proportion of capital stock, that is, since

$$K_t - K_{t-1} = A_t - \delta K_{t-1} \tag{5}$$

then $$K_t = A_t + (1 - \delta) K_{t-1} \tag{6}$$

and so, Equation (4) can be derived by continually substituting for K_{t-r} in Equation (6)[2].

The assumption of proportionality between replacement investment and capital stock requires that the measure of capital stock employed must be based on the parallel assumption of a geometric replacement (depreciation) rate. If it is not, Equation (4) no longer holds. Jorgenson (1971; p 1139) notes that many studies fail to enforce this requirement, bringing a basic inconsistency into the model specification.

Having noted the three components of any theory of investment behaviour, and discussed more fully the final two components, attention is now focussed on the first component of investment theories, that is, the selection of the determinants of the desired level of capital. While all theories of investment behaviour broadly accept the flexible

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[2]For example, in Equation (6) above,

$$K_{t-1} = A_{t-1} + (1-\delta) K_{t-2} \quad \text{(i)}$$

Substituting this equation into Equation (6) yields

$$K_t = A_t + (1-\delta) (A_{t-1} + (1-\delta) K_{t-2}) \quad \text{(ii)}$$

$$K_t = A_t + (1-\delta) A_{t-1} + (1-\delta)^2 K_{t-2} \quad \text{(iii)}$$

or $$K_t = \sum_{r=0}^{1} (1-\delta)^r A_{t-1} + (1-\delta)^2 K_{t-2} \quad \text{(iv)}$$

Continued substitution for K_{t-r} will enable the general form written in Equation (4) above to be derived. As $r \rightarrow 00$, the last term in Equation (iv) will approach zero.

accelerator mechanism as a good representation of the time structure underlying the investment process, and generally assume that replacement investment is proportional to capital stock, little consensus has been reached as to how the desired capital stock is determined. This issue will now be discussed, and the alternative theories presented.

2.2.2 The Determinants of the Desired Level of Capital Stock

There are three major theories explaining the desired level of capital stock. These are: the accelerator hypothesis, the residual funds hypothesis and the external finance hypothesis. As will be shown below, these theories are often described in the literature under different names.

(i) The Accelerator Hypothesis[3]

The accelerator hypothesis in its most basic form assumes that the desired level of capital stock is proportional to output, i.e.

$$K_t^* = f(Q_t) \tag{7}$$

where $Q_t \equiv$ output from the production process using the capital stock.

Therefore, changes in demand for the output result in changes in the capital stock necessary to produce that output. The accelerator hypothesis is often stated in terms of a capacity utilisation hypothesis. In this case, the desired level of capital stock is determined by the difference between current output and the maximum output possible

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[3] Not to be confused with the flexible accelerator mechanism described earlier.

from the current stock of capital, i.e.

$$K_t^* = f\ (Q_t^{max} - Q_t) \qquad (8)$$

where $Q_t^{max} \equiv$ maximum output.

As the pressure on production capacity increases, so does the desired level of capital stock.

Another variant of the accelerator hypothesis expresses the desired level of capital stock as a function of changes in output, i.e.

$$K_t^* = f\ (Q_t - Q_{t-1}) \qquad (9)$$

(ii) The Residual Funds Hypothesis

The residual funds hypothesis is known variously as the profit theory and the liquidity theory. Despite the assortment of names, all these themes deal with the general concept of the flow of internal funds.

The level of desired capital stock is thought to be determined by the amount of funds able to be generated by the firm from its own resources. Therefore, various models have been specified with the exogenous variable described as profit, net income, savings, cash flow, stock of liquid assets or transitory income.

The basic premise of internal fund theories is that firms are debt-averse. Duesenbery (1958; p 110) developed this proposal and concluded that the cost of funds to a firm rises sharply for a firm when it goes into debt, "due to increases in the risk premiums imputed by firms as the amount of debt rises."

Firms would tend to fund investment from internal

resources unless the rates of return from investment were very high; for example, when demand was growing quickly. In this case, only after internally generated investment funds were exhausted would higher cost external funds be borrowed up to a certain debt capacity.

(iii) The External Funds Hypothesis

The external funds hypothesis assumes that desired capital is independent of factors reflecting internal fund capacity. This is the principle conclusion of what is known as the Modigliani-Miller theory of finance. Most basically, this theory concludes that "the type of instrument used to finance an investment is irrelevant to the question of whether or not the investment is worthwhile" (Modigliani and Miller, 1958; p 292). Investment studies based on the point of view proposed by the Modigliani-Miller theory of finance are in Jorgenson's (1971; p 1134) view "seriously incomplete". This is due to the way in which the cost of external finance is represented. Usually, the market rate of interest is used as the appropriate cost of capital. However, Jorgenson (1963) describes how the appropriate cost of external finance for investment involves a more complex formulation. Jorgenson's formulation is based on a weighted average of the expected return to equity, and the return to debt. The return to equity is measured by capital gains (or losses), while the return to debt is a function of the depreciation rate, the interest rate, and the taxation structure.

Mathematically, Jorgenson's cost of external finance is represented by

$$c_i = q_i \left(\frac{1-uv_i}{1-u} \delta_i + \frac{1-uw}{1-u} r - \frac{1-u\chi}{1-u} \frac{\dot{q}}{q} \right)$$

where $c_i \equiv$ the cost of capital services for capital good i

$q_i \equiv$ the price of capital good i

$u \equiv$ the rate of taxation for the firm

$v_i \equiv$ the proportion of replacement investment on capital good i chargeable against income

$\delta_i \equiv$ the rate of replacement investment for capital good i

$w \equiv$ the proportion of interest chargeable against income

$r \equiv$ the rate of interest

$\dot{q} \equiv$ the change in the price of capital good i (representing capital gains or losses)

$\chi \equiv$ the proportion of capital losses chargeable against income.

Jorgenson describes how the higher the interest rate (r) and the rate of replacement investment (δ), the higher the cost of capital services. The higher the marginal tax rate (u), the proportion of replacement investment chargeable against income (v_i), or the proportion of interest chargeable against income (w), the lower is the cost of capital services.

Jorgenson assumed a proportional tax system, u was therefore constant. An alternative cost of capital equation based on a progressive tax structure has been derived by Glau (1971; pp 86-93). The capital services cost under average expected conditions is adjusted downwards for the tax

saving realised on depreciation allowed in the year of purchase. Tax savings arise since some of the higher tax burden of taxpayers with fluctuations in taxable incomes is avoided. Glau's formula is:

$$c_i = q_i \frac{(r+\delta_i)}{(1-\bar{u})} \frac{(1-\bar{u})}{} z_i \frac{(1+r)}{} - \frac{\hat{u}_1 \, d_{i1}}{1-\bar{u}} r$$

where c_i, q_i, r, δ_i as defined earlier,

$\bar{u}$ ≡ the permanent component of the marginal tax rate

$\hat{u}_1$ ≡ the transitory component of the marginal tax rate in period 1

d_{i1} ≡ the amount of tax depreciation allowed for capital expenditure on capital good i in period 1

z_i ≡ the present value of depreciation on one dollar's worth of capital expenditure on good i

≡ $\sum_{t=1}^{\infty} d_{it} (1+r)^{-t}$, where d_t is the amount of tax depreciation allowed on one dollar of investment, t periods after investment has taken place.

Unlike Jorgenson, Glau ignores the impact of capital gains on the cost of capital services.

Increases in the interest rate and the replacement rate increase the cost of capital services. Increases in the tax depreciation allowed and the transitory component of the marginal tax rate lower the cost of capital services.

Jorgenson favours the external finance hypothesis as the theory best describing the determinants of the desired capital stock. The external funds hypothesis is compatible with the neoclassical theory of optimal capital accumulation.

In this neoclassical theory, a firm's desire to maximise its net worth determines its demand for capital. The optimality conditions show the desired level of capital stock as being a function of changes in relative factor prices or the ratio of factor prices to the price of output. That is,

$$K^* = f\ (P_Q/P_k) \tag{10}$$

or $$K^* = f\ (P_k/P_L) \tag{11}$$

where $P_Q \equiv$ output price

$P_k \equiv$ cost of capital services

and $P_L \equiv$ cost of labour.

In spite of appeals made to neoclassical theory, the applied econometric studies of investment behaviour fail to enforce the theoretical model's specification. "By contrast, the econometric literature on business investment consists of ad hoc descriptive generalisations such as the "capacity principle", and the "profit principle", and the like" (Jorgenson, 1963; p 247).

Having surveyed briefly the theoretical aspects of investment theory, it is now appropriate to review some Australian agricultural investment studies. This, together with the previous discussion, will provide the basis for specifying a New Zealand agricultural investment model. Australian studies are emphasised for two reasons. Firstly, since investment theory originates from the manufacturing sector rather than the agricultural sector, few agricultural investment studies are reported in the literature. Some Australian studies, both theoretical and applied, do exist. Secondly, while the pastoral livestock sectors in Australia

and New Zealand differ considerably, the form and role of capital in pastoral production is similar.

2.3 AUSTRALIAN STUDIES OF AGRICULTURAL INVESTMENT

It is not surprising when reviewing the Australian literature to find that the area of greatest disagreement centres on the determinants of the desired capital stock. Campbell (1958; p 98) argues that traditional investment models of economic theory have little relevance to agriculture. Profit maximisation theories of investment have "value in providing a basis for setting up ideal goals for agricultural investment rather than as an explanation of, or guide to, entrepreneurial action". He justifies this statement by arguing that choices made between alternative farm investments frequently bear no relation to the productivities of the capital employed. Also, a cost-reducing innovation and the replacement of worn-out capital cannot occur unless it could be paid for. Therefore, internal liquidity is identified by Campbell as the major determinant of investment expenditure. Drawing on Friedman's concept of transitory and permanent income, Campbell argues that it is the transitory component of income that determines the level of capital formation. This conclusion is supported by the empirical work of Girao et al. (1974) who found that farmers with unstable incomes decided on their investment expenditure according to their transitory incomes.[4] For farmers with stable incomes, savings were more important than transitory income as a determinant of investment expenditure. These results have obvious policy implications.

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[4] Note, study based on U.S. farmers.

Firstly, if instability of income leads to greater investment, then to the extent that the objective of greater income stability for agriculture is achieved, capital investment will be slowed. This exposes a fundamental conflict between stability and growth. Secondly, if transitory income is a major determinant of agricultural investment, then farm investment decisions are dominated by short-run considerations. This makes the timeliness of government policy even more critical.

Herr (1964) challenged Campbell's arguments against profit-maximisation theory being used to represent investment decisions. While his empirical results supported Campbell's hypothesis that farmers with unstable income had a higher marginal propensity to invest additional income, Herr argued that this could be explained by profit-maximising theory incorporating risk and uncertainty. Herr also argued that although in the long run internal financing had to pay for investments, in the short-run debt is also used. Finally, Herr notes that investment expenditure was closely related to expansion in crop production, evidence that an accelerator type model could also be justified, since investment followed production increases, Herr's arguments show that each investment theory provides some insight into describing investment behaviour. This conclusion is supported by Glau (1971; p 210-231).

Glau's study on the effects of taxation on agricultural investment in Australia specified a useful framework in which to bring the conflicting theories of investment behaviour together. Glau saw taxation as having a dual effect on investment. Firstly, the desired stock of capital was dependent on the demand for services from capital inputs. This in turn was dependent on the relative prices of capital inputs and non-

capital inputs, and on the relative prices of capital inputs and outputs. In other words, Glau hypothesised the desired stock of capital to be dependent on variables suggested by neoclassical theory. Glau also recognised the relevance of the accelerator model. Therefore,

$$K^* = f\ (Q_t,\ \frac{PQ}{Pk},\ \frac{Pk}{PL}) \qquad (12)$$

Since the effective cost of the capital inputs (the neoclassical user cost of capital services) was affected by tax policy, Glau described this effect of the taxation policy as the substitution effect.[5]

The second effect of taxation on investment was the income effect. Glau (1971; p 213) stated that the income effect "operates on the internal liquidity of the firm and will affect the rate of adjustment from the existing stock of capital owned by the farmer to that stock of capital which he desires to own." Therefore, mathematically,

$$K_t - K_{t-1} = \beta_t\ (K^*_t - K_{t-1}) \qquad (13)$$

and

$$\beta_t = f\ (Y_{t-r}) \qquad (14)$$

where $Y_{t-r} \equiv$ relevant variables representing liquidity with appropriate lags placed on them.

Specifying a variable rather than a constant rate of adjustment provides a more realistic reflection of the true lag structure of investment response found in agriculture. If transitory income is a motivating force behind investment expenditures, then in periods of improved prices and incomes

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[5]For example, initial depreciation allowances lower the effective cost of capital and therefore increase the demand for capital goods, replacing non-capital inputs.

a backlog of desired expenditure on new and replacement investment would occur. Therefore, a geometrically distributed investment response implied by a constant coefficient is not realistic. Also, allowing the β coefficient to vary removes the restriction that β must be greater than zero but less than or equal to one. The variable coefficient β_t could even be negative in some years.

The theories of investment would therefore seem to be less mutually exclusive than seemed at first. While the accelerator and neoclassical hypotheses are thought to determine the desired level of capital stock, liquidity variables "are considered to exert an impact on the time path chosen for the investment response (to a given change in desired capital) - 'the timing role' - rather than determining the actual level of desired capital - 'the determining role' " (Waugh, 1977b; p 154). In the New Zealand context, this conclusion is supported by Johnson (1978; p 7), who states that farmers' "propensity to invest will be coloured by their expectations as to future price and volume trends as well as those of the immediate past ..... The strongest economic factor, however, remains the availability of finance out of current earnings."

As a consequence of the preceding discussion, it can be seen that a model describing investment behaviour must incorporate two important dimensions. Firstly, it must describe how the desired level of capital stock is established, and secondly, it must describe the timing or rate of actual investment.

At this point, it should be noted that although the approach described above is intuitively appealing, it still has not faced up to the basic criticism of using the adjustment

mechanism after optimising behaviour is assumed to have occurred in setting the desired capital stock. The imposition of constraints which are themselves the subject of optimising behaviour needs to be analysed simultaneously with the optimising behaviour concerned with setting the desired stock. Analytically, this approach is certain to be highly complex. For the purposes of specifying a model describing agricultural investment in New Zealand, the simpler though ad hoc approach will be used.

2.4 A MODEL SPECIFICATION FOR NEW ZEALAND AGRICULTURAL INVESTMENT

2.4.1 A General Specification

From Equation (14), net investment is defined as a variable proportion of the desired net investment, i.e.

$$K_t - K_{t-1} = \beta_t \quad (K_t^* - K_{t-1}) \tag{15}$$

Gross investment is equal to net investment plus replacement investment,

$$A_t = K_t - K_{t-1} + \delta K_{t-1} \tag{16}$$

therefore,

$$A_t = \beta_t(K_t^* - K_{t-1}) + \delta K_{t-1} \tag{17}$$

Equation (17) implies that while net investment is not necessarily able to be simultaneously adjusted to a desired level, replacement investment is. Replacement investment is therefore assumed to always be undertaken. Campbell (1958;

p 99) argues convincingly against such a view with respect to building and machinery replacement. He says that "except for income tax purposes, farmers do not usually regard depreciation as a regularly occurring expense of production. They consider outlays to replace worn-out machinery and buildings to be in the same class as those made for additions. Moreover, they are likely to finance replacements and additions in identical ways." This view can also be extended to replacement investment in land improvements. Given the blurred distinction between replacement and additions to capital, Equation (17) could be rewritten as:

$$A_t = \beta_t (K_t^* - K_{t-1} + \delta K_{t-1}) \tag{18}$$

or

$$A_t = \beta_t (K_t^* - (1 - \delta) K_{t-1}) \tag{19}$$

Therefore, Equation (19) implies the same adjustment mechanism for both net and replacement investments.

It was stated earlier that the rate of adjustment, β, need not be constant. Equation (15) hypothesised that adjustment rate to be a function of variables representing liquidity, that is,

$$\beta_t = f(Y_t) \tag{20}$$

Glau suggests that the rate of adjustment can be taken to be a linear function of internal liquidity relative to the desired investment, for example

$$\beta_t = b_1 + b_2 \frac{Y_t}{(K_t^* - (1 - \delta) K_{t-1})} \tag{21}$$

Internal liquidity could be measured by savings, net income or transitory income. The choice of which variable

to use may be suggested by the stability of farm income, as was suggested earlier. The effect of income instability on New Zealand farm investment was pointed out by Zanetti et al. (1975; p 70). "..... the instability in farm prices and incomes (inherent in the industry) is a direct impediment to continuity in farm investment since the most important source of funds for on-farm investment in New Zealand has in the past been 'plough-back' of current profits with loan finance of lesser significance." Therefore, transitory income is likely to be the best measure of internal liquidity.

Waugh (1976; p 152) suggests that variables representing external liquidity could also be included. Specifically, he suggests the change in the level of real debt (ΔD_t). Other variables are suggested by Girao et al. (1974), for example, the debt to asset ratio. The inclusion of the variable representing external liquidity in Equation (21) produces Equation (22), i.e.

$$\beta_t = b_1 + b_2 \frac{Y_t}{K_t^* - (1-\delta) K_{t-1}} + b_3 \frac{\Delta D_t}{K_t^* - (1-\delta) K_{t-1}} \qquad (22)$$

Equation (22) may be substituted into Equation (19), after simplification producing Equation (23), i.e.

$$A_t = b_1 (K_t^* - (1-\delta) K_{t-1}) + b_2 Y_t + b_3 \Delta D_t \qquad (23)$$

Since Equation (23) includes the unobservable variable K* (the desired stock of capital), the determinants of K* can be used as its substitute. In its simplest form, the equation specifying the desired capital stock can be written

as a linear function of output and relative prices, i.e.

$$K_t^* = a_o + a_1 Q_t + a_2 \frac{PQ}{PK_t} + a_3 \frac{PK}{PL_t} \qquad (24)$$

More sophisticated variations of Equation (24) could be developed using distributed lags in the independent variables.[6]

Equation (24) must be substituted into Equation (23), producing the estimating equation found below.

$$A_t = a_0 b_1 + a_1 b_1 Q_t + a_2 b_1 \frac{PQ}{PK} + a_3 b_1 \frac{PK}{PL} - (1-\delta) b_1 K_{t-1} +$$

$$b_2 Y_t + b_3 \Delta D_t \qquad (25)$$

To obtain unique estimates of a_0, a_1, a_2 and b_1, an estimate of the replacement rate (δ) is required. Equation (25) is then estimated in the form,

$$A_t = \alpha_1 + \alpha_2 Q_t + \alpha_3 \frac{PQ}{PK} + \alpha_4 \frac{PK}{PL} + \alpha_5 K_{t-1}^A +$$

$$b_2 Y_t + b_3 \Delta D_t \qquad (26)$$

---

[6] As an aside, it is interesting to note how, ceteris paribus, an increase in output prices increases both the level of desired capital stock (Equation (24)), and the ability of the firm to pay for it, since liquidity is also increased when prices increase (Equation 23)). From Equation (22) it can be seen that if both liquidity and the desired level of capital stock increase, then the rate of adjustment (β_t) will not change significantly. Therefore, periods of high farm liquidity will not necessarily increase the adjustment rate if it is associated with high output prices. The level of investment will, of course, be higher.

where $\alpha_1 = a_0 b_1$,

$\alpha_2 = a_1 b_1$,

$\alpha_3 = a_2 b_1$,

$\alpha_4 = a_3 b_1$,

$\alpha_5 = -b_1$,

and $K^A_{t-1} = (1 - \delta) K_{t-1}$.

2.4.2 Data Availability and Sources

Data collection and model specification are highly inter-related stages in model building. The specification of the model determines what data should be collected. Data availability determines the possibilities in model specification.

For the purposes of this research, data availability has limited the model specification to models which deal with quite aggregate data. The preferred model specification would include equations explaining gross capital investment by type of capital, and by farm type. The subdivision of capital expenditure by farm type has only been available since 1966, when the Department of Statistics began collecting data on farm capital expenditure. Even then, the man-hours necessary to extract the farm type data has made such extraction unpracticable until computer-based data systems were instituted in the early 1970s. Capital expenditure data from 1946-1969 are available from Johnson (1970) and Johnson and Hadfield (1971), but again, no subdivision of the data into farm types was practicable. For the purposes of the current research, the Department of Statistics and Johnson's data were

combined to provide time series data for gross, net, and replacement investment, and consequently, the capital stock. An estimate of depreciation rates for land, buildings, and plant and machinery was calculated using Johnson's estimates of replacement investment, which were based on normal physical deterioration of the capital stock, rather than taxation allowances.

Given the data available, Section 2.4.3 now develops equation specifications for farm capital expenditure subdivided into three categories: land, buildings, and plant and machinery.[7]

2.4.3 Gross Capital Investment by Investment Category: Equation Specifications

Having developed a general equation specification for modelling agricultural capital investment, individual model specifications will now be developed for the three categories of capital investment.

(i) Land Development

Let,

$$GIL_t = \beta_{L',t} \left(L_t^* - (1 - \delta_L)\, L_{t-1}\right) , \tag{27}$$

$$L_t^* = a_{11} + a_{12}PW_t + a_{13}PPB_t + a_{14}PD_t, \tag{28}$$

and

$$\beta_{L,t} = a_{21} + a_{22} \frac{Y_t}{L_t^* - (1-\delta_L)L_{t-1}} + a_{23} \frac{\Delta D_t}{L_t^* - (1-\delta_L)L_{t-1}} \tag{29}$$

---

[7] See Variable list in Appendix I

where

GIL_t ≡ gross investment in land development in period t ($m),

L_t^* ≡ desired capital stock of land in period t ($m),

L_{t-1} ≡ actual capital stock of land in period t ($m),

$\beta_{L,t}$ ≡ adjustment coefficient for land development in period t,

δ_L ≡ replacement rate for developed land,

PW_t ≡ average auction wool price (c/kg),

PPB_t ≡ schedule price of prime beef (c/kg),

PD_t ≡ milkfat price (c/kg),

Y_t ≡ gross income per farm in period t ($)

and ΔD_t ≡ change in debt per farm in period t ($).

Equation (28) omits a variable representing output, which is hypothesised to be a determinant of the desired capital stock in the theoretical model. In the case of land development, however, it is a basic fact that land development precedes increases in livestock numbers or livestock productivity. Land development does not occur in response to increases in livestock numbers or productivity, since such increases do not occur autonomously, but occur after new land has been cleared and subdivided, water supplies provided, and fertiliser applied.

A variable representing the costs of capital services is also excluded from Equation (28). Unlike building, and plant and machinery capital, land investment expenditure is often indistinguishable from working expenditure. Because of

this, land capital does not appear in the depreciation schedule, and therefore no tax depreciation rate is allowed for.[8] While a cost of capital services cannot be computed for land development, a variable representing working expenditure could be experimented with in Equation (29), which explains the adjustment coefficient ($\beta_{L,t}$).

Wool and prime beef prices are included as variables representing the profitability of the sheep and beef enterprise. Lamb returns could also be tested for significance. The milkfat price represents the profitability of dairying.

The adjustment coefficient is expressed as a function of liquidity and debt variables. Various forms of the liquidity variable can be experimented with; for example, gross farm income, the change in gross income, and savings. The debt variable is also expressed on a per farm basis. Current liabilities, fixed liabilities, the change in liabilities, or the ratio between liabilities and net worth could be used to represent debt.

For estimation purposes, Equations (28) and (29) must be substituted into Equation (27), so that Equation (30) is derived.

$$GIL_t = a_{31} + a_{32}PW + a_{33}PPB + a_{34}PD + a_{35}L^A_{t-1} + a_{22}Y_t + a_{23}\Delta D_t \qquad (30)$$

---

[8] Although, if claimed as working expenditure, tax depreciation is 100%. Development expenses may also be written off against income for up to nine years after the expenditure takes place.

where $a_{31} = a_{21}\, a_{11}$,

$a_{32} = a_{21}\, a_{12}$,

$a_{33} = a_{21}\, a_{13}$,

$a_{34} = a_{21}\, a_{14}$,

$a_{35} = -a_{21}$

and $L^{A}_{t-1} = (1 - \delta_{L})\, L_{t-1}$.

(ii) Buildings

The buildings capital investment model incorporates some of the variables excluded from that developed for land development.

Firstly, a quantity variable has been included in the equation describing the desired capital stock of buildings. Actual output from pastoral production has not been included in the equation. Instead, since it is the number of livestock that are directly affected by capital investment, and which produce the pastoral products, the number of stock units is considered the appropriate variable. The change in stock units might be used instead of the absolute numbers, hypothesising that it is the pressure on building facilities (e.g., woolsheds, haybarns, milkingsheds) that encourage building investment. Accommodation for the farmer and his employees is also included in the building capital investment category. The livestock numbers variable is less easily justified for this type of investment.

The second change in the building equation is the inclusion of the cost of capital services in a ratio with enterprise profitability variables (see Equation (32)). The

cost of capital services, as described in Section 2.2.2 (iii), is made up of variables such as the interest rate, the tax rate, the depreciation rate, the amount of tax deductible capital investment, and the price and change in price of capital goods. These variables must be combined to produce the cost of capital services. Glau's formula for combining the variables was presented earlier. While the formula ignores the impact of capital gains on the cost of capital, it is more relevant to the New Zealand situation than Jorgenson's formula because it is based on the assumption of a progressive tax structure. Glau's formula is presented again below:

$$c_i = q_i \left(\frac{(r + \delta_i)}{(1-\bar{u})} \frac{(1-\bar{u}) z_i}{} \frac{(1 + r)}{} - \frac{\hat{u}_1 \, d_{il} \, r}{(1-\bar{u})} \right)$$

Depending on the replacement rate (δ), the tax depreciation allowance (d), the present value of depreciation (z), and the price of capital goods (q), the cost of capital services will differ between different types of capital good. The cost of capital services will also differ between farms since the tax rates ($\bar{u}$ and $\hat{u}_1$) depend on each farm's income level. Glau's cost of capital services formulation may now be rewritten as:

$$c_{ij} = q_i \left(\frac{(r + \delta_i)}{(1-\bar{u}_j)} \frac{(1-\bar{u}_j) z_i}{} \frac{(1 + r)}{} - \frac{\hat{u}_{1j} \, d_{il} \, r}{(1-\bar{u}_j)} \right)$$

where the subscript refers to the enterprise. The other variables, q, r, δ , z and d are assumed not to vary between enterprises.

Given the complexity of Glau's formulation, a

simpler version of his formula was developed by just calculating the negative term in the formula above. This represents the tax saving from capital expenditure,

$$\text{i.e. } c_{ij} = \frac{q_i \hat{u}_{ij} d_{il} r}{1-\bar{u}_j}$$

The theoretical capital investment model also includes as a variable the ratio between the cost of capital services and the wage rate. On sheep and beef farms, farm buildings and labour are not seen as being competitive inputs. For dairy farms, however, improvements in milking sheds may be labour-saving. Therefore, the capital services cost to farm usage ratio may or may not be justified in the building capital equation's specification.

The estimating form of the building capital investment equation can be derived by substituting Equations (32) and (33) found below, into Equation (31), to produce Equation (34), i.e., let

$$GIB_t = \beta_{B,t} (B^*_t - (1 - \delta_B) B_t), \tag{31}$$

$$B_t^* = b_{11} + b_{12} SU_t + b_{13} \frac{PW}{PKB}_t + b_{14} \frac{PD}{PKB}_t + b_{15} \frac{PK^B}{PLAB}_t \tag{32}$$

$$\text{and } \beta_{B,t} = b_{21} + b_{22} \frac{Y_t}{B^*_t - (1 - \delta_B) B_{t-1}} + b_{23} \frac{\Delta D_t}{B^*_t - (1 - \delta_B) B_{t-1}} \tag{33}$$

then,

$$GIB_t = b_{31} + b_{32}SU_t + b_{33}\frac{PW}{PK^B}_t + b_{34}\frac{PD}{PK^B}_t +$$

$$b_{35}\frac{PK^B}{PLAB}_t + b_{36}B^A_{t-1} + b_{22}Y_t + b_{23}\Delta D_t \qquad (34)$$

where

GIB_t ≡ gross investment in buildings in period t ($m),

B_t^* ≡ desired capital stock of buildings in period t ($m),

B_{t-1} ≡ actual capital stock of buildings in period t ($m),

$\beta_{B,t}$ ≡ adjustment coefficient for building investment in period t,

δ_B ≡ building replacement rate,

SU_t ≡ total number of stock units in period t ('000),

PK^B ≡ cost of building capital services (index) in period t,

PLAB ≡ farm wage index in period t,

$b_{31} = b_{21}, b_{11}$,

$b_{32} = b_{21}\ b_{12}$,

$b_{33} = b_{21}\ b_{13}$,

$b_{34} = b_{21}\ b_{14}$,

$b_{35} = b_{21}\ b_{15}$,

$b_{36} = -b_{21}$, and

$B^A_{t-1} = (1 - \delta_B)\ B_{t-1}$.

(iii) Transport Vehicles, Plant and Machinery

Equations (35) to (38) develop the specification for an equation explaining gross investment in transport vehicles, plant, and machinery.

Let,

$$GIM_t = \beta_{M,t} \left(M_t^* - (1 - \delta_M)\, M_{t-1}\right) \tag{35}$$

$$M_t^* = c_{11} + c_{12} SU_t + c_{13} \left(\frac{PW_M}{PK}\right)_t + c_{14} \left(\frac{PD}{PM^M}\right)_t + c_{15} \left(\frac{PK^M}{PLAB}\right)_t \tag{36}$$

and

$$\beta_{M,t} = c_{21} + c_{22} \frac{Y_t}{M_t^* - (1 - \delta_M)\, M_{t-1}} + c_{23} \frac{\Delta D_t}{M_t^* - (1 - \delta_M)\, M_{t-1}} \tag{37}$$

Substitution of Equations (36) and (37) into Equation (35) yields Equation (38).

$$GIM_t = c_{31} + c_{32} SU_t + c_{33} \left(\frac{PW}{PK^M}\right)_t + c_{34} \left(\frac{PD}{PK^M}\right)_t + c_{35} \left(\frac{PK^M}{PLAB}\right) + c_{36}\, M^A_{t-1} + c_{22}\, Y_t + c_{23}\, \Delta D_t \tag{38}$$

where

GIM_t ≡ gross investment in transport vehicles, plant and machinery in period t ($m),

M_t^* ≡ desired level of transport vehicles, plant and machinery capital stock in period t ($m),

M_{t-1} ≡ actual level of transport vehicles, plant and machinery capital stock in period t-1 ($m),

$\beta_{M,t}$ ≡ adjustment coefficient for transport vehicles, plant and machinery in period t,

δ_M ≡ replacement rate for transport vehicles, plant and machinery,

PK^M_t ≡ cost of capital for transport vehicles, plant and machinery in period t (index),

$c_{31} = c_{21}\, c_{11}$,

$c_{32} = c_{21}\, c_{12}$,

$c_{33} = c_{21}\, c_{13}$,

$c_{34} = c_{21}\, c_{14}$,

$c_{35} = c_{21}\, c_{15}$,

$c_{36} = -c_{21}$, and

$M^A_{t-1} = (1-\delta_M)\ M_{t-1}$

2.4.4 Net and Replacement Capital Investment, and The Capital Stock

To round off the model for farm capital investment, identities must be calculated to determine replacement investment and net investment, and consequently, the capital stock.

Following the earlier discussion regarding replacement investment (see 2.2 (iii)), replacement investment is assumed to be some fixed proportion of the capital stock. From

Equation (3)

$$R_t = \delta K_{t-1}$$

where R ≡ replacement investment in period t,

δ ≡ the replacement rate,

and K_{t-1} ≡ the capital stock in period t-1.

Equation (3) assumes that the capital stock decays geometrically. This assumption requires the measure of capital stock employed to be based on a parallel assumption. The capital stock data calculated for this study is consistent with the assumption of a geometric replacement rate. Therefore, an identity for the capital stock series can be calculated.

$$K_t = A_t + (1 - \delta) K_{t-1}$$

where A_t ≡ gross capital investment in period t.

An identity for net investment is found by calculating the difference between gross and replacement investment.

Three identities, calculating replacement and net capital investment, and the capital stock respectively, have been included in the model specification for each of the three investment categories: land, buildings, and transport vehicles, plant and machinery.

CHAPTER 3

LIVESTOCK NUMBERS AND PRODUCTION MODEL SPECIFICATION

3.1 INTRODUCTION

In Laing and Zwart (1981), the livestock numbers and production components of the pastoral livestock sector model were specified and estimated. However, while in general the estimated equations fitted the historical data quite closely, the theoretical base on which the estimated equations were specified was not developed rigorously. The primary objective of the discussion that follows is therefore to develop a sound theoretical model specification which may then be confronted with actual data through regression analysis. A secondary objective is to establish a link between the capital investment model developed in Chapter 2 and a model explaining changes in livestock numbers and production. Laing and Zwart (1981, p49-51) recognised that their treatment of investment as it affected these variables was very simplistic and consequently in need of further theoretical development.

The objective of the following discussion then is to examine alternative specifications of a model explaining livestock numbers and production. The discussion centres upon a number of earlier studies which had

similar objectives. Although both American and United Kingdom studies are relevant to the discussion, Australian and New Zealand studies are emphasised. This is not unexpected since both countries' farming systems are largely made up of pastoral-based, multi-enterprise, and owner-operated units. An Argentinian study is, to a certain degree, also relevant in this respect.

A common thread running through many of the studies is the influence capital theory has had on recent modelling practice. As is shown, the use of capital theory-based specifications has not led to any unique model structure. However, the discussion below emphasises that no matter which style of model specification is favoured, individual equations specified must be consistent with the overall model framework. The widespread use of the partial adjustment mechanism is also critically evaluated. Throughout the discussion, many of the peculiarities of modelling livestock systems are highlighted. Finally, equations are specified describing livestock numbers in each of the New Zealand pastoral enterprises (sheep, beef cattle, and dairy cattle), and for the outputs from these enterprises.

3.2 THE DECISION-MAKING PROCESS

Table 1 provides a summary of eighteen studies which developed econometric models explaining livestock numbers, slaughter, and/or output. The majority of model structures have been derived by viewing the farmer's decision-making process in terms of a constrained dynamic optimisation problem. The usual assumption made is that farmers aim to maximise profits over time. This objective is subject to a number of constraints, both physical and economic. The physical production constraints relate firstly to initial conditions such as the capital stock of land, buildings, and plant. These are usually regarded as fixed productive resources. The second type of physical production constraint relates to livestock demographic factors, that is, the farmer's livestock numbers and his ability to vary them over time. While livestock numbers may be adjusted downward readily, the biological lags that exist make increases in livestock numbers a more time-consuming process. Climatical conditions are usually included as a constraint also.

The economic constraints are usually described in terms of expected output prices and input costs.

Having set up the objective and constraint functions, first order derivatives are taken in order to derive the equations that determine the optimum time sequence of decision variables (i.e., livestock numbers, slaughter and output) which result in the objective function being maximised. The derived decision equations are found, depending on the exact specification of the objective and constraint functions, to be functions of variables such as expected market prices for a particular enterprise and competing enterprises, the variabil-

Table 1: Econometric Studies of Livestock Numbers and Production

Name	Country modelled	How Model structure derived	Endogenous variables	Form Of endogenous variables	Behavioural or identity	Exogenous Variables Included														Simultaneous, recursive or single equation
						Output price	Competitive price	Relative prices	Variance of prices	Variance of competitive prices	Time	Investment	Livestock numbers	Lagged Dependent variable	Land	Labour	Farm costs	Stocks	Exports	Weather	
Court (1967)	N.Z.	Constrained dynamic optimisation	Output	Volume	Behavioural	Yes								Yes							Single equation
Freebairn (1973)	Australia	Constrained dynamic optimisation	Livestock No.s	Number	Behavioural	Yes	Yes		Yes						Improved pasture					Rainfall	Simultaneous (price also endogenous)
			Output	Volume	Behavioural	Yes	Yes		Yes		Productivity		Yes							Rainfall	
Freebairn and Rausser (1975)	U.S.A.	Constrained dynamic optimisation	Livestock No.s	Change in numbers	Behavioural	Yes	Yes		Yes												Simultaneous (price also endogenous)
			Output	Volume	Behavioural	Yes	Yes		Yes				Yes								
Harrison (1981)	Australia	Appeal to Freebairn (1973)	Livestock No.s	Number	Behavioural	Yes	Yes		Yes	Yes				Yes						Pasture available	Recursive
Jarvis (1974)	Argentina	Constrained dynamic optimisation	Slaughter	Number	Behavioural	Yes							Yes			Change			Yes	Yes	
			Carcase Wgt	Weight	Behavioural		Not Reported														Recursive
			Output	Volume	Identity																
			Livestock No.s	Number	Identity																
Martin and Haack (1977)	Nth America	Intuitive	Livestock No.s	Number	Behavioural	Yes															
			Slaughter	Number	Behavioural	Yes							Yes				Feed				Recursive
			Carcase Wgt	Weight	Behavioural	Yes											Feed				
			Output	Volume	Identity																
Heikle et al. (1981)	Australia	Intuitive	Output	Volume	Behavioural	Yes		Yes										Yes	Yes	Carcase weight	Simultaneous (price also endogenous)
Rattigan and Fisher (1981)	Australia	Appeal to Reynolds and Gardiner (1980)	Output	Volume	Behavioural	Yes	Yes							Yes						Rainfall	Simultaneous (price also endogenous)
Rayner (1968)	N.Z.	Intuitive	Livestock No.s	Number or Δ number	Behavioural	Yes					Yes			Implied							Recursive
			Slaughter	Per cent	Behavioural	Yes							Implied								
Rayner (1975)	U.K.	Constrained dynamic optimisation	Livestock No.s	Number	Behavioural	Yes					Yes			Yes			Yes				Recursive
			Output/animal	Volume	Behavioural						Productivity						Feed			RAINFALL, temp	
			Output	Volume	Identity																
Reutlinger (1966)	U.S.A.	Static profit maximisation	Slaughter	Volume	Behavioural	Beef/corn					Yes		Yes	Implied							Single equation
Reynolds and Gardiner (1980)	Australia	Constrained dynamic optimisation	Slaughter	% slaughtered	Behavioural	Yes	Yes													Rainfall	Recursive
			Output/animal	Weight	Behavioural	Yes	Yes				Yes									Rainfall	
			Adjustment decisions	% bred from % lambing	Behavioural	Yes	Yes													Rainfall	
			Output	Volume	Identity																
			Livestock No.s	Number	Identity																
Rowe (1956)	N.Z.	Intuitive	Livestock No.s	Number	Behavioural			Yes			Yes										Single equation
Smith and Smith (1976)	Australia	Intuitive	Supply	$ value	Behavioural	Yes		Yes			Yes			Yes					Yes	Yes	Animal production	Simultaneous (price endogenous)
Throsby (1977)	Australia	Intuitive	Supply	$ value	Behavioural	Yes								Yes						Rainfall	Simultaneous (price endogenous)
Tryfos (1974)	Canada	Appeals to Reutlinger (1966)	Livestock No.s	Number	Behavioural	Yes								Yes			Feed				Simultaneous
			Slaughter	Number	Behavioural								Yes	Implied							
Tweedie and Spencer (1980)	N.Z.	Constrained dynamic optimisation	Livestock No.s	% change	Behavioural	Yes		Yes				Current expenditure		Total No.s						Soil moisture deficit	Recursive
			Output	Volume	Behavioural						Yes			Yes						Soil moisture deficit	
Woodford and Woods (1978)	N.Z.	Intuitive	Livestock No.s	Stock units	Behavioural	Yes						Income per S.U.								Rainfall/ Fleece wt.	Single equation

ity of market prices, prices of important purchased inputs, the level of important fixed resources (including breeding animals), and variables reflecting climatical conditions and technological change.[9]

The more intuitive specifications described in Table 1 result in similar specifications for the estimated equations as those derived from the more rigorous analytical results obtained from the optimisation structure.

The most important implication of the preceding description that derived a model specification for livestock numbers, slaughter and output, is that a farmer's decision in one period affects the range of values future decisions may take. Intuitively, this result is obvious. Livestock have dual potential uses for the farmer. Firstly, they can be slaughtered now for current production, and secondly, they can be retained for future production. This future production can be in the form of either breeding stock producing an annual 'crop' of offspring, the production of other products such as wool or milkfat, or through future slaughter, producing meat and its byproducts. It is this dual nature of livestock that has led researchers to apply capital theory and the principles of investment behaviour it proposes to livestock sector modelling.[10] Livestock become capital goods, and "in essence, producers become portfolio managers seeking the optimal combination of different categories of animals to complement their non-

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[9] This descriptive account is carried out more analytically by Freebairn (1973), Rayner (1975), Court (1967) and Jarvis (1974).

[10] Jorgenson's work involving the manufacturing sector has inspired many livestock studies along similar lines (see Jorgenson (1963) and Freebairn (1973)).

cattle assets, given existing conditions and future expectations" (Jarvis, 1974; p 489). This viewpoint underlies the dynamic optimisation formulation of livestock model specification outlined above.

In order to fully develop a capital theory-based model of the livestock sector, the model should be disaggregated by animal categories to obtain a meaningful explanation of producers' responses. Animals of different age, sex and breeding ability have different economic functions within the herd, making disaggregation necessary since each category will be affected in different ways and to varying degrees by economic forces. In addition, each individual demographic category's ability to respond to economic stimuli is influenced by current and past responses in other demographic categories. An increase in the desired level of breeding cows, for example, might not be met if the heifer herd is depleted due to past slaughtering, or low calf drop.

Formulating livestock models based on capital theory has enabled the apparently perverse phenomenon of a negative short-run supply response in livestock industries to be seen instead as a "necessary, logical, and distinctive feature" of such models (Reynolds and Gardiner, 1980; p 198). Jarvis (1974; pp 491-506) showed that the steer as a capital good had an optimum slaughter age, given the price of beef, the cost of inputs, and a declining marginal product with respect to inputs. If the price of beef increased, the marginal value product of inputs rises, so that both the optimum feed ration and the optimum slaughter age increases. An increase in the beef price will therefore lead to less beef being produced in the short-run.

Unlike steers, heifers can produce a stream of returns throughout their lifetimes by producing calves, as well as having a current slaughter value. If the value of a female as a breeding animal relative to its value as a slaughter animal rises, some females formally destined for slaughter will be withheld. Again, the short-run response is negative. In the long-run, beef supply will increase, as a larger number of heavier animals come to slaughter. In specifying his slaughter equations, Jarvis (1974; p 508) assumes that there is a permanent and a transitory component to observed slaughter. "In equilibrium a constant proportion of the herd, or category, is slaughtered each year. This number, however, may be increased or decreased depending on the desires of producers, which in turn depend on the level of certain parameters. These parameters, such as the current price or current climatic conditions, affect producer expectations and thereby the size of the desired future herd". Reutlinger (1966) and Tryfos (1974) use similar logic to derive their slaughter equations. Available supply of slaughter animals, a technical relationship based on livestock numbers, is adjusted by a price-determined demand for change in livestock numbers, the net result being actual slaughter.

The impact of competitive enterprises on livestock numbers can also be predicted. For example, in the New Zealand context, a rise in the prime beef price relative to the lamb price will lead to disinvestment in the less profitable capital good (sheep) in favour of beef animals. Disinvestment in sheep would be characterised by increased slaughterings, resulting in higher sheepmeat, but lower wool production. Beef production would also fall as investment in beef stock occurred.

So far, it has been shown that models explaining livestock numbers, slaughter or production, will, as a general specification, include variables such as output prices, input costs, climate, fixed resources, technology, and livestock demographic variables. To obtain meaningful estimates of producer behaviour, animals with different economic functions should be included in the model as individual categories, enabling the different patterns of demographic change in response to physical and economic variables to be distinguished.

3.3 THE MODEL'S STRUCTURE AND THE CHOICE OF DECISION VARIABLES

This section discusses the place of the individual decision variables (i.e., livestock numbers, number slaughtered, and output) in the overall model structure. Single equation, and simultaneous equation models describing only one decision variable and price, need not be considered, restricting the discussion to only ten of the eighteen models summarised in Table 1.[11]

Models which include at least two of the three decision variables must be structured carefully, since the number of livestock, the number of livestock slaughtered, and total production, are closely inter-related. The approaches to modelling stock numbers, slaughter and output can be subdivided into

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[11] See Rayner (1968), Freebairn (1973), Jarvis (1974), Tryfos (1974), Freebairn and Rausser (1975), Rayner (1975), Martin and Haack (1977), Reynolds and Gardiner (1980), Tweedie and Spencer (1980). Harrison (1981) is also relevant, since the slaughter equation is substituted into the livestock number equation.

two categories. The approach of the first category can be shown by discussing the work of Reynolds and Gardiner (1980). In their model of the Australian sheep industry, the percentage of the sheep flock slaughtered, the carcase weight and adjustment decisions such as the percentage of the ewe flock bred from, and the death rate, are all estimated as behavioural relationships. End of period stock numbers are found in an accounting manner through the identity relating opening stock numbers, natural increase and slaughter, with closing livestock numbers. Slaughter, births and deaths, Reynolds and Gardiner call investment decisions, and so are behavioural equations in their model. Livestock number response to economic variables is, "led by and dependent on investment decisions" already made, and so is an identity (ibid; p 199). The stock numbers response is therefore a mirror image of the slaughter response. Total production is also an identity in Reynolds and Gardiner's model, being the product of livestock slaughtered and carcase weight.

The recursive nature of the decision-making process outlined by Reynolds and Gardiner can be shown by a schematic outline of their model, found in Figure 2. Reynolds and Gardiner's work is based directly on the earlier study of Jarvis, who used a similar specification.[12]

Harrison (1981; p 5), like Reynolds and Gardiner, recognises the equivalence between the decision to slaughter and the decision to change the level of the capital stock of animals (or inventory): "Intuitively, the factors causing variation in the level of purchases, sales, slaughterings, and mortalities

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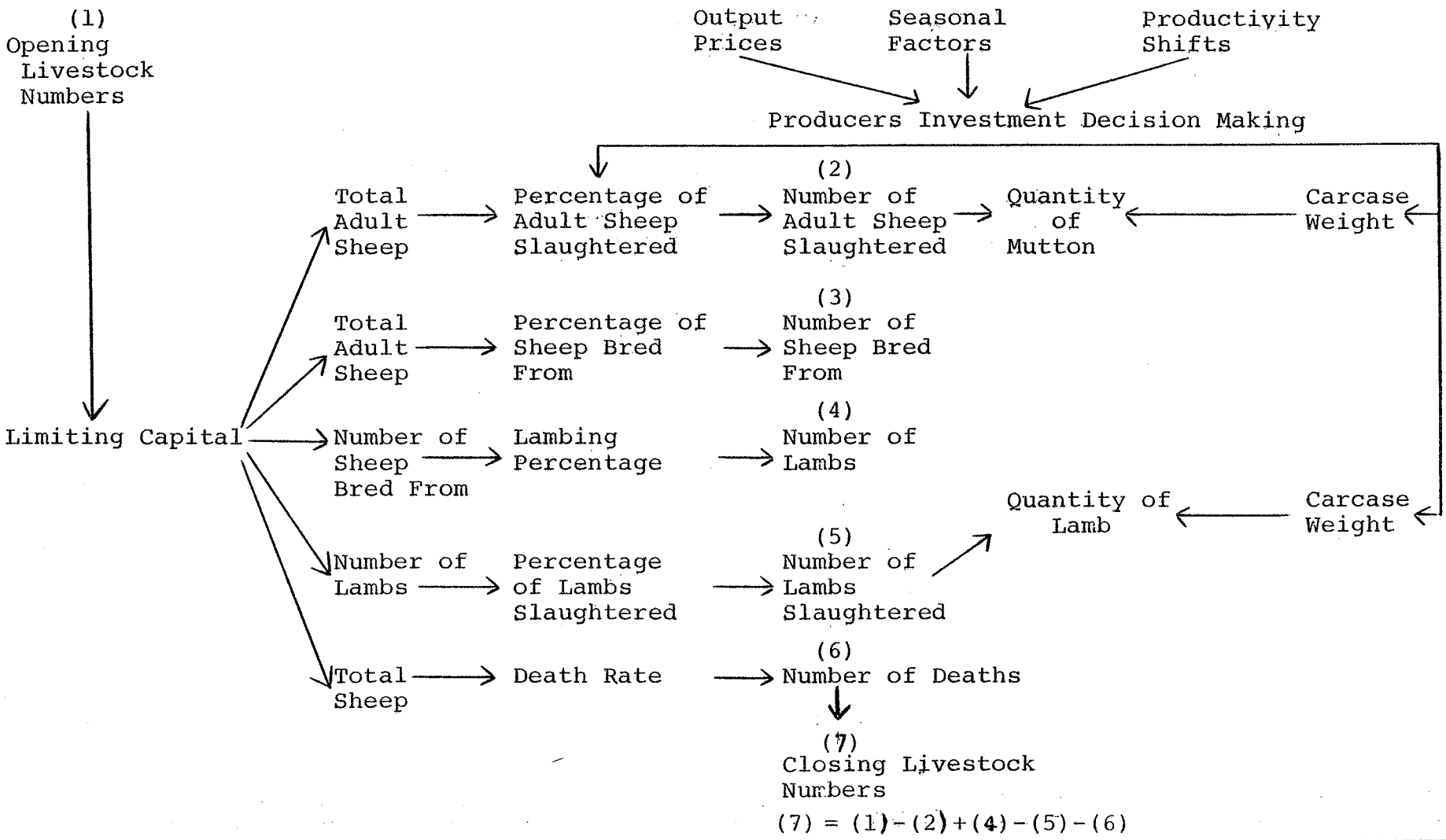
[12] See Jarvis (1974), p 508

Figure 2: Reynolds' and Gardiner's Model Structure



Source: based on Reynolds and Gardiner (1980), Figure 1, p 200.

of cows and heifers are the same as those determining the level of closing inventory." Harrison specifies closing inventory to be identically determined by the opening inventory, slaughter, and net agistment of cattle in and out of the region. Slaughter and agistment equations are then specified as behavioural functions of prices and climate. By substituting these behavioural functions into the identity, a behavioural equation for closing inventory is specified, a function of opening inventory, prices, and climate. Tweedie and Spencer (1980) also use stock numbers as their dependent variable, except in the form of the percentage change in livestock. Given a certain reproductive rate, the slaughter rate can be generated.

Rayner (1975), in his study of United Kingdom milk supply, treated dairy cattle numbers as a behavioural equation, and together with an equation describing yield per cow, found total reproduction through the multiplicative identity of stock, numbers and yield.

So far, all the studies discussed have recognised that slaughter and changes in livestock numbers are two ways of viewing the same decision. Therefore, the authors concerned consider it inconsistent to estimate both slaughter and stock number equations in a behavioural form. One or the other are instead found through an identity, after account is taken of deaths and the reproduction rate. Similarly, output can be found from an identity if slaughter and per head production are treated as behavioural equations. Therefore, it is also considered inconsistent to have a model structure estimating behavioural equations for both slaughter and output, or livestock numbers and output. The second category of studies to

to be discussed are those where the model structure incorporates these apparent inconsistencies.

Tryfos' (1974) study of Canadian beef supply estimates an equation for both the number of beef animals, and the number of beef animals slaughtered. However, while the stock number equation is a function of physical and economic variables, the slaughter equation is a function only of demographic considerations, reflecting the difference between available slaughter animals and the change in stock number requirement already determined by the stock number equation. In effect, therefore, the slaughter equation has simply estimated in functional form what is usually obtained through an identity. This approach, based on that of Reutlinger (1966), is therefore consistent with the model structure developed by the studies discussed earlier. Another study, Martin and Haack (1977), also estimates behavioural equations for both the number of livestock and the number of animals slaughtered. Unlike Tryfos and Reutlinger, price variables are specified to affect both equations. This is apparently inconsistent, since once the number of animals to be slaughtered is decided, so has the number of livestock to be retained. Price, having affected the former decision, has indirectly affected the latter decision, so it cannot be introduced explicitly into the stock number equation. Martin and Haack (1977; p 31) recognised, to a certain extent, their inconsistency but argued that "because of its importance, it is necessary to estimate the inventory relationship, which can be regarded as a recursive link in the supply response system." Therefore, they prefer to estimate two equations providing essentially the same information. Rayner's (1968) study of the New Zealand sheep industry also

contains the inconsistency of estimating both stock number and slaughter number equations. Rayner, however, proposes a more reasonable justification than Martin and Haack for using this approach. In recognising the inconsistency, Rayner felt that since the identity approach required an estimate of the death rate so that, for example, the number slaughtered could be obtained as a residual, then the calculated slaughter series might contain large errors in it when compared to actual slaughter data. Rayner argued that since he couldn't predict the death rate, and wanted to explain as much of the variation in both livestock numbers and slaughterings as possible, he was justified in estimating behavioural equations for the two variables, and then calculating the death rate through the identity. Of course, Rayner recognised that since residual errors from the estimated equations would show up in the death rate, an implausible series of estimated death rates could result.

The final two studies to be discussed that have apparent inconsistencies in their specification are those of Freebairn (1973) and Freebairn and Rausser (1975). Both studies have stock numbers and the volume of output as their dependent variables. The inconsistency, as argued by Reynolds and Gardiner, is that the closing number of livestock is dependent on output decisions (via slaughtering decisions) already made. Therefore, the output equation should not have price variables included in it, but instead should contain only livestock numbers as variables. Judging by the arguments presented by Freebairn for the inclusion of the price variables, Reynolds and Gardiner are correct in their criticism. For example, with respect to sheep activities, Freebairn (1973; p 62) writes that "annual wool

production (Q_W) is assumed to be a function of the beginning inventory of adult sheep (KAS_{-1}) with adjustments to this number as influenced by the expected relative profitability of sheep production (P_W^*, P_L^*, VP_W) to that of beef production (P^*_B) and sheep slaughter (P_M) ....". With respect to the beef production equations, price variables are justified by saying that they reflect "the expected relative profitability of beef production (P^*_B and VP_B) to that of competing forms of livestock production" (ibid; p 61). Clearly, Freebairn is justifying the price variables because of their effect on livestock numbers. While Reynolds and Gardiner argue convincingly that this rationale is inconsistent, Freebairn's specification and its justifications can be defended. The defence rests on the fact that the stock number variable in Freebairn's production equation is entered in its lagged form, and not as the end of period (after slaughter) number of livestock. In its lagged form, the livestock number variable can be described as representing the permanent component of livestock slaughter, a function of the livestock capital stock. The transitory component of slaughter is determined by price expectations, and reflects the changing desired level of end of period livestock.[13] This argument justifies the inclusion of price data in Freebairn's production equation. However, an inconsistency in Freebairn's model still exists. If the price data does represent the changing desired level of end of period livestock, then the livestock number equation has in effect been substituted into the production function, so that it need not be estimated independently.

The estimation of both livestock number and production

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[13] Similar logic to Tryfos (1974), Reutlinger (1966), and Reynolds and Gardiner (1980).

equations, including price data in both, is not unjustifiable. Freebairn's model would be consistent if instead of having lagged stock numbers in the production equation, current (end of period) stock numbers were used. The estimated livestock number equation would then flow recursively into the production equation, representing the actual change in livestock numbers (i.e., the difference between births, deaths, and slaughterings). This still leaves the price data in the production equation to be justified. However, since total production is determined by the number of animals slaughtered (or milked or shorn), times the carcase weight (or yield or woolweight), price variables can be justified. As Jarvis (1974) showed, the carcase weight is a decision variable in itself, affected by prices and other economic variables. Therefore, modifying Freebairn's specification by including current instead of lagged stock numbers in the production equation would make such a specification consistent. The current livestock number variable would represent the number of animals slaughtered. The price data is substitued into the production equation for some hypothetical carcase weight equation. The alternative to this change in Freebairn's specification is to omit the livestock number equation. This also would make Freebairn's specification consistent.[14] Of course, Freebairn could fall back on Rayner's argument that estimating both equations will reduce the residual errors compared with deriving a production series via an identity.

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[14]Another alternative is to estimate both a livestock number and a per head production equation, and then to estimate production as a function of current livestock numbers and per head production.

3.4 THE PARTIAL ADJUSTMENT MECHANISM

Having dealt with the important issue of developing a consistent model specification for the estimation of equations determining the decision variables, the issue of the use of the partial adjustment mechanism must now be faced. As with the discussion dealing with the specification of the agricultural investment sub-model (Chapter 2), the ad hoc nature of the partial adjustment mechanism compared to the rigorous development of a capital theory-based model is highlighted.

From Table 1, it can be seen that thirteen studies either explicitly or implicitly include the use of the lagged dependent variable usually associated with models specified with a partial adjustment mechanism. Only six of the thirteen studies actually claim the partial adjustment mechanism in the model's specification.[15] Three other studies don't give any reason for the inclusion of the lagged dependent variable but probably are claiming the partial adjustment mechanism.[16] Court (1967) and Throsby (1974) include the lagged dependent variable via the adaptive expectations hypothesis relating to price expectations. The final two studies derive the lagged dependent variable as part of their model specification without claiming an adjustment mechanism.

From the discussion of investment behaviour in Chapter 2, a number of justifications for the partial adjustment mechanism can be summarised. Firstly, the partial adjustment mechanism is claimed to represent the staggering of capital stock adjustment to a new desired level. Staggered adjustment is rational

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[15] Tweedie and Spencer (1980), Reynolds and Gardiner (1980), Jarvis (1974), Rayner (1975).

[16] Meikle et al. (1981), Rattigan and Fisher (1981), Smith and Smith (1976).

since the marginal cost of capital increases as the rate of adjustment increases. Secondly, partial adjustment represents the lag between the changes in the determinants of the desired stock and the decision to undertake the investment. Thirdly, a gestation lag exists between the decision to invest and its completion, so that partial adjustment exists. Fourthly, imperfect foresight is thought to prevail among decision-makers, so that discrepancies arise between the actual and the expected values of the determinants of investment. Therefore, actual change in the capital stock will not be the same as the desired change determined by expectations. Finally, the discussion of investment concluded that the investment rate may not be the optimum desired to adjust the capital stock to its desired level because of the inability (or unwillingness) of the farmer to finance the required investment. That is, liquidity problems and debt aversion are claimed as a justification for the partial adjustment mechanism.

Few of the studies of livestock numbers and production claiming the partial adjustment mechanism actually discuss any justification for its use. Reynolds and Gardiner (1980; p 200) propose the fourth justification noted above; that is, that "inter-temporal adjustment may be only partial due to the lack of perfect forecasts and full information." Rayner (1975) provides the only complete discussion dealing with the partial adjustment mechanism use. His study was concerned with milk production in the United Kingdom. Dairy cow numbers and yield per cow were estimated as behavioural equations, production being a multiplicative identity. Rayner's discussion of partial adjustment is based on describing the increasing marginal costs of adjustment as the rate of adjustment increases.

Increasing marginal costs arise for two reasons. Firstly, the implicit supply price of the investment good (heifers in calf) rises as the rate of investment increases. The implicit supply price of heifers in calf is the opportunity cost of these heifers in terms of their value for immediate or future slaughter. Therefore, it is obvious that the adjustment rate of dairy cow numbers to their desired level is inversely related to the supply price of heifers. For example, if the price of beef is used as an indication of the opportunity cost of heifers in calf, then in periods of high beef prices, the rate of adjustment of the dairy cow stock to its desired level will be slow.

The second reason for increasing marginal costs is due to what Rayner calls the "indirect" cost of adjustment (ibid; p 138). As the number of heifers reared increases, so does the amount of land and other resources that must be allocated to them. These resources would otherwise be devoted to the milking herd and therefore to the revenue-producing activity of milk production. Increasing the number of heifers reared therefore results in the opportunity cost of income forgone.

Given that direct and indirect marginal costs imply that complete adjustment of dairy cows to their desired level in any period is unlikely, Rayner then argues that the use of the standard partial adjustment mechanism is an ad hoc way of representing this adjustment process. Echoing the criticisms discussed in Chapter 2, Rayner argues that if livestock models are to view decisions about the level of livestock numbers in terms of investment theory, then multi-period optimisation models must be specified and the optimal distributed lag adjustment path for stock numbers derived. Making a static model

dynamic by adding on an adjustment process which spreads the realisation of the static equilibrium over time is not an equivalent procedure. A major limitation of this expressed by Rayner (1975; p 141) is that "the distributed lag pattern (geometrically declining) which is given by the ad hoc partial adjustment model may be a poor representation of the lag structure specified by the optimising investment model which incorporates increasing marginal costs of adjustment." Instead, Rayner states that "there is no a priori reason to expect that all the weights attached to the lag distribution will necessarily be positive. Cyclical adjustment patterns are possible if it pays to over-adjust. This is in contrast to the restrictions imposed by the partial adjustment model (ibid; p 139).

One convenient though not necessarily optimal way in which to develop a model with a more realistic adjustment lag structure is that proposed in the model specification for capital investment.[17] The partial adjustment mechanism is still assumed, but variable rates of adjustment are also allowed for. The problem then becomes one of specifying the determinants of the rate of adjustment. It was noted earlier how the ability of each demographic category of livestock to respond to economic stimuli was influenced by past responses in other demographic categories.[18] The number of breeding cows desired, for example, would not be satisfied if the number of heifers of appropriate age was too low compared to the number required for the breeding herd. Climatic conditions are also likely to affect the rate of adjustment of livestock numbers to their

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[17] See Chapter 2, Section 2.3.

[18] See Section 3.2,

desired levels.

In conclusion, while the desired level of livestock may be specified as a function of economic variables such as price, risk, and capital investment, the rate of adjustment to this desired level may be a function of demographic constraints and climate.

3.5 SPECIFICATION OF EQUATIONS DESCRIBING NEW ZEALAND LIVESTOCK NUMBERS AND PRODUCTION

3.5.1 A General Framework

Along with the studies discussed so far, the objective of this discussion is to specify a model that will determine the decision variables endogenously. In addition to the need to ensure that the model is specified consistently, is the over-riding concern of data availability. This latter consideration favours the specification of a model with livestock numbers and production estimated as behavioural equations, instead of estimating slaughter, births, deaths, and per head production as behavioural equations, and finding livestock numbers and output via identities. While data series can be found for livestock numbers and production, slaughter data that distinguishes between beef and dairy cattle are unavailable. A sheep model could be specified along the lines of the alternative specification, but it would seem of some benefit to have a consistent model specification used for all pastoral enterprises.

A general model specification for livestock numbers and output can be found below:

$$KL_t - KL_{t-1} = \beta_t (KL^*_t - KL_{t-1}) \quad (1)$$

$$KL^*_t = f_1 (PE, PA, R, GIC) \quad (2)$$

$$\beta_t = f_2 (LDV, W) \quad (3)$$

$$Q_t = f_3 (LDV, PE, PA, GIC, W, T) \quad (4)$$

where $KL_t \equiv$ livestock numbers in period t,

$KL^*_t \equiv$ desired livestock numbers in period t,

$\beta_t \equiv$ adjustment coefficient in period t,

$Q_t \equiv$ quantity of output in period t,

PE $\equiv$ profitability of the enterprise,

PA $\equiv$ profitability of alternative enterprises,

R $\equiv$ uncertainty (risk) associated with profitability,

GIC $\equiv$ gross investment in farm capital,

LDV $\equiv$ livestock demographic variables,

W $\equiv$ climate

and T $\equiv$ technological or genetical improvement (trend).

The actual change in livestock numbers is some proportion (β_t) of the desired change in numbers. The desired number of livestock is a function of expectations about the profitability of the enterprise and competitive enterprises, the riskiness of the enterprise, and gross invest-

ment in farm capital. The profitability of an enterprise is usually represented in models as the output price deflated by a relevant cost index. Sometimes a return per animal is estimated[19], and one writer has suggested that a complex ratio of the profitability of slaughter relative to a discounted profitability of retention be used.[20] Expectations about profitability are often represented by a distributed lag of past prices, usually using either arithmetic, geometric, or polynomial distributions.[21] While the use of distributed lags is widespread and intuitively appealing, their use depends largely on the subjective judgement of the researcher. For example, when using the polynomial lag, both the length of the lag and the degree of the polynomial must be decided upon. If the arithmetic lag is used, the appropriate weightings over the specified lag length must be determined. In recognising the subjective nature of choosing between different lag distributions, simple 'naive' or extrapolative expectations are often chosen in order to avoid the complexity of other distributed lag formulations. Expectations are assumed to be formulated on the basis of one year's prices, the appropriate year being determined by a priori (to some degree subjective) knowledge about the dynamics of the decision environment.

The profitability of competitive enterprises can be introduced into the model in an identical way to own enterprise profitability. Table 1 shows that competitive enterprise returns are usually included as variables in their own

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[19] Tweedie and Spencer (1980).

[20] Malcolm (1981).

[21] Freebairn (1973) uses arithmetic distributed lags; Harrison (1981) and Trail (1978) geometric lags, and Rattigan and Fisher (1981) and Kulshreshtha (1976) polynomial lag distributions.

right. Alternatively, they are introduced by forming a ratio between themselves and the return from alternative enterprises. Practically, this latter formulation is often favoured since it saves some degrees of freedom and reduces possible sources of multi-collinearity. Intuitively, it is a more explicit way of representing competition.

Harrison (1981; p 2) has shown that responses in terms of changes in livestock numbers will occur "where an alternative less risky enterprise can be partly or completely substituted" for a more risky enterprise. Harrison used a complex risk formulation in his model, the risk variable being a geometrically weighted sum of the squared deviations of actual from expected prices. Trail (1978) used a similar formulation, except the geometrically weighted sum of the absolute differences between actual and expected price was calculated. A simpler formulation was used by Freebairn (1973), when risk was represented as the range between current price, and lagged prices. Clearly, numerous risk specifications could be formulated. Ratios of the relative risk between competitive enterprises could also be calculated.

The role of farm investment in determining stock numbers and agricultural output has been discussed in an earlier section. Of the studies represented in Table 1, only two attempt to account for the influence of investment. Tweedie and Spencer (1980) use current expenditure as a variable, while Woodford and Woods (1978) use gross income per stock unit. This study is attempting a more systematic approach to the role of investment, and so will experiment with the various types of investment to gauge which is associated most strongly with production responses. The investment variable can be introduced

using distributed lags or with more simple specifications. Again, this is a matter for experimentation.

Equation (3) in the general model specification shows the rate of adjustment to be a function of livestock demographic variables and climate. The appropriate demographic variable depends on which category of livestock is being modelled. The adjustment rate for breeding stock depends largely on the numbers of replacements available to it, while the adjustment rate for fattening stock such as steers would depend on the number of cows bred from. The demographic variable could enter the equation either in absolute or first difference form. It would also be convenient to express the variable as a ratio, the denominator being the desired change in livestock from the righthand-side of Equation (1).

Table 1 shows that a variety of measures have been used to represent climatical influences on livestock numbers. Where available, direct measures of climatical conditions such as soil moisture deficit and rainfall indexes would be preferred to indirect measures such as animal performance. Direct measures of New Zealand weather are available. Again, the weather variable is conveniently represented in a ratio with the desired livestock number change.

In its most simple form, the equation representing the variable adjustment coefficient can be presented in a linear form, for example,

$$\beta_t = b_0 + b_1 \frac{LDV}{(KL^*_t - KL_{t-1})} + b_2 \frac{W}{(KL^*_t - KL_{t-1})} \qquad (5)$$

Equation (5) can be substituted into Equation (1) producing Equation (6) below:

$$KL_t - KL_{t-1} = b_0 (KL^*_t - KL_{t-1}) + b_1 LDV + b_2 W \quad (6)$$

Assuming that Equation (2) is a linear function, for example,

$$KL^*_t = a_0 + a_1 PE + a_2 PA + a_3 R + a_4 GIC \quad (7)$$

it can be substituted into Equation (6) to give,

$$KL_t - KL_{t-1} + b_0 a_0 + b_0 a_1 PE + b_0 a_2 PA + b_0 a_3 R +$$

$$b_0 a_4 GIC - b_0 KL_{t-1} + b_1 LDV + b_2 W \quad (8)$$

Equation (8) is estimated by,

$$DKL_t = \alpha_0 + \alpha_1 PE + \alpha_2 PA + \alpha_3 R + \alpha_4 GIC + \alpha_5 KL_{t-1}$$

$$+ b_1 LDV + b_2 W \quad (9)$$

where $DKL_t = KL_t - KL_{t-1}$

$\alpha_0 = b_0 a_0$

$\alpha_1 = b_0 a_1$

$\alpha_2 = b_0 a_2$

$\alpha_3 = b_0 a_3$

$\alpha_4 = b_0 a_4$

and $\alpha_5 = -b_0$.

The second equation to be estimated is that dealing with output from the livestock modelled by Equation (9). Depending on the type of output being modelled, the livestock

demographic variable in Equation (4) would be in the form either of the current number of animals, or of the change in livestock numbers. For example, wool, lamb and milkfat production would be determined by the current number of sheep, breeding ewes, and milking cows respectively. On the other hand, mutton and beef production would be better explained by the change in the numbers of adult sheep and cows, since this would reflect the number slaughtered. Of course, the change in stock numbers is not equivalent to the number of animals slaughtered, since other animals enter the sheep flocks or cattle herds over the same period. What the change in animal numbers does represent is whether numbers are being built up, or alternatively whether the flocks or herds are in a liquidation phase. As such, the change in livestock numbers reflects the transitory part of meat production. The permanent part of production is determined by usual culling or fattening policies. Therefore, the opening numbers of the appropriate category of livestock should also be included as a livestock demographic variable.

The other variables in the supply functions are claimed to represent the per head production of animals. The price, capital investment, and climate variables were explained earlier. The price variables should enter the production equations with appropriate lags placed on them. Since they deal with the largely short-term phenomenon of animal productivity, the lags would at most be one period. The lag placed on the capital investment variable will probably be longer than those put on prices.

Some types of animal productivity would be expected to be less price responsive than others. Wool clip per animal,

for example, is likely to be largely determined by climatical influences. However, in periods of high wool prices, the incentive for these farmers to double shear increases, so per head production should be price sensitive to some degree.

The final variable included in Equation (4) represents technological and genetical improvements in New Zealand farm systems and farm animals. Following the example of the studies in Table 10, a time trend is the most convenient way of representing such effects.

Assuming that Equation (4) is a linear function of the predetermined variables, it can be written as,

$$Q_t = c_0 + c_1 LDV + c_2 PE + c_3 PA + c_4 GIC + c_5 W + c_6 T \qquad (10)$$

3.5.2 The Specification of Enterprise Models

The New Zealand pastoral sector is made up of the sheep, beef cattle, and dairy cattle populations. The major outputs from the sector are wool, mutton and lamb, prime and manufacturing beef, and milkfat. For the purposes of model specification, the sheep, beef cattle, and dairy cattle populations have been subdivided into different stock classes, so that the dynamics of response by these different classes to economic stimuli could be identified. Also, the inter-relationships between the different classes can be observed. The sheep flock has been divided into breeding ewes, ewe hoggets, and other sheep; the last category made up largely of wethers, rams and some dry ewes. Beef cattle are divided into beef breeding cows, one to two-year-old heifers, heifer calves, and other beef cattle. The latter category is made up of

steers, bulls, and cull beef and dairy cows. The dairy herd is divided into two categories, cows and heifers in milk or in calf, and dairy heifers under one year old. The number of categories distinguished has been largely determined by data availability. Apart from data for sheep numbers, the quality of available data on livestock numbers over a long time series is not high. A full description of data sources is found in Appendix I. Needless to say, the quality of the data will be reflected in the quality of the results obtained from the econometric analysis.

Equations describing changes in the number of each livestock category, and the level of output produced by the animals, will now be specified.

(a) The Sheep Enterprise

The sheep population has been divided into three categories, ewes, ewe hoggets and other sheep. The products from sheep enterprises are wool, mutton and lamb.

(i) Breeding Ewes: Taking first the ewe flock, Equations (11) to (15) derive an estimating form for the equation specifying the change in livestock numbers.

Let,

$$KE_t - KE_{t-1} = \beta_{Et} (KE^*_t - KE_{t-1}), \qquad (11)$$

$$KE^*_t = a_{11} + a_{12} \frac{PW}{PPB} + a_{13} \frac{PW}{PM} + a_{14} \frac{VPW}{VPB} + a_{15} GIC, \qquad (12)$$

$$\text{and } \beta_{Et} = a_{21} + a_{22} \frac{KHGT_{t-1}}{(KE^*_t - KE_{t-1})} + a_{23} \frac{WS}{(KE^* - KE_{t-1})} \qquad (13)$$

Substitute (12) and (13) into (11) to derive the estimating form, (14).

$$DKE_t = a_{31} + a_{32}\frac{PW}{PPB} + a_{33}\frac{PW}{PM} + a_{34}\frac{VPW}{VPB} + a_{35}GIC + a_{36}KE_{t-1} + a_{22}KHGT_{t-1} + a_{23}WS \qquad (14)$$

where KE_t ≡ number of breeding ewes in period t,

KE^*_t ≡ the desired number of breeding ewes in period t,

β_{Et} ≡ the adjustment coefficient for breeding ewes in period t,

PW ≡ wool sale price (cents/kg),

PPB ≡ schedule prime beef price (cents/kg),

PM ≡ schedule mutton price (cents/kg),

VPW ≡ variance in the wool price (cents/kg),

VPB ≡ variance in the beef price (cents/kg),

GIC ≡ gross farm capital expenditure ($m),

$KHGT_{t-1}$ ≡ number of ewe hoggets in period t-1,

WS ≡ days of soil moisture deficient, weighted by sheep population,

$DKE_t \equiv KE_t - KE_{t-1}$,

$a_{31} = a_{21}a_{11}$,

$a_{32} = a_{21}a_{12}$,

$a_{33} = a_{21}a_{13}$,

$a_{34} = a_{21}a_{14}$,

$$a_{35} = a_{21}a_{15},$$

and $$a_{36} = -a_{21}.$$ [22]

In the estimating form of the breeding ewe equation, price ratios reflect the relative profitability of the alternative livestock enterprises. The relative riskiness of the alternative enterprises is represented by a ratio between the price variables. The wool price is one measure of the future stream of returns from a breeding ewe. Alternatively, the lamb schedule price could be used, or some weighting of wool and lamb returns. The prime beef price represents the return from the competitive enterprise, beef breeding cows. The mutton schedule price is a measure of the value a breeding ewe has if it is slaughtered immediately. Price variances are used to represent the relative riskiness of the alternative enterprises. The variance over a three year period would be a suitable measure, but could be experimented with. The level of farm capital investment can be used as the final variable in Equation (12). The adjustment coefficient for breeding ewes is a linear function of the opening number of ewe hoggets available, and weather, in this case measured by days of soil moisture deficient weighted by sheep population. The constant part of the adjustment coefficient (b_0) appears in the estimating equation as the coefficient on the lagged dependent variable. Ewe hogget numbers and weather, relative to the desired change in ewe numbers, complete the determination of the adjustment coefficients.

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[22] For all subsequent equations, the coefficients of the equation to be estimated will not be defined, since all would be very similar to this example. Hopefully this will improve readability as well as economising on space.

Apart from the variables representing stock numbers and the adjustment coefficient, no time subscripts are placed on the variables. This is done to allow experimentation with different lag specifications. Because the various age groups in the sheep population have been split out, only short lags would be expected to be important. The lagged livestock number variables will incorporate the influences of past prices in them.

(ii) Ewe Hoggets: The ewe hogget population is made up of rising one year female sheep, and therefore represent a pool of potential breeding stock. The number of ewe hoggets, lagged one period, determines the ability of the ewe flock to be adjusted to its desired level (see Equation (13)). In a similar fashion, the lagged number of breeding ewes determines the number of ewe lambs available for inclusion in the ewe hogget flock. The higher the number of breeding ewes, the larger is the number of ewe lambs, and therefore, the higher is the rate of adjustment of hogget numbers to their desired level. This desired number of ewe hoggets is determined by the same variables that determine ewe numbers, but the demographic inter-relationship between the two populations influences the ability of both to attain their desired level. The estimating equation is derived below from Equations (15-18). Let,

$$KHGT_t - KHGT_{t-1} = \beta_{Ht} (KHGT^*_t - KHGT_{t-1}) \qquad (15)$$

$$KHGT^*_t = b_{1I} + b_{12} \frac{PW}{PPB} + b_{13} \frac{PW}{PL} + b_{14} \frac{VPW}{VPB} + b_{15} GIC \qquad (16)$$

$$\text{and } \beta_{Ht} = b_{21} + b_{22} \frac{KE_{t-1}}{(KHGT^*_t - KHGT_{t-1})} +$$

$$b_{23} \frac{WS_t}{(KHGT_t^* - KHGT_{t-1})} \qquad (17)$$

Substitute (16) and (17) into (15) to derive (18), the estimating form.

$$DKHGT_t = b_{31} + b_{32} \frac{PW}{PPB} + b_{33} \frac{PW}{PL} + b_{34} \frac{VPW}{VPB} + b_{35} GIC +$$

$$b_{36}\ KHGT_{t-1} + b_{22}\ KE_{t-1} + b_{23}\ WS_t \qquad (18)$$

Variables not already defined are,

$DKHGT \equiv KHGT_t - KHGT_{t-1}$,

$KHGT_t \equiv$ numbers of ewe hoggets in period t,

$KHGT^*_t \equiv$ desired number of ewe hoggets in period t,

$\beta_{Ht} \equiv$ adjustment coefficient for ewe hoggets in period t,

and $PL \equiv$ schedule price of lamb, cents/kg.

For ewe hoggets, the wool price has been used to represent the possible future returns from the hoggets. Since the ewe hoggets are being kept for breeding purposes, the lamb price could also be used. However, the lamb price also represents the value of immediate slaughter, since the farmer has the option of slaughtering the ewe hoggets as lambs. For this reason, a wool-to-lamb price ratio is included in Equation (16).

(iii) Other Sheep: Nearly half the population of other sheep is made up of wether hoggets. Dry ewes and rams make up most of the remaining stock. The derivation of the estimating form for the equation describing the change in other sheep is found below. The specification is similar to that of ewe hoggets, with wool price used to represent future returns, and lamb price the value of immediate slaughter. Since a large proportion of the 'other sheep' category are older stock, the mutton price can also be tested as a representation of the value of immediate slaughter.

Let,

$$KOS_t - KOS_{t-1} = \beta_{St} (KOS^*_t - KOS_{t-1}) \tag{19}$$

$$KOS^*_t = c_{11} + c_{12} \frac{PW}{PBB} + c_{13} \frac{PW}{PL} + c_{14} \frac{PW}{PM} + c_{15} \frac{VPW}{VPB} + c_{16} GIC \tag{20}$$

$$\beta_{St} = c_{21} + c_{22} \frac{KE_{t-1}}{(KOS^*_t - KOS_{t-1})} + c_{23} \frac{WS_t}{(KOS^*_t - KOS_{t-1})} \tag{21}$$

Substitute (20) and (21) into (19) to derive (22),

the estimating form

$$DKOS_t = c_{31} + c_{32} \frac{PW}{PBB} + c_{33} \frac{PW}{PL} + c_{34} \frac{PW}{PM} + c_{35} \frac{VPW}{VPB} + c_{36} GIC + c_{37} KOS_{t-1} + c_{22} KE_{t-1} + c_{23} WS \tag{22}$$

where $DKOS_t = KOS_t - KOS_{t-1}$,

β_{St} = adjustment coefficient for other sheep in period t,

KOS_t = number of other sheep in period t,

and KOS^*_t = desired number of other sheep in period t.

(iv) Wool Production: Having specified the estimating forms for the livestock categories in the sheep enterprise, the output equations can now be specified.

Taking wool first, Equation (23) below shows it to be a function of the number of sheep at the start of the period, and variables that are hypothesised to influence wool weight. Relative prices may be significant determinants of wool weights if high competitive enterprise prices, or high returns for immediate slaughter, result in sheep being slaughtered at earlier ages with less wool growth. High wool prices might lead to later slaughter and subsequently heavier fleeces. The wool price also influences the incidence of double shearing. Capital investment in land is also likely to influence animal productivity, since improvements in the quantity and quality of pasture can be turned into heavier fleeces. Finally, genetic improvements may result in increased wool weights. A time trend might account for this. A factor against the trend being significant is the switch to 'easy care' sheep such as the Coopworth and Perendale, both generally having lower wool weights than the traditional Romney breed.

Therefore,

$$QW_t = d_{11} + d_{12}\,(KE_{t-1} + KHGT_{t-1} + KOS_{t-1}) + d_{13}\,\frac{PW}{PPB} + d_{14}\,\frac{PW}{PL} + d_{15}\,\frac{PW}{PM} + d_{16}\,GIC + d_{17}\,WS + d_{18}\,T \qquad (23)$$

where,

$QW_t \equiv$ total amount of wool produced in period t (000 tonnes) and $T_t \equiv$ technological and genetic improvement, a time trend.

(v) Mutton: Mutton production is derived from both the breeding ewe flock and the other sheep flock. Under normal management practice, a certain percentage of both these flocks would be culled each year. In addition to this, the change in flock numbers would be associated with mutton production. Periods of flock liquidation would result in increases in mutton production, and vice versa when flocks were being built up. This is what is often called the transitory part of production. It should be noted that the change in flock numbers is not equivalent to the number slaughtered, since some sheep will be entering the flock during the period. Therefore,

$$QM_t = e_{11} + e_{12}\, KE_{t-1} + e_{13}\, KOS_{t-1} + e_{14}\, (KE_t - KE_{t-1}) +$$

$$e_{15}\, (KOS_t - KOS_{t-1}) + e_{16}\, \frac{PM}{PPB} + e_{17}\, \frac{PM}{PL} +$$

$$e_{18}\, GIC + e_{19}\, WS + e_{110}\, T \qquad (24)$$

where QM_t = quantity of mutton produced in period t (000 tonnes). It may be convenient to combine the four livestock number variables into two, implying that coefficients e_{12} and e_{13}, and e_{14} and e_{15}, are equal.

The price data included hypotheses that mutton carcase weights are influenced by the relative return of mutton compared with beef and lamb, recognising the pressure

on pasture resources for fattening various classes of stock.

(vi) Lamb Production: The quantity of lamb produced is a simple function of the opening number of breeding ewes, prices, farm investment, weather and genetic improvement.

$$QL_t = f_{11} + f_{12}\, KE_{t-1} + f_{13}\, \frac{PL}{PPB} + f_{14}\, \frac{PL}{PM} + f_{15}\, GIC + f_{16}\, WS + f_{17} T \qquad (25)$$

where QL_t = quantity of lamb produced in period t (000 tonnes).

(b) The Beef Cattle Enterprise

The beef cattle herd has been divided into four categories, beef breeding cows, heifers one to two years old, heifers under one year old, and other beef cattle. The 'other beef' cattle category largely consists of mixed age steers and bulls. Cull dairy cows are also statistically included in the 'other' beef herd, although they may not be held on beef farms. Dairy steers and heifers are also included with the beef herd for statistical purposes.

Beef production has been divided into prime and manufacturing beef. Prime beef largely originates from the heifer and steer population, while manufacturing beef largely comes from cull cows from the beef breeding herd and the dairy herd. A short-term decision to reduce the beef breeding cow or milking herd will increase current manufacturing beef production, but reduce the future supply of younger stock for prime beef production.

(i) Beef Breeding Cows: Equations (26) to (29) derive the estimating form for the beef breeding cow number

equation. Let,

$$KBBC_t - KBBC_{t-1} = \beta_{Bt} (KBBC^*_t - KBBC_{t-1}) \quad (26)$$

$$KBBC^*_t = g_{11} + g_{12} \frac{PPB}{PW} + g_{13} \frac{PPB}{PMB} + g_{14} \frac{VPB}{VPW} + g_{15} GIC \quad (27)$$

and

$$\beta_{Bt} = g_{21} + g_{22} \frac{KBH_{t-1}}{(KBBC^*_t - KBBC_{t-1})} + g_{23} \frac{WB}{(KBBC^*_t - KBBC_{t-1})} \quad (28)$$

Substitute Equations (27) and (28) into (26) to derive Equation (29), the estimating form.

$$DKBBC_t = g_{32} + g_{32} \frac{PPB}{PW} + g_{33} \frac{PPB}{PMB} + g_{34} \frac{VPB}{VPW} + g_{35} GIC + g_{36} KBBC_{t-1} + g_{22} KBH_{t-1} + g_{23} WB \quad (29)$$

where $KBBC_t$ ≡ number of beef breeding cows in period t,

$KBBC^*_t$ ≡ desired number of beef breeding cows in period t,

β_{Bt} ≡ the adjustment coefficient for beef breeding cows in period t,

PMB ≡ schedule price of manufacturing beef, cents/kg,

WB ≡ days of soil moisture deficit weighted by beef cattle population,

and KBH_{t-1} ≡ number of beef heifers, 1-2 years old, in period t-1.

Prime beef price is used to represent the future returns from holding breeding cows, while manufacturing beef price represents the value of immediate slaughter. The wool price represents returns from the competitive sheep enterprise. The lamb price could also be tested for significance.

Since dairy cows and heifers set aside for beef production are counted statistically as being part of the beef herd, a variable to be experimented with would be the ratio between the prime beef and milkfat price. These prices represent the alternative breeding policies open to a dairy farmer. That is, either a dairy or a beef sire may be put over the dairy cows.

The adjustment coefficient is a function of heifers available to be included in the breeding herd, and climate. Climate is represented by a soil moisture deficit variable weighted by the national distribution of beef cattle.

(ii) Beef Heifers, 1-2 Years Old: Beef heifers are usually mated as two-year-olds to calve as three-year-olds. Because of this, the 1-2 year-old beef heifers comprise an important component of the beef cattle herd, being crucial to its future breeding potential. Equations (30) to (33) specify an equation describing changes in the number of 1-2 year-old heifers.

Let,

$$KBH_t - KBH_{t-1} = \beta_{Ht} \, (KBH^*_t - KBH_{t-1}) \qquad (30)$$

$$KBH_t^* = h_{11} + h_{12} \frac{PPB}{PW} + h_{13} \, PPB + h_{14} \frac{VPB}{VPW} + h_{15} \, GIC \qquad (31)$$

$$\text{and } \beta_{Ht} = h_{21} + h_{22} \frac{KBC_{t-1}}{(KBH^*_t - KBH_{t-1})} +$$

$$h_{23} \frac{WB}{(KBH^*_t - KBH_{t-1})} \qquad (32)$$

Equations (31) and (32) are substituted into Equation (30) to derive Equation (33) which is the estimated equation

$$DKBH_t = h_{31} + h_{32} \frac{PPB}{PW} + h_{33}\ PPB + h_{34} \frac{VPB}{VPW} + h_{35}\ GIC +$$

$$h_{36}\ KBH_{t-1} + h_{22}\ KBC_{t-1} + h_{23}\ WB \qquad (33)$$

where KBH_t ≡ number of beef heifers 1-2 years old in period t,

KBH^*_t ≡ desired number of beef heifers 1-2 years old in period t,

β_{Bt} ≡ adjustment coefficient for beef heifers in period t,

$DKBH_t$ ≡ $KBH_t - KBH_{t-1}$,

and KBC_{t-1} ≡ number of heifer calves (under 1 year old) in period t.

As with the beef breeding cows, the prime beef price represents future returns, while the wool price represents the competitive enterprises.

Since dairy heifers set aside for beef production, irrespective of whether they are being set aside for fattening or breeding purposes, are included with beef heifers, the ratio between the prime beef and milkfat price could be used in Equation (31). This will account for the competitive options

of the beef and dairy enterprises.

The prime beef price, as well as representing future returns, also represents the value of immediate slaughter, and so is included in the equation as a variable in its own right. A negative coefficient would be expected for this variable, reflecting a short-run decision to take advantage of high beef prices for current income. In ratio form with the wool price, increases in the prime beef price should have a positive effect on heifer numbers, reflecting a long-run decision to increase the beef herd at the expense of the relatively less profitable sheep flock.

The appropriate demographic variable for inclusion in the model is the opening number of heifer calves. The equation for these under one-year-old heifers is developed below.

(iii) Beef Heifers Under One Year Old:

Let,

$$KBC_t - KBC_{t-1} = \beta_{Ct} \, (KBC^*_t - KBC_{t-1}) \tag{34}$$

$$KBC^*_t = k_{11} + k_{12} \frac{PPB}{PW} + k_{13} \, PPB + k_{14} \frac{VPB}{VPW} + k_{15} \, GIC \tag{35}$$

$$\text{and } \beta_{Ct} = k_{21} + k_{22} \frac{KBBC_{t-1}}{(KBC^*_t - KBC_{t-1})} + k_{23} \frac{WB}{(KBC^*_t - KBC_{t-1})} \tag{36}$$

Equations (35) and (36) are substituted into Equation (34) to derive Equation (37).

$$DKBC_t = k_{31} + k_{32}\frac{PPB}{PW} + k_{33}\,PPB + k_{34}\frac{VPB}{VPW} + k_{35}\,GIC +$$

$$k_{36}\,KBC_{t-1} + k_{22}\,KBBC_{t-1} + k_{23}\,WB \qquad (37)$$

where KBC_t ≡ number of heifers under one year old in period t,

KBC^*_t ≡ desired number of heifers under one year old in period t,

β_{Ct} ≡ adjustment coefficient for heifer calves in period t,

and $DKBC_t \equiv KBC_t - KBC_{t-1}$.

Equation (37) is very similar to that developed for the older heifers in Equation (33). The difference is that the relevant livestock demographic variable is now the opening number of beef breeding cows, and so completes the chain of linkages from the breeding herd to the replacements, and then back to the breeding herd.

(iv) Other Beef Cattle: This category is made up of predominantly steers and non-breeding bulls, with the balance being made up of cows not used for breeding and cull dairy cows. The common feature among these types of stock is that they are destined for slaughter rather than for breeding purposes.

Equations (38) to (41) develop the estimating equation for changes in the numbers of 'other beef'.

Let,

$$KOB_t - KOB_{t-1} = \beta_{Nt}\,(KOB^*_t - KOB_{t-1}) \qquad (38)$$

$$KOB^*_t = m_{11} + m_{12}\frac{PPB}{PW} + m_{13}\frac{PPB}{PD} + m_{14}\,PPB +$$

$$m_{15}\frac{VPB}{VPW} + m_{16}\frac{VPB}{VPD} + m_{17}\,GIC \qquad (39)$$

and $$\beta_{Nt} = m_{21} + m_{22}\frac{KBBC_{t-1}}{(KOB^*_t - KOB_t)} + m_{23}\frac{KD_{t-1}}{(KOB_t^* - KOB_{t-1})} +$$

$$m_{24}\frac{WB}{(KOB^*_t - KOB_{t-1})} \qquad (40)$$

Equations (39) and (40) are substituted into Equation (38) to derive Equation (41) which can be estimated to obtain the size and signs of the coefficients.

$$DKOB_t = m_{31} + m_{32}\frac{PPB}{PW} + m_{33}\frac{PMB}{PD} + m_{34}\,PPB +$$

$$m_{35}\frac{VPB}{VPW} + m_{36}\frac{VMB}{VPD} + m_{37}\,GIC + m_{38}KOB_{t-1} +$$

$$m_{22}\,KBBC_{t-1} + m_{23}\,KD_{t-1} + m_{24}\,WB \qquad (41)$$

where

KOB_t ≡ number of 'other beef' in period t,

KOB_t^* ≡ desired number of 'other beef' in period t,

$DKOB_t$ ≡ $KOB_t - KOB_{t-1}$,

β_{Nt} ≡ adjustment coefficient for 'other beef' in period t,

KD_{t-1} ≡ number of dairy cows in milk in period t,

PD ≡ milkfat price, cents/kg,

and VPD ≡ variation in milkfat price, cents/kg.

Prime beef prices are used to represent the return from the 'other beef' herd. Higher beef prices increase the optimal slaughter age and weight. The beef price also represents the value of immediate slaughter. Wool prices are used as a representation of competition from sheep enterprises. An alternative would be to use the lamb schedule price.

Because cull dairy cows destined for beef production are included in the other beef herd, the relative profitability of dairying to beef is represented by the ratio of manufacturing beef to milkfat prices. The ratio of the variance of these prices is also included.

The number of dairy cows in milk also appears as a livestock demographic variable in Equation (40), implying that a constant proportion of dairy cows are set aside for beef production irrespective of price relativities.

(v) Prime Beef Production: The two outputs of interest from the beef herd are prime and manufacturing beef.

Prime beef is largely derived from the 'other beef' herd and the two heifer age groups. A certain constant proportion of the opening numbers of 'other beef' are likely to be slaughtered. A transitory component reflecting the build-up or liquidation of the beef herd can be represented by the current change in the 'other beef' herd. This magnitude of this variable is determined by decisions made earlier in the livestock numbers equation.

A measure of the contribution heifers make to prime beef production could be taken by calculating the number of heifers from the under one-year-old category in the past year that are not kept as one to two-year-old heifers in the current year (i.e., KBC_{t-1}-KBH_t). Also, if a constant pro-

portion of heifers at the start of each year are destined for slaughter, the lagged heifer variables can be included in the equation specification. Therefore, like the 'other beef' herd, a constant and a transitory proportion of the heifer herds produce prime beef each year.

The weight of the carcases are specified as being determined by farm capital investment in land, climatical conditions, and genetic improvements in cattle. The relative price of prime beef to lamb may also be important, since the associated enterprises compete for pasture resources. Therefore, let

$$QPB_t = n_{11} + n_{12}\ KOB_{t-1} + n_{13}\ (KOB_t - KOB_{t-1}) + n_{14}\ (KBC_{t-1} - KBH_t)$$

$$+ n_{15}\ KBH_{t-1} + n_{16}\ \frac{PPB}{PL} + n_{17}\ GIC + n_{18}\ WB + n_{19}T \qquad (42)$$

where, QPB_t = quantity of prime beef produced in period t (000 tonnes).

(vi) Manufacturing Beef Production: Manufacturing beef is mainly the product of the beef breeding herd and the dairy herd. The older steers, and bulls from the 'other beef' herd, are also important contributors.

As with the prime beef equation, it is hypothesised that a permanent, and a transitory proportion of the cattle herds are slaughtered for beef production. The transitory proportion is dependent on decisions made about desired numbers of livestock.

Because manufacturing beef comes from three different categories of livestock, six livestock demographic variables are included in Equation (42).

The relative price of manufacturing beef to lamb is used to represent competition between beef and sheep enterprises for pasture. Given that older ewes are likely to be more competitive with older cattle, the mutton price could replace the lamb price variable.

Therefore, let

$$QMB_t = p_{11} + p_{12}\ KBBC_{t-1} + p_{13}\ (KBBC_t - KBBC_{t-1}) + p_{14}\ KOB_{t-1} +$$

$$p_{15}\ (KOB_t - KOB_{t-1}) + p_{16} KD_{t-1} + p_{17}\ (KD_t - KD_{t-1}) +$$

$$p_{18}\ \frac{PMB}{PL} + p_{19}\ GIC + p_{1\ 10} WB + p_{1\ 11}\ T \qquad (43)$$

where QMB_t = quantity of prime beef produced in period t (000 tonnes).

(c) The Dairy Cattle Enterprise

The dairy cattle enterprise has been categorised into two categories. The first category comprises dairy cows and heifers in milk or in calf. All heifers between the age of one and two years are also included with the milking herd data. Historically, a large proportion of these heifers are mated to calve as two-year-olds. Data available for the 1970s produces figures up to 75%. Lack of data before 1970 precludes any separation of one to two heifers on the basis of whether they calve as two-year-olds or not. All one- to two-year-old heifers are therefore included in the milking herd at June.

The second category of the dairy herd is called 'dairy heifers under one year old'. This category also includes a small number of older cows, and heifers over two years old, that are not in milk or in calf at June, but are intended

for dairying in the future.

Milkfat is the predominant output from the dairy cattle. Manufacturing beef is also produced, but the dairy population's contribution to this output is accounted for in Equation (43). Dairy cows and heifers set aside entirely for beef production are counted among the beef herd.

(i) Dairy Cows and Heifers in Milk or in Calf: Since the data year for dairy cattle ends in June, most of the dairy cows will be in calf, rather than milking at this date.[23] This fact has important implications for the specification of equations explaining changes in dairy herd numbers and milkfat production. Firstly, current milkfat production is determined by the number of milking cows at the previous June. Secondly, lagged prices should be more important than current prices in determining changes in cow numbers, since the main decision regarding cow numbers is made at mating time, before the total milkfat return for the current season is known.

Equations (44) to (47) develop a model explaining changes in the number of dairy cows. The stream of income potentially available from dairy cows is represented by the milkfat price. This price is used in ratio form with both the prime and manufacturing beef price. The prime beef price represents the option a dairy farmer has of using his dairy cows as beef cows producing fattening stock. The manufacturing beef price accounts for the option to slaughter the dairy cow for immediate return. The ratio between the milkfat and wool price has been recognised by dairy industry leaders as an important determinant of dairy cow numbers. The strength of

[23] The data include town supply herds, which will be in milk at June.

this competition between sheep and dairy enterprises can be tested by the inclusion of the price ratio proposed.

The adjustment coefficient is determined by the number of heifers available and weather, both expressed as ratios with respect to the desired change in dairy cow numbers.

Therefore, let

$$KD_t - KD_{t-1} = \beta_{Dt} \, (KD^*_t - KD_{t-1}) \tag{44}$$

$$KD^*_t = q_{11} + q_{12} \frac{PD}{PPB} + q_{13} \frac{PD}{PMB} + q_{14} \frac{PD}{PW} + q_{15} \frac{VPD}{VPB} + q_{16} \, GIC \tag{45}$$

$$\text{and } \beta_{Dt} = q_{21} + q_{22} \frac{KDH_{t-1}}{(KD^*_t - KD_{t-1})} + q_{23} \frac{WD}{(KD^*_t - KD_{t-1})} \tag{46}$$

By substituting Equations (45) and (46) into Equation (44), Equation (47) can be derived.

$$DKD_t = q_{31} + q_{32} \frac{PD}{PPB} + q_{33} \frac{PD}{PMB} + q_{34} \frac{PD}{PW} + q_{35} \frac{VPD}{VPB} + q_{36} \, GIC + q_{37} \, KD_{t-1} + q_{22} \, KDB_{t-1} + q_{23} \, WD \tag{47}$$

where KD_t ≡ number of dairy cows and heifers over 1 year old in period t,

KD^*_t ≡ desired number of dairy cows and heifers over 1 year old in period t,

β_{Dt} ≡ adjustment coefficient for dairy cows in period t,

DKD_t ≡ $KD_t - KD_{t-1}$,

and KDH_{t-1} ≡ number of dairy heifers under 1 year old in period t-1.

(ii) Dairy Heifers Under One Year Old: The young dairy animals represent the majority of replacements available for the dairy herd. A small number of replacements are also available from cows and heifers over two years old, not in milk or in calf, but intended for the milking herd in the future. Heifers between the ages of one and two years old that are not in calf for the coming season also represent replacements. However, as was explained earlier, these are included in the milking herd because of data limitations.

Equations (48) to (51) derive the equation explaining changes in heifer replacement numbers.

Let,

$$KDH_t - KDH_{t-1} = \beta_{Ft} \, (KDH^*_t - KDH_{t-1}) \qquad (48)$$

$$KDH_t = r_{11} + r_{12} \frac{PD}{PPB} + r_{13} \frac{PD}{PW} + r_{14} \frac{VPD}{VPB} + r_{15} \, GIC \qquad (49)$$

and $$\beta_{Ft} = r_{21} + r_{22} \frac{KD_{t-1}}{(KDH^*_t - KDH_{t-1})} + r_{23} \frac{WD}{(KDH^*_t - KDH_{t-1})} \qquad (50)$$

To derive an equation to be estimated, substitute Equations (49) and (50) into Equation (48). Equation (51) can be derived.

$$DKDH_t = r_{31} + r_{32} \frac{PD}{PPB} + r_{33} \frac{PD}{PW} + r_{34} \frac{VPD}{VPB} + r_{35} \, GIC +$$

$$r_{36} \, KDH_{t-1} + r_{22} \, KD_{t-1} + r_{23} \, WD \qquad (51)$$

where

KDH_t $\equiv$ number of dairy heifers under one year old in period t,

$KDH^*_t \equiv$ desired number of dairy heifers under one year old in period t,

$\beta_{Ft} \equiv$ adjustment coefficient for dairy heifers,

and $DKDH_t \equiv KDH_t - KDH_{t-1}$.

(iii) Milkfat Production: Milkfat production is largely determined by the number of dairy cows and heifers in milk or in calf.

The yield per cow is largely determined by climatical conditions, capital investment on dairy farms, and improvements in the genetic make-up of cows. The relative price of milkfat to manufacturing beef may also be important, since it may affect the time of drying off.

Therefore, let

$$QMLK_t = s_{11} + s_{12} KD_t + s_{13} \frac{PD}{PMB} + s_{14} GIC + s_{15} WD + S_{16}T \quad (52)$$

where $QMLK_t \equiv$ quantity of milkfat produced in period t, thousand tonnes.

3.5.3 Summary

Table 2 summarises the fifteen equations to be estimated for the livestock submodel. As long as the capital stock variable used to represent investment appears in some lagged formulation, the system of equations is recursive with respect to the investment submodel.

The output equations also fit recursively into the farm income submodel that follows.

Table 2: Summary of Livestock Number and Output Equation Specifications

Equation number from text	Dependent variable	Predetermined Variables: Livestock Demographic Variables									Enterprise Competition												Risk			Investment	Climate			Technical change
		KE	KHGT	KOS	KD	KDH	KBBC	KBH	KBC	KOB	$\frac{PW}{PPB}$	$\frac{PW}{PM}$	$\frac{PH}{PL}$	$\frac{PM}{PPB}$	$\frac{PM}{PL}$	$\frac{PL}{PPB}$	$\frac{PD}{PW}$	$\frac{PD}{PPB}$	$\frac{PD}{PMB}$	$\frac{PPB}{PMB}$	PPB	$\frac{PMB}{PL}$	$\frac{VPW}{VPB}$	$\frac{VPD}{VPB}$	$\frac{VMB}{VPD}$	GIC	WS	WB	WD	T
14	DKE	$-*$	$-*$								*	*											*			*	*			
18	DKHGT	$-*$	$-*$								*		*										*			*	*			
22	DKOS	$-*$		$-*$							*	*	*										*			*	*			
23	QW	$-*$	$-*$	$-*$							*	*	*													*	*			*
24	QM	$-*$ Δ		$-*$ Δ										*	*											*	*			*
25	QL	$-*$													*'	*										*	*			*
47	DKD				$-*$	$-*$											*	*	*					*		*			*	
51	DKDH				$-*$	$-*$											*	*						*		*			*	
52	QMLK				*														*							*			*	*
29	DKBBC						$-*$	$-*$			*'									*			*'			*		*		
33	DKBH							$-*$	$-*$		*'										*		*'			*		*		
37	DKBC						$-*$		$-*$		*'										*		*'			*		*		
41	DKOB				$-*$		$-*$			$-*$	*'								*'		*		*'		*'	*		*		
42	QPB							$-*$	$-*$	$-*$ Δ						*'										*		*		*
43	QMB				$-*$ Δ		$-*$ Δ			$-*$ Δ												*				*		*		*

KEY: * = variable appears in equation; $-*$ = lagged variable; *' = inverse of variable; Δ = change in variable.

CHAPTER 4

FARM INCOME MODEL SPECIFICATION

4.1 INTRODUCTION

This chapter specifies a model relating output prices and production to farm income. Farm expenditure is also modelled as a behavioural equation, leaving net income to be determined through an identity. Like the capital investment model described in Chapter 2, this component of the overall theoretical model for the pastoral livestock sector was not developed by Laing and Zwart (1981). However, the development of a simple income submodel is now necessary, so that the livestock number and output models are linked with the farm capital investment model. From Figure 1 (in Chapter 1) it can be seen that output from the livestock populations, together with output prices, determines gross income. The level of gross income determines farm liquidity, affecting the rate at which desired capital investment is undertaken. Capital investment then affects livestock numbers and output, completing the cycle.

The income and expenditure data for this farm income model are calculated on a per-farm basis, using data provided by the New Zealand Meat and Wool Boards' Economic Service's (NZMWBES) and the New Zealand Dairy Board's (NZDB) farm surveys. Production data is the total New Zealand production of each farm output. These output data were also utilised in Chapter 3. Relating aggregate production to per-farm income implies that variations in aggregate production reflect variations in per-farm production. Similarly, variations in per-farm income are assumed to reflect aggregate income variations.

The use of per-farm income and expenditure data have been determined by inadequate national income data. National

income accounts are available for the agricultural sector, but a change in accounting methods during the mid-1970s makes a consistent long-term data series difficult to derive. Another major drawback with the national data is that national income by farm type cannot be determined. Per-farm data's main advantages are availability, and the fact that the data are widely used by policy-makers when examining the economic position of sheep and beef, and dairy farms. Another advantage is its disaggregation into the two farm types of interest. The main disadvantage is that the data cannot be used directly in macro-economic analysis of the pastoral sector's impact on the New Zealand economy. The level of aggregate farm income is thought to be a major determinant of the economy's stability.

4.2 GROSS FARM INCOME

Gross farm income is simply the product of quantity of output times its price. Each of the six outputs from the pastoral livestock sector (i.e., wool, mutton, lamb, prime and manufacturing beef, and milkfat) will be used individually or in an aggregated form to produce behavioural equations for the components of farm gross income. These components of gross income are then aggregated through an identity to estimate total gross farm income. Two farm type categories are also accounted for by the model specification, sheep and beef farms, and dairy farms.

(a) Gross Income on Sheep and Beef Farms

Four behavioural equations will be estimated for the components of gross income on sheep and beef farms. Gross income derived from wool is simply a function of wool production and

the average wool price. Gross income obtained from sheep-meats is a function of total output of mutton and lamb, and schedule prices for mutton and lamb. Similarly, gross income from beef is a function of total output of prime and manufacturing beef, and beef schedule prices. If national rather than per-farm income data were available, the relationship between gross income, output, and farm product prices could be obtained through an identity, rather than as a behavioural function. An equation estimating gross income from 'other' sources will also be specified. 'Other income' is earned from the sale of crops, skins, hay, seed, and sometimes milkfat. In the absence of price and quantity data for these products, a simple equation specification will be estimated. To represent quantity, a time trend will be used. To represent price, the schedule price for prime beef and the average wool auction will be used, making the assumption that the price variability for 'other income' production is similar to that experienced for other agricultural products.

Gross income on sheep and beef farms is also determined by the direct effects of some agricultural policy. Specifically, the effects of wool income deposited in Retention Accounts and the Farm Income Equilisation Scheme have lowered or raised a farm's gross income in many years. To account for this, the gross income from other sources will be used in an identity with the income adjustment effects of government policy, so that a fifth equation, adjusted total gross income from other sources, is calculated.

Therefore, let

$$GYW_t = a_0 + a_1 PW_t + a_2 QW_t \qquad (1)$$

$$GYSM_t = b_0 + b_1 PM_t + b_2 PL_t + b_3 QM_t + b_3 QL_t \quad (2)$$

$$GYB_t = c_0 + c_1 PPB_t + c_2 PMB_t + c_3 QPB_t + c_4 QMB_t \quad (3)$$

$$SBGYO_t = d_0 + d_1 T_t + d_2 PPB_t + d_3 PW_t \quad (4)$$

$$SBGYTO_t = SBGYO_t + WRISB_t + IEASB_t \quad (5)$$

$$GYSB_t = GYW_t + GYSM_t + GYB_t + SBGYTO_t \quad (6)$$

where,

GYW ≡ gross income per farm from wool ($),

GYSM ≡ gross income per farm from sheepmeats ($),

GYB ≡ gross income per farm from beef ($),

SBGYO ≡ gross income per farm from other sources ($),

SBGYTO ≡ adjusted gross income per farm from other sources ($),

PW ≡ average auction price for wool (c/kg),

PM ≡ average schedule price for mutton (c/kg),

PL ≡ average schedule price for lamb (c/kg),

PPB ≡ average schedule price for prime beef (c/kg),

PMB ≡ average schedule price for manufacturing beef (c/kg),

QW ≡ quantity of wool produced (T'000),

QM ≡ quantity of mutton produced (T'000),

QL ≡ quantity of lamb produced (T'000),

QPB ≡ quantity of prime beef produced (T'000),

QMB ≡ quantity of manufacturing beef produced (T'000),

T ≡ a time trend,

WRISB ≡ wool income deposited/withdrawn from wool income retention account ($),

IEASB ≡ income per farm placed in the income equilisation accounts ($),

and t ≡ the current time period.

(b) Gross Income on Dairy Farms

Gross income on dairy farms is derived predominantly from milkfat. Sales of cull cows and dairy beef produces the majority of other income generated.

The data for dairy farm incomes is based on the financial year (usually March) rather than the production year (May). Given a March financial year, dairy produce payments will be made up of advance payments for milkfat over the March to May part of the previous season, and the May to March part of the current season, final payments made by the dairy company on the previous season's manufacturing results, and end of season payments by the Dairy Board in respect of the previous season's trading results. Therefore, in an equation estimating gross income per dairy farm, both current and lagged milkfat prices must be used, together with total production of milkfat.

Due to lack of data, an equation estimating 'other dairy income' cannot be estimated. The dependent variable for Equation (7) found below is therefore total gross income per dairy farm. The schedule price for manufacturing beef is also included to account for income derived from beef production.

Therefore, let

$$GYD_t = e_0 + e_1 PD_t + e_2 PD_{t-1} + e_3 PMB_t + e_4 QMLK_t \qquad (7)$$

where,

GYD ≡ gross income per dairy farm ($),

PD ≡ total milkfat payments for season (c/kg),

and QMLK ≡ quantity of milkfat produced (T'000).

4.3 GROSS EXPENDITURE

Having specified equations for gross income per sheep and beef, and dairy farm, equations for gross expenditure must also be estimated so that net income may be obtained through an identity.

Much of farm expenditure is unavoidable. Normal farm operations require that sheep must be shorn dipped and drenched, and dairy cattle milked. Also, sheep and cattle must be transported to freezing works or saleyards, and wool to wool-stores, in order for the farmer to generate the gross income. At least a basic level of maintenance expenditure on fences, buildings, and machinery must also be undertaken if the ability to farm in an orderly and efficient manner is to be maintained. In order to reflect the unavoidable nature of most expenditure, the equations specifying gross expenditure include livestock numbers and the capital stock of land, buildings and plant and machinery. Livestock numbers are converted to stock units to allow different categories of animals to be aggregated.

In addition to the unavoidable, permanent component of gross expenditure, farm expenditure also includes a transitory

component, dependent on the level of gross income received in any one year. Typically, the transitory component of farm expenditure is most easily identified in the level of expenditure on fertiliser and lime.

Equations for gross expenditure on both sheep and cattle, and dairy farms, may now be specified. From the preceding discussion, it is clear that they should include gross income, stock units, and capital stock as the pre-determined variables.

Therefore, let

$$SBE_t = f_0 + f_1\ GYSB_t + f_2\ SUSB_t + f_3\ KSTK_{t-1} \qquad (8)$$

$$DE_t = g_0 + g_1\ GYD_t + g_2\ SUD_t + g_3\ KSTK_{t-1} \qquad (9)$$

where SBE ≡ gross expenditure per sheep and beef farm ($),

SUSB ≡ number of stock units on sheep and beef farms ('000),

KSTK ≡ total capital stock of land, buildings, and plant and machinery ($m),

DE ≡ gross expenditure per dairy farm ($),

and SUD ≡ number of stock units on dairy farms ('000).

4.4 NET INCOME

Net income per farm is obtained via an identity between gross income and expenditure. Let,

$$SBNY_t = GYSB_t - SBE_t \qquad (10)$$

$$DNY_t = GYD_t - DE_t$$

where

SBNY ≡ net income per sheep and beef farm ($),

and DNY ≡ net income per dairy farm ($).

CHAPTER 5

ESTIMATION OF THE MODEL

5.1 INTRODUCTION

Chapters 2, 3 and 4 have developed precise equation specifications for the investment, livestock numbers and production, and income components of the theoretical pastoral livestock model. In all, twenty-five behavioural equations must be estimated. A further fifteen equations have been specified using identities.

The system of equations is recursive. Livestock numbers flow into the production equations, which in turn flow into the income model. The income model then is linked with the investment model through the impact of gross farm income on the rate of investment. The investment model then flows recursively into the livestock number and production equations.

Because the system of equations is recursive, ordinary least squares (OLS) can be used to estimate the equations. A computer package, MASSAGER, was used for the OLS regression analysis.

Most of the model's equations were estimated over the period 1958 to 1979. Some were estimated only up to 1978 due to a lack of more recent data. All data expressed in terms of value (dollars or cents) have been deflated by appropriate indices. Farm product prices were deflated by a prices paid by farmers index, and farm incomes deflated by a prices paid to farmers index. Capital investment data are deflated by capital price indices for land, buildings, and plant and machin-

ery.

The results of the regression analysis are now presented and discussed. Only the final estimated equation will be reported, but the differences between the final equation and the theoretical specification will be highlighted. The choice as to which variables made up variable final equations was determined according to a priori, statistical, and econometric criteria. The a priori criteria relate to the concern that the estimated coefficients had both the correct sign, and the correct magnitude expected of them. If the estimates do not have the correct sign and magnitude, they should normally be rejected, in spite of their significance. However, sometimes a wrong sign may be evidence that the economic theory underlying the equation specification is invalid. In this case, the 'wrong' sign may be accepted after the underlying hypotheses of the equation are reformulated.

Statistical criteria were used to evaluate the statistical reliability of the model's parameter estimates. The adjusted coefficient of determination ($\bar{R}^2$), the Student's t test, and the F test are widely used measures of statistical reliability. In many cases, a priori considerations have over-ruled statistical criteria. That is, the correct sign and magnitude of a parameter estimate has been valued more highly than its statistical reliability.

The third set of evaluation criteria deal with the assumptions of econometric theory, and test whether these assumptions have been satisfied. In a time series model, multicollinearity and auto-correlation are two of the most common ways in which the assumptions are violated. To the degree that the econometric criteria are violated, the statistical criteria

are made invalid, and hence cannot be used to evaluate the estimated parameters.

The three evaluation criteria discussed and their application to individual equations is complicated by the fact that individual equations themselves are only a part of a multi-equation system. The acceptability of individual equations must therefore be viewed in association with the determination of the acceptability of the entire theoretical model structure. Chapter 6 discusses and reports on the use of an historical simulation to determine the validity of the overall model structure. Because individual equation, and complete model structure validation are inter-related, trade-offs exist between the validity of individual equations, and the complete system's validity. Sometimes it is necessary to accept specifications for some of the equations in the model that are less desirable from a statistical point of view (e.g., low $\bar{R}^2$), but that improve the ability of the model to simulate well. "The model builder is thus forced to make some compromises, accepting some equations which do not have a particularly good statistical fit in order to build a complete structural model" (Pindyck and Rubinfeld, 1981; p 362).

The livestock numbers and production equations will be presented first in Section 5.2, followed by the income equations in 5.3, and in 5.4, the gross investment equations. A brief summary of the estimated equations is provided in Section 5.5.

5.2 LIVESTOCK NUMBERS AND PRODUCTION EQUATIONS

(a) The Sheep Enterprise

(i) Breeding Ewes: As expected, the results in Table 12 show that the ratio between the wool and prime beef price is an important determinant of the change in breeding ewe numbers. The lamb to prime beef ratio also shows some significance. The mutton price, representing the value of immediate slaughter, showed little significance and was excluded from the final equation.

Table 3: Dependent Variable DKE.

Independent variable	Estimated coefficient	T-statistic[24]
C	-2241.73	-1.06
KE_{t-1}	-0.26	-2.95
$KHGT_{t-1}$	1.02	3.72
$(PW/PPB)_t$	695.38	2.77
$(PL/PPB)_{t-1}$	312.13	0.81
VPW_t	-13.17	-1.43
GIL_{t-2}	33.65	2.96
WS_t	-63.73	-5.03
$GOVT_t$	1291.84	2.67
R-squared = 0.89	$\bar{R}$ squared = 0.83	
Durbin-Watson statistic = 2.49		
F Statistic (8,13) = 13.55		
Number of Observations = 22		

[24] With 13 degrees of freedom, the critical values for a one-tailed t-test are 1.4 at a 90% level of significance, and 1.8 at a 5% level of significance.

Price variance for wool (VPW), representing risk, was specified in the theoretical model in a ratio with the prime beef price variance. This theoretical specification was not significant.

Gross investment in land, lagged two periods, was found to have a significant positive impact on breeding ewe numbers. Gross investment in buildings, or plant and machinery were not found to significantly influence ewe numbers.

The weather variable, measured by days of soil moisture deficit, has a predictably negative impact on ewe numbers.

A dummy variable representing government policy such as the Livestock Retention Scheme, the Livestock Incentive Scheme and the Land Development Encouragement Loan, had a positive effect on ewe numbers.

Overall, the estimated equation is satisfactory, all signs being correct, and the $\bar{R}$-squared and F-statistic being quite high.

(ii) Ewe Hoggets: The estimated parameters for the equations describing the change in ewe hogget numbers are found in Table 4. The variables included are the same as those specified in the theoretical model, except for two changes. The absolute wool price has been included, and variables representing risk (i.e, price variance) were excluded due to lack of significance.

Gross investment in buildings, lagged one period, was found to be significant in determining the change in ewe hoggets. Since increases in ewe hoggets reflect a desire to increase the future breeding flock, building investment (e.g., improved woolsheds, covered yards, haysheds) may be done in anticipation of the increased pressure on current farm build-

ing facilities. Gross investment in land, and plant and machinery were not significant variables.

The signs on the estimated coefficients fulfilled *a-priori* expectations.

Table 4: Dependent Variable DKHGT.

Independent variable	Estimated coefficient	T-statistic
C	-3511.12	-2.46
KE_{t-1}	0.28	3.63
$KHGT_{t-1}$	-0.84	-3.23
PW_t	3.48	1.30
$(PW/PPB)_{t-1}$	185.10	1.34
GIB_{t-1}	14.07	1.99
WS_t	-29.05	-2.71
$GOVT_t$	496.49	1.81
R-squared = 0.74	$\bar{R}$-squared = 0.61	
Durbin-Watson Statistic = 2.10		
F-Statistic (8,13) = 5.71		
Number of Observations = 22		

(iii) *Other Sheep*: Table 5 presents a summary of the regression results for the 'other sheep' category.

Regression analysis showed that price ratios between wool and prime beef, wool and lamb, and wool and mutton did not show any strong significance. The ratio between the price variances of wool and prime beef also showed little significance.

It was expected that the lagged number of breeding ewes would have a positive influence on 'other sheep' numbers, given a normal percentage of older ewes and wether lambs flowing into

the 'other sheep' category. The negative sign on KE_{t-1} may indicate that normal culling practices are suspended to some degree when the breeding ewe flock is being increased.

The mutton price, representing the value of immediate slaughter of the 'other sheep', was expected to have a negative sign. A positive sign may indicate that fewer old ewes are killed in the autumn, but instead more ewes and wethers are wintered in anticipation of high mutton and store stock prices in the spring.

Table 5: Dependent Variable DKOS.

Independent variable	Estimated coefficient	T-statistic
C	1233.39	0.66
KE_{t-1}	-0.068	-2.22
KOS_{t-1}	-0.48	-3.32
PW_{t-1}	7.44	3.08
PM_t	15.69	2.01
VPW_t	-17.71	-2.41
GIL_{t-1}	26.37	2.85
WS_t	3.86	0.41
$GOVT_t$	649.77	2.09
R-squared = 0.74	$\bar{R}$-squared = 0.58	
Durbin-Watson Statistic = 2.27		
F-Statistic (8,13) = 4.67		
Number of Observations = 22		

(iv) Wool Production: The wool production equation is very similar to the theoretical specification developed in

Chapter 3.[25] An unusual result shown in Table 6 is the impact that gross investment in plant and machinery (GIM) has had on wool production. Unlike gross investment in land, a negative impact has been calculated. The absolute impact on wool production, however, given by the coefficient's size and the level of gross investment in machinery, is small relative to the quantity of wool produced.

Table 6: Dependent Variable QW.

Independent variable	Estimated coefficient	T-statistic
C	-114.67	-3.12
$(KE+KHGT)_{t-1}$	0.0075	14.52
KOS_{t-1}	0.0053	2.25
$(PW/PL)_t$	14.63	2.71
$(PW/PM)_t$	1.72	1.60
GIL_{t-2}	0.32	2.34
GIM_{t-1}	-0.16	-3.04
WS_t	-0.77	-4.46

R-squared = 0.98 $\bar{R}$-squared = 0.96
Durbin-Watson Statistic = 2.48
F-Statistic = 35.60
Number of Observations = 21
Mean of Dependent Variable = 295.45

The time trend hypothesised in the theoretical specification was found not to be significant.

[25] See Section 3.5.2, a. (iv)

(v) Mutton Production: Table 7 shows that the livestock demographic variables account for most of the variation in mutton production. The permanent (KE_{t-1} and KOS_{t-1}) and transitory (DKE_t) components of mutton production as specified, are found to be highly significant.

Table 7: Dependent Variable QM.

Independent variable	Estimated coefficient	T-statistic
C	-91.16	-1.44
DKE_t	-0.014	-4.74
KE_{t-1}	0.0051	4.18
KOS_{t-1}	0.017	5.42
PM_t	-0.56	-1.92
PW_t	0.096	0.88
WS_t	-0.41	-1.16

R-squared = 0.87 $\bar{R}$-squared = 0.82
Durbin-Watson Statistic = 2.71
F-Statistic (6,14) = 15.86
Number of Observations = 21
Mean of Dependent Variable = 177.65

Price ratios were not found to be useful in explaining mutton production. The absolute wool and mutton prices do show some significance, although the sign of PM_t is hard to reconcile. The wool price (PW_t) has a positive sign, perhaps indicating that sheep to be slaughtered are slaughtered later in the season when wool prices are high, increasing carcase weights.

(vi) Lamb Production: Price ratios were again found to be insignificant determinants of production when equations determining lamb production were estimated. To a large extent, this is not surprising since price ratios largely reflect competition between the sheep and beef enterprises already accounted for in the livestock number equations. The significance of the absolute current prices of lamb and wool reveal more short-run behaviour influencing lamb carcase weights.

Table 8: Dependent Variable QL.

Independent variable	Estimated coefficient	T-statistic
C	-37.07	-0.86
KE_{t-1}	0.0094	10.76
PL_t	-0.75	-3.03
PW_t	0.21	2.02
GIL_{t-2}	0.52	2.93
WS_t	-0.67	-2.13

R-squared = 0.95 $\bar{R}$-squared = 0.93
Durbin-Watson Statistic = 1.59
F-Statistic = 54.12
Number of Observations = 21
Mean of Dependent Variable = 319.95

The wool price had a positive sign, indicating that high wool prices encourage farmers to hold lambs longer to increase the wool obtained from them either before or after slaughter. The lambs are therefore heavier when they are slaughtered. The negative sign on the lamb price is harder to reconcile. One explanation could be that since high lamb prices increase the

number of desired breeding ewes, and hence the demand for ewe hoggets (see Table 3), a high lamb price will result in less ewe lambs being slaughtered. The ewe lambs drafted for future production rather than immediate slaughter would also be heavier than the average weight of ewe lambs assigned for slaughter. Hence, not only would the number of ewe lambs slaughtered fall, but also their average weight.

The other variables in the lamb production equation have the expected signs. The time trend is again excluded from the equation.

(b) The Dairy Cattle Enterprise

(i) Dairy Cows and Heifers in Milk or in Calf: The regression results for a function explaining the change in milking cow numbers are presented in Table 9. Compared to the theoretical specification developed in Chapter 3,[26] the main difference in the final equation presented in Table 9 is the use of absolute rather than relative prices. Relative prices did not show a high degree of significance. An interesting result is that the beef price was insignificant when it was included in the function. Instead, it is the competition from the sheep enterprise, as represented by the wool price, that shows significance.

The signs attached to the included variables all follow *a priori* expectations, except the sign attached to the land capital investment variable (GIL). However, the data for GIL includes capital invested for all farm types, including market gardening, orcharding and other horticultural activities. The sign of GIL may be representing the loss of dairying land to horticulture, and the subsequent capital expenditure on horti-

[26] See Section 3.5.2, c(i).

Table 9: Dependent Variable DKD.

Independent variable	Estimated coefficient	T-statistic
C	2.85	0.010
KD_{t-1}	-0.096	-1.06
KDH_{t-1}	0.68	3.74
PD_{t-1}	2.38	2.90
PW_{t-1}	-0.46	-1.30
VPD_{t-1}	-9.34	-3.73
GIL_{t-2}	-3.39	-2.78
WD_t	-1.07	-1.10

R-squared = 0.70 $\bar{R}$-squared = 0.56
Durbin-Watson Statistic = 2.61
F-Statistic (7,14) = 4.75
Number of Observations = 22

cultural land development.

While the R-squared value is only 0.56, it should be noted that since the dependent variable is in first differences, a higher proportion of the variation in the absolute number of milking cows is probably accounted for by the estimated equation.

(ii) Dairy Heifers Under One Year Old: Absolute prices are again used, rather than relative prices, in the results presented in Table 10. This time, the prime beef price shows significance rather than the wool price, indicating that for young dairy stock, the option to set heifers aside for beef production is an important consideration when deciding on the fate of heifer calves. Therefore, the effect of high beef prices is not to encourage dairy farmers out of milkfat production, but rather to set aside fewer replacements for the milking herd. Increases in the wool price, however, may lead to a shift out of dairying and into sheepfarming.

The sign attached to the ratio between the variance of milkfat prices and the variance of prime beef prices is unexpectedly positive. The variable is highly significant. An explanation for this positive sign could be found in the historical trend of milkfat prices. Milkfat prices have tended to rise steadily. Therefore, while the variance of milkfat prices may be high, the fact that the trend in milkfat prices is upwards makes farmers react positively to increases in the price variance.

Unlike the results for milking cows, the effect of capital investment on dairy heifers is found to be positive. Building, rather than land investment, showed significance.

Table 10: Dependent Variable DKDH.

Independent variable	Estimated coefficient	T-statistic
C	-162.89	-1.03
KD_{t-1}	-0.029	-0.48
KDH_{t-1}	-0.00064	-0.0051
PD_{t-1}	1.06	2.26
PPB_{t-1}	-0.62	-1.19
$(VPD/VPB)_t$	14.75	2.90
GIB_{t-1}	0.94	1.68
WD_t	-0.86	-1.29
GOVT	45.55	1.52
R-squared = 0.77	$\bar{R}$-squared = 0.62	
Durbin-Watson Statistic = 2.49		
F-Statistic (8,12) = 5.34		
Number of Observations = 22		

(iii) Milkfat Production: Milkfat production was specified as a simple function of dairy cow numbers, the ratio between the milkfat and manufacturing beef price, capital investment, weather, and time (representing technological and genetical improvement). Table 11 presents an equation that has been estimated based on this specification.

The most obvious point to be discussed deals with the sign on KD, the number of milking cows. Unexpectedly, a negative sign has been estimated. The reason for this negative sign lies with the use of the time trend (T). The simple correlation coefficient between KD and T is just under 0.7, indicating quite high multi-collinearity between the two variables. When the equation is estimated without the time trend, KD attains a

significant and positive coefficient. However, severe autocorrelation then exists, and other variables in the equation lose most of their significance. The time trend included in the equation can be justified quite easily, given the structural change in the dairy industry that has occurred in association with technological and genetical advances.

Table 11: Dependent Variable QMLK.

Independent variable	Estimated coefficient	T-statistic
C	-9200.72	-5.97
KD_t	-0.029	-1.21
KDH_t	0.11	2.77
PD_t	0.85	0.79
GIL_{t-2}	0.22	1.10
GIM_{t-1}	-0.16	-1.89
WD_t	-0.61	-3.37
T_t	4.82	6.04

R-squared = 0.87 $\bar{R}$-squared = 0.81
Durbin-Watson Statistic = 1.38
F-Statistic = 13.27
Number of Observations = 21
Mean of Dependent Variable = 273.88

The inclusion of the replacement heifers in the equation (KDH) should also be noted. If the heifers are excluded from the equation, a very small and positive coefficient is estimated for the milking cows. Over the last decade, the ratio between replacement heifers and milking cows has fallen, compared with

the increase in that ratio during the growth era of the 1960s. A fall in the ratio indicates that the average age in the milking herd is rising. Mature cows are higher producers than younger cows. Therefore, the trend in replacement heifer numbers may reflect the falling ratio between heifers and milking cows, resulting in higher average production per cow.

The variables representing gross capital investment in land and weather both have the expected signs. The sign attached to GIM, gross investment in machinery capital, was unexpected, though could be explained if the investment took the form of vehicles or other capital unrelated to milkfat production.

Overall, the milkfat equation is not entirely satisfactory, and needs further work to be done so that more intuitively reasonable results are obtained.

(c) The Beef Cattle Enterprise

(i) Beef Breeding Cows: Table 12 presents the final regression results for the beef breeding cow equation. The equation is similar to the theoretical specification, the main difference being the use of the lamb price rather than the wool price as a representation of the competition from the sheep enterprise for resources devoted to beef production. The inverse of the prime beef to lamb price ratio appeared in the breeding ewe equation, reinforcing the influence the lamb price has on choices between the sheep and beef enterprises.[27]

The equation presented in Table 12 was obtained after a

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[27] See Table 3.

constraint was placed on the coefficient of the lagged dependent variable (KBBC). Unconstrained estimation produced a coefficient of 0.29 attached to $KBBC_{t-1}$, and a coefficient of -1.17 attached to KBH_{t-1}. The signs obtained were wrong on the basis of a priori reasoning. Because the dependent variable is in first difference form, the implied coefficient on the lagged dependent variable is therefore 1.29. This implies that if nothing else changes, beef cow numbers will increase continuously. Clearly, this is unrealistic. The negative sign of KBH is also unrealistic since a positive relationship is expected between the change in breeding cow numbers, and the available supply of replacement heifers.[28] While the unconstrained estimates were accepted at first, the use of the equation in a simulation context proved unacceptable, since the effect of the wrong signs was to make the simulation results decline continuously, so that negative stock numbers were obtained. A more reasonable estimate of the coefficient attached to $KBBC_{t-1}$ was thought to be -0.15, reflecting an average culling rate for breeding cows. Constraining the coefficient on $KBBC_{t-1}$ to this figure lowered the overall fit of the equation, and produced a coefficient on KBH_{t-1} that was positive, though small and insignificant. However, the equation now fits into the overall model structure, and simulates well when all the equations in the model are simulated over time.[29]

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[28] The wrong signs were probably produced by the multicollinearity between KBBC and KBH. (The simple correlation coefficient between the two variables was almost 1.)

[29] See Chapter 6, Model Validation.

Table 12: Dependent Variable DKBBC.

Independent variable	Estimated coefficient	T-statistic
C	-260.68	-1.88
$KBBC_{t-1}$	-0.15	
KBH_{t-1}	0.12	1.06
$(PPB/PL)_t$	124.17	1.44
$(PPB/PL)_{t-1}$	258.44	3.26
VPB_t	5.23	2.52
GIL_{t-1}	1.32	1.36
WB_t	-1.76	-1.44

R-squared = 0.79 $\bar{R}$-squared = 0.71
Durbin-Watson Statistic = 1.92
F-Statistic (6,15) = 9.40
Number of Observations = 22

(ii) Beef Heifers, 1-2 Years Old: The equation for beef heifers was also estimated after constraining the coefficient on the lagged dependent variable. Table 13 shows that the coefficient was constrained at a value of -0.55. Unconstrained estimates of the final equation produced negative and very small coefficients for both KBH_{t-1} and KBC_{t-1}. A positive sign on KBC was expected. Some experimental forms of the equation presented in Table 13 did produce realistic coefficients for the two livestock demographic variables. It was on the basis of these estimates that the value of the constrained coefficient was assumed to be around -0.55. It is difficult to determine whether this estimate is a reasonable one, since the implied coefficient on the lagged dependent

variable of 0.45 cannot be interpreted as directly as the one for breeding cows. This is because the entire one-to-two year old heifer category flows on each year either into the breeding herd, the 'other beef' herd, or into slaughter. A coefficient of 0.45 implies therefore not the proportion of the heifer herd retained, but a base level that the current heifer herd will be built up to.

Table 13: Dependent Variable DKBH.

Independent variable	Estimated coefficient	T-Statistic
C	4.44	0.15
KBH_{t-1}	-0.55	
KBC_{t-1}	0.47	15.79
$(PPB/PL)_{t-1}$	50.99	2.56
PW_t	-0.17	-1.48
$(VPB/VPW)_t$	-23.20	-1.09
$GOVT_t$	-16.80	-1.40

R-squared = 0.96 $\bar{R}$-squared = 0.95
Durbin-Watson Statistic = 1.04
F-Statistic (5,16) = 77.22
Number of Observations = 22

The effect of the constrained estimation was to increase the $\bar{R}$-squared over 10%. However the Durbin-Watson statistic was reduced from about 1.8 to 1.0, thus indicating that positive autocorrelation exists. Autocorrelation results in overestimated T, $\bar{R}$-square and F statistics, and the estimated coefficients may be biased.

(iii) Beef Heifers, Under 1 Year Old: The equation for heifer calves presented in Table 14 is similar to that developed in Chapter 3.[30] Both land and building capital investment were significant variables, though building investment has an unexpectedly negative sign. The dummy variable representing government policy was also unexpectedly negative.

Table 14: Dependent Variable DKBC.

Independent variable	Estimated coefficient	T-statistic
C	-106.81	-1.77
$KBBC_{t-1}$	0.45	4.55
KBC_{t-1}	-1.09	-4.49
PPB_t	-0.60	-1.38
$(PPB/PL)_t$	121.32	3.02
GIL_{t-1}	0.60	1.62
GIB_{t-1}	-0.72	-1.89
GOVT	-36.44	-2.65

R-squared = 0.84 $\bar{R}$-squared = 0.76
Durbin-Watson Statistic = 1.19
F-Statistic (7,14) = 10.65
Number of Observations = 22

The negative sign attached to the absolute level of prime beef prices was expected, indicating that farmers do take advantage of high beef prices for short-term income purposes, at the expense of reducing the number of beef heifers that can be chosen from when selecting breeding animals

[30] See Section 3.5.2, b (iii).

in later years.

Risk and weather variables did not prove to be significant.

(iv) Other Beef Cattle: A satisfactory equation has been estimated for the 'other beef' category of livestock. Once again, the lamb price is preferred to the wool price as a representation of competition from the sheep enterprise. The choice between the two prices was difficult, since in this equation both were found to be equally significant. Inclusion of both lamb and wool prices produced less significant coefficients, and some incorrect signs.

The prime beef to lamb price ratio has the expected positive sign. The absolute lamb price is also positive, though not unexpectedly. Increases in the lamb price may cause some breeding cows and heifers to be re-classified by the farmer as 'other beef', i.e., the farmer uses them for direct beef production rather than as breeding cows producing beef calves. The absolute prime beef price is negative, and in a similar explanation as that offered in the discussion of the beef heifer calves equation, is thought to represent the 'cashing-in' behaviour of cattle farmers when beef prices are high. The low t-statistic associated with the prime beef price is probably due to the correlation between it and the beef to lamb price ratio ($r = 0.77$).

A certain degree of autocorrelation would seem to exist, evidenced by the high Durbin-Watson statistic (2.97).

Table 15: Dependent Variable DKOB.

Independent variable	Estimated coefficient	T-statistic
C	-10006.59	-2.85
$KBBC_{t-1}$	0.40	2.03
KOB_{t-1}	-0.29	-2.35
$(PPB/PL)_{t-1}$	660.49	1.74
PL_{t-1}	6.28	1.77
PPB_{t-1}	-1.80	-0.44
WB_t	-1.54	-0.96

R-squared = 0.83 $\bar{R}$-squared = 0.76
Durbin-Watson Statistic = 2.97
F-Statistic (6,15) = 11.98
Number of Observations = 22

(v) Prime Beef Production: While the equation describing prime beef production produces a good fit, the signs of three of the variables used need some explanation. The signs of PPB_t and $(PPB/PW)_t$ were expected to be positive, indicating that high beef prices encourage the farmer to devote more resources to beef production so that heavier beef carcases are produced. That is, higher beef prices were assumed to increase the optimal slaughter weight of animals. However, with respect to the absolute price variable (PPB), if farmers feel doubtful that high beef prices will last, they may take advantage of the high beef prices while they still exist. Therefore, carcase weights of the animals slaughtered may fall as a higher proportion of animals are slaughtered in less than prime condition. This explanation is consistent with those given in the previous two equations concerning a

similar issue.

The beef to wool price ratio may be negative due to farmers retaining more beef heifers in a move towards cattle farming and away from sheep. Heavier beef heifers make better breeding cows, so that the distribution of heifers culled for slaughter would be skewed towards lighter animals. Therefore, average carcase weight would fall.

Table 16: Dependent Variable QPB.

Independent variable	Estimated coefficient	T-statistic
C	76.77	2.22
$DKBH_t$	-0.44	-3.13
$(KBH + KOB)_{t-1}$	0.031	5.72
PPB_t	-0.49	-1.90
$(PPB/PW)_t$	-51.79	-2.33
GIL_{t-2}	1.15	4.19
WB_t	0.66	2.13

R-squared = 0.89 $\bar{R}$-squared = 0.85
Durbin-Watson Statistic = 2.94
F-Statistic (6,14) = 19.61
Number of Observations = 21
Mean of Dependent Variable = 198.60

The variable representing weather, WB (days of soil moisture deficit), was unexpectedly positive. Dry weather adversely affecting pasture growth should lower carcase weights. If, however, the dry weather inhibits pasture growth so much that desired stock numbers must be reduced, then heavier breeding animals not normally slaughtered may be slaughtered.

Once again, the presence of autocorrelation is indicated by the Durbin-Watson statistic.

(vi) Manufacturing Beef Production: A feature of the manufacturing beef equation is the over-riding influence of livestock demographic variables. The importance of the dairy herd in manufacturing beef production is especially significant.

Table 17: Dependent Variable QMB.

Independent variable	Estimated coefficient	T-statistic
C	-497.27	-5.04
$(DKBBC+DKOB)_t$	-0.082	-2.67
$(KBBC+KOB)_{t-1}$	0.040	4.04
KD_{t-1}	0.27	5.34
$(PM/PPB)_t$	103.82	2.73
GIL_{t-1}	-1.11	-2.74
WB_t	-1.56	-3.22

R-squared = 0.97 $\bar{R}$-squared = 0.96
Durbin-Watson Statistic = 2.16
F-Statistic (6,14) = 74.78
Number of Observations = 21
Mean of Dependent Variable = 154.91

The weather variable this time has the more expected negative sign. The land capital investment variable has a negative sign. Though unexpected, it perhaps indicates that as land development occurs, the older beef stock are not grazed on the developed land but instead are allocated increas-

ingly inferior pieces of land.

The mutton to beef price ratio has a positive sign, reflecting competition between older sheep and cattle for pasture resources. As mutton becomes more profitable, relative to beef, more old ewes are retained as store animals, so that older beef animals must be quit. The higher culling rates for beef animals will produce a heavier average cull animal, so that average carcase weight increases.

5.3 FARM INCOME EQUATIONS

(a) Gross Farm Income

(i) Gross Income on Sheep and Beef Farms: Tables 18 to 21 report on the equations estimated that describe income generation on sheep and beef farms.

The theoretical specifications outlined in Chapter 4 have produced good statistical fits in the estimated equation. Only two unexpected signs were generated, in Table 19 a negative sign attached to QM_t, and in Table 20 a similar sign attached to PMB_t. The negative sign on the manufacturing beef price (PMB) could not be attributed to being multicollinear with the prime beef price (PPB). The variables were retained in the equations to maintain the original a priori structural model which specified the income equations to link the production equations with the investment equations, and therefore recursively link back into the livestock number equations.

A significant degree of autocorrelation was detected in the equation for wool income generation. The reason for this autocorrelation is clear when it is considered that a linear equation has been fitted using price and quantity when a multi-

plicative identity using the two variables is probably a better way of calculating gross income. Autocorrelation is often produced when the functional form of the equation is mis-specified in such a way. However, in the interests of simplicity and consistency with other equations in the model, the linear function is accepted as an acceptable approximation of the non-linear alternative. The cost of this choice is the degree of autocorrelation present in the income equations.

Table 18: Dependent Variable GYW.

Independent variable	Estimated coefficient	T-statistic
C	-9557.58	-3.50
PW_t	103.69	20.16
QW_t	28.55	3.91

R-squared = 0.96 $\bar{R}$- quared = 0.96
Durbin-Watson Statistic = 0.49
F-Statistic (2,18) = 233.35
Number of Observations = 21
Mean of Dependent Variable = 16600.43

Table 19: Dependent Variable GYSM.

Independent variable	Estimated coefficient	T-statistic
C	1185.28	0.36
PM_t	116.93	4.90
PL_t	83.41	2.88
QM_t	-16.34	-1.50
QL_t	14.28	2.05

R-squared = 0.93 $\bar{R}$-squared = 0.91
Durbin-Watson Statistic = 1.48
F-Statistic (4,16) = 52.45
Number of Observations = 21
Mean of Dependent Variable = 14578.43

Table 20: Dependent Variable GYB.

Independent variable	Estimated coefficient	T-statistic
C	-391.95	-0.25
PPB_t	76.52	7.73
PMB_t	-9.11	-1.21
QPB_t	2.10	0.37
QMB_t	8.37	4.97

R-squared = 0.91 $\bar{R}$-squared = 0.89
Durbin-Watson Statistic = 1.60
F-Statistic (4,16) = 40.43
Number of Observations = 21
Mean of Dependent Variable = 6747.05

Table 21: Dependent Variable SBGYO.

Independent variable	Estimated coefficient	T-statistic
C	-438937.58	-8.49
T_t	223.87	8.53
PPB_t	32.33	3.68
PW_t	1.80	0.48

R-squared = 0.85 $\bar{R}$-squared = 0.82
Durbin-Watson Statistic = 1.90
F-Statistic (3,17) = 31.69
Number of Observations = 21
Mean of Dependent Variable = 4491.19

(ii) Gross Income on Dairy Farms: The equation specified in Chapter 4 for gross income in dairy farms did not produce a good functional fit. When a trend term was added to the function, the overall fit improved dramatically (e.g., the $\bar{R}$-squared from around 0.60 to 0.95). The inclusion of the trend term also improved the Durbin-Weston statistic significantly.

The effect of the trend term on the significance of individual variables was to lower the significance of the quantity variable, but to increase the significance of the price variable. The trend term may be accounting for the historical trend towards larger herd sizes. Table 22 summarises the final equation.

Table 22: Dependent Variable GYD.

Independent variable	Estimated coefficient	T-statistic
C	-1791854.9	-13.29
PD_t	83.44	4.74
PD_{t-1}	83.44	4.38
$QMLK_t$	20.64	0.88
PMB_t	53.04	2.70
T_t	903.75	12.91
R-squared = 0.96	$\bar{R}$-squared = 0.95	
Durbin-Watson Statistic = 1.22		
F-Statistic (5,15) = 76.77		
Number of Observations = 21		
Mean of Dependent Variable = 25201.76		

An interesting result is the identical coefficients and significance of the current and lagged milkfat price (PD_t, PD_{t-1}). The two variables are not highly correlated with each other ($r = 0.43$). The significance of the lagged price indicates the importance of end of season payments in generating current income. The end of season payments are calculated on the previous season's production. Given the importance of dairy cows in manufacturing beef production,[31] the significance of the prime beef price is not unexpected.

(b) Gross Expenditure

Tables 23 and 24 summarise the expenditure equations estimated for sheep and beef, and dairy farms.

[31] See Table 17.

Table 23: Dependent Variable SBE.

Independent variable	Estimated coefficient	T-statistic
C	743.28	0.65
$GYSB_t$	0.31	11.50
$SUSB_t$	0.16	8.98

R-squared = 0.96 $\bar{R}$-squared = 0.96
Durbin-Watson Statistic = 1.91
F-Statistic (2,18) = 232.46
Number of Observations = 21
Mean of Dependent Variable = 25003.91

For sheep and beef farms, Table 23 shows that gross income (GYSB) and total stock units (SUSB) have positive impacts on farm expenditure. The capital stock of land (CSKL) was the only category of capital to show any significance, but was highly correlated with total stock units (r = 0.99). This is evidence of a link between the carrying capacity of the land, represented by stock units, and the capital necessary to maintain that carrying capacity. The livestock number equations have already revealed the link between gross capital investment and changes in livestock numbers. Clearly increases in current expenditure resulting from an increase in total stock units must be composed of both capital as well as the working expenditure needed to farm the animals in any particular year. For example, the distinction between capital and working expenditure on fencing and fertiliser is very blurred. Table 24 presents the regression results for a dairy farm expenditure equation. Once again, gross income and total stock units (GYD and SUD) are positive impacts on total expenditure. Building capital stock (CSKB), the only category of capital to show any signifi-

cance in the equation, also had a positive impact on current expenditure.

Table 24: Dependent Variable DE.

Independent variable	Estimated coefficient	T-statistic
C	-8469.91	-8.23
GYD_t	0.45	21.05
SUD_t	0.18	3.45
$CSKB_{t-1}$	2.61	9.31

R-squared = 0.996 $\bar{R}$-squared = 0.996
Durbin-Watson Statistic = 2.35
F-Statistic (3,17) = 1508.53
Number of Observations = 21
Mean of Dependent Variable = 15549.67

5.4 GROSS CAPITAL INVESTMENT EQUATIONS

(a) Land Development

Considerable difficulty was experienced in estimating the theoretical specification for gross investment in land development that was outlined in Chapter 2.[32] The output price variables suggested by neoclassical theory showed some significance, but their effect on the farm variable representing farm liquidity was marked, making the inclusion of both price and income data unacceptable. The price variables, being highly related to the income variables, made the coefficient attached

[32] See Chapter 2, Section 2.4.3, (i).

to the income variable either insignificant, or wrongly signed (negative).

A significant level of positive autocorrelation was also found to be present in the estimated equations. Assuming a first order autoregressive scheme a Hildreth-Lu procedure was used to estimate the autoregressive coefficient (p). A p of 0.80 was found to produce a function that yielded the minimum residual sum of squares. Given the high value of p, it was decided to simplify the estimating procedure by assuming that p was equal to 1. This is equivalent to transforming the equation's variables into first-differences and then applying O.L.S. to the transformed model.

The final equation estimated is summarised in Table 25. The change in gross investment is estimated as a function of the lagged capital stock of land adjusted for depreciation ($ACSKL_{t-1}$), net liabilities per sheep and beef farm (DSB_t), the government policy dummy variable ($GOVT_t$), gross income per sheep and beef farm ($GYSB_t$), and weather (WS_t), all expressed in first differences.

With the exclusion of the output price variable, the strict theoretical specification has been abandoned in favour of an unrestricted model specification, including no variables that determine the desired capital stock (K*). Only variables affecting the rate of investment are included in the equation. While in the theoretical model a negative sign on $ACSKL_{t-1}$ was expected, it is unexpected in the unrestricted model, since increases in the capital stock increase the level of investment necessary to maintain it.

The debt variable has a positive sign, suggesting the importance of borrowed money for land development. The negative

Table 25: Dependent Variable DGIL.

Independent variable	Estimated coefficient	T-statistic
$(ACSKL_{t-1}-ACSKL_{t-2})$	-0.08	-1.56
(DSB_t-DSB_{t-1})	0.0016	2.08
$(GOVT_t-GOVT_{t-1})$	-14.15	-2.28
$(GYSB_t-GYSB_{t-1})$	0.0011	3.55
(WS_t-WS_{t-1})	-0.17	-1.08

R-squared = 0.61 $\bar{R}$-squared = 0.52
Durbin-Watson Statistic = 1.71
F-Statistic (4,17) = 6.69
Number of Observations = 22

sign in the policy variable (GOVT) suggests that the stock retention incentive, the LIS and the LDEL may not be achieving their objectives of increasing or maintaining farm investment levels. The individual effects of these different policies perhaps would be better analysed with separate dummy variables. For example, it is difficult to see how the LDEL has reduced farm investment.

Variables representing income and weather both have their expected signs. Increases in income from one year to the next increase gross investment in land. Drier weather conditions reduce land development since the success of pasture establishment is reduced considerably.

(b) Buildings

As with the land capital investment equation, the estimated equation for building capital investment differs considerably from the theoretical specification.[33] The ratios between output prices and the cost of capital services have been eliminated in the final equation due to lack of significance. A simple variable representing the first year depreciation allowances on buildings is included in the estimated equation (TAXB). The variable has statistical significance as well as the correct sign.

The pressure on farm building capital from stock numbers shows some significance when expressed by DKE_t and DKD_t (the change in breeding ewe and milking cow numbers respectively).

Gross income per dairy farm showed significance also, reflecting the importance of building capital on dairy farms,

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[33] See Chapter 2, Section 2.4.3, (ii).

and the impact of income changes on the farm's ability to adjust the building capital stock to its desired level.

Table 26 summarises the final estimated form of the building capital investment equation. While the structure of the theoretical specification is maintained by the estimated form, the equation as a whole explains little of the variation in gross capital investment in building. Significant auto-correlation is again found to be present in the equation. However, given the equation's poor fit, and its relatively un-important role in the overall model, no effort has been made to eliminate the autocorrelation.

Table 26: Dependent Variable GIB.

Independent variable	Estimated coefficient	T-statistic
C	110.23	2.46
DKE_t	0.0071	2.07
DKD_t	0.031	0.55
$TAXB_t$	0.96	2.39
$ACSKB_{t-1}$	-0.020	-1.20
GYD_t	0.00045	1.04
$GOVT_t$	-22.56	-2.04

R-squared = 0.47 $\bar{R}$-squared = 0.26
Durbin-Watson Statistic = 1.41
F-Statistic (6,16) = 2.21
Number of Observations = 22
Mean of Dependent Variable = 85.07

(c) Transport Vehicles, Plant and Machinery

In a similar fashion to the buildings equation, the equation explaining gross capital investment in transport vehicles, plant and machinery is greatly simplified from that specified in Chapter 2.[34] In this case, however, a much better fit has been obtained than for land or buildings.

The desired capital stock is determined in the estimated equation (see Table 27) by the pressure of stock numbers (in this case, $DKBBC_t$, the change in beef breeding cows), and the first year tax depreciation allowances for plant and machinery ($TAXM_t$). The significance of DKBBC is surprising, since beef cattle farming in New Zealand is generally not a capital intensive operation.

Gross income on dairy, and sheep and beef farms determines the rate at which the capital stock is adjusted to its desired level. The significance of both these variables is quite high, indicating the importance of transitory income in determining capital spending on plant and machinery. Together with the significance of the tax depreciation variable, the significance of the income variables highlights the impact of tax policy on the type of capital investment undertaken.

All the signs on the variables included in the estimated equation, presented in Table 27 fulfil a-priori expectations, except the government policy dummy variable where a negative sign has been estimated.

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[34] See Section 2.4.3 (iii).

Table 27: Dependent Variable GIM.

Independent variable	Estimated coefficient	T-statistic
C	-5.83	-0.19
$TAXM_t$	0.93	1.70
$DKBBC_t$	0.067	1.60
$ACSKM_{t-1}$	-0.090	-2.51
$GYSB_t$	0.0021	4.19
GYD_t	0.0052	12.80
$GOVT_t$	-15.84	-1.79

R-squared = 0.96 $\bar{R}$-squared = 0.94
Durbin-Watson Statistic = 1.71
F-Statistic (5,16) = 60.63
Number of Observations = 22
Mean of Dependent Variable = 136.01

5.5 SUMMARY

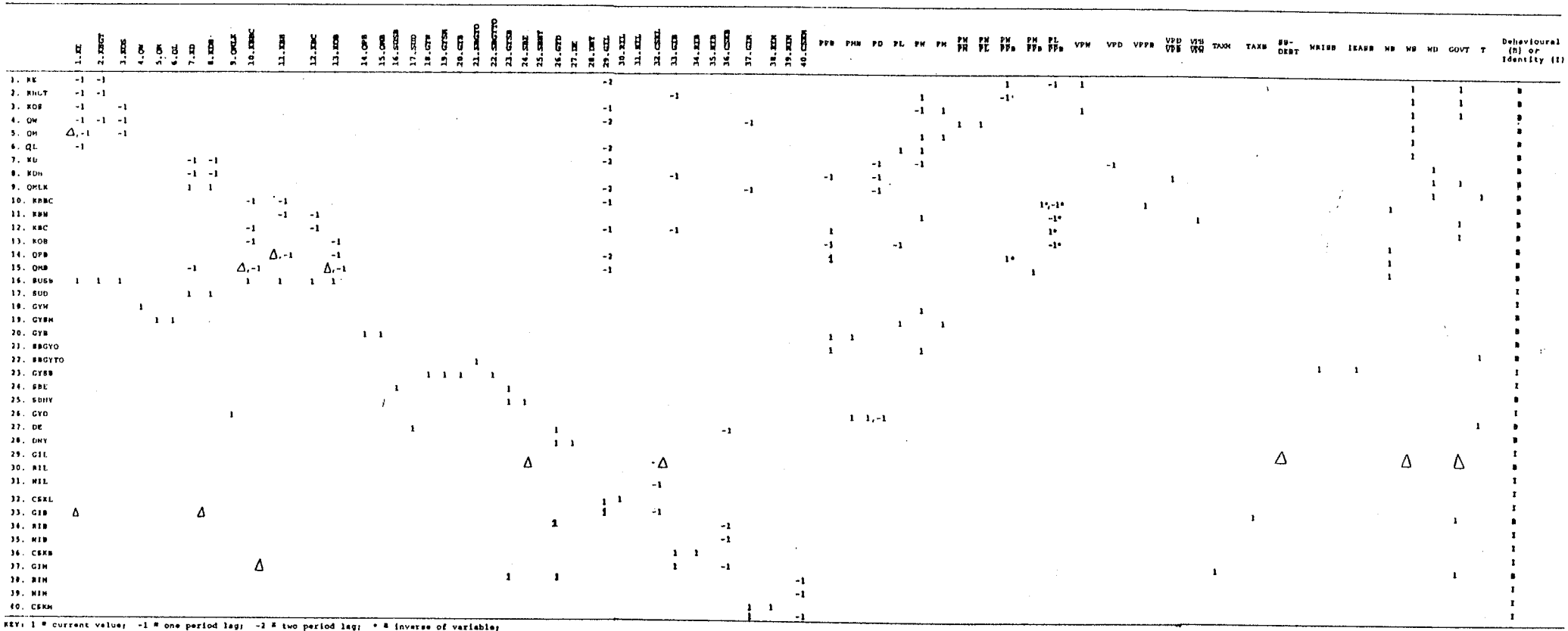
Sections 5.2, 5.3 and 5.4 have presented the results from the estimation of the behavioural equations specified in the preceding three chapters. Overall, the equations estimated satisfy the theoretical equation specifications. However, the equation explaining gross capital investment in land proved difficult to estimate, so that the theoretical specification for this equation was abandoned in favour of an un-restricted specification.

Autocorrelation proved to be a problem in some equations, but given the number of equations that had to be estimated, little effort went into solving the problem.

The use of current and lagged endogenous variables in many of the equations estimated highlights the recursive nature of the model, and the interaction between the various sub-models within the overall system. This is shown in Table 28. which summarises the estimated equations and their determinants. The strong link between gross capital investment in land, and changes in livestock numbers and production, is especially evident.

Having reported on the estimation of individual equations in the model, the entire model is evaluated in Chapter 6 by carrying out a historical simulation.

Table 28: Equation Summary



KEY: 1 = current value; -1 = one period lag; -2 = two period lag; * = inverse of variable;
Δ = current change in variable; -Δ = one period lag on the change in variable.

CHAPTER 6

MODEL EVALUATION

6.1 INTRODUCTION

The discussion of individual equations from an overall model structure is important in determining whether the estimated model, based on the theoretical specification, can be accepted as a reasonable description of the actual environment the model seeks to describe. Chapter 5 reported on the estimation of the individual equations specified for the current model. However, since the individual equations have been specified as part of an overall model structure, the model as a whole must now be evaluated to see whether the individual equations, when viewed as components of an inter-related system of equations, are compatible with one another. Therefore, individual equations will no longer be viewed in isolation from the other equations that combine to form the overall model structure.

Chapter 6 reports on one approach to evaluating the overall validity of the estimated theoretical model, namely, the ability of the estimated model to generate a time path of data conforming to the historical pattern.[35] Section 6.2 discusses the results of a deterministic, multi-period, historical simulation. The simulation is deterministic because variation that could be attributed to the stochastic estimates of the equations coefficients, and stochastic disturbance terms is ignored. The simulation is

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[35] See Pindyck and Rubinfelds (1981), pp 360-363.

described as multi-period (or dynamic), because the values for lagged endogenous are determined from previous model solutions, rather than using actual data. If actual data are used, then a single period (or static) simulation is undertaken. The estimation of a deterministic and dynamic historical simulation to evaluate a model's validity, is considered the most demanding of all simulation options.[36]

6.2 HISTORICAL SIMULATION RESULTS

The results of the historical simulation can be discussed in terms of summary measures such as the mean absolute percentage error (MAPE), and the Theil U statistic. Also, graphical techniques are important in evaluating the simulation results, since summary statistics fail to explicitly show up turning-point errors produced by the simulation.

Table 29 presents the summary statistics calculated from the simulation. The MAPE attempts to capture the size of errors relative to the size of actual values, and is defined as:

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[36] Dhrymes (1972), p 311.

$$MAPE = \sum_{t=1}^{T} \left| \frac{A_t - S_t}{A_t} \right| \times \frac{100}{1}$$

where $A_t \equiv$ the actual value,

and $S_t \equiv$ the simulated value.

From Table 29, it can be seen that MAPE is under 10% for 26 out of the 40 equations. One of the largest MAPE (50%) was calculated for the manufacturing beef equation, which is surprising considering the estimated equations $\bar{R}$-squared. The manufacturing beef equation is particularly sensitive to the value of KD (the number of milking cows) so that the errors in the equation determining KD (Figure 3f) are passed onto the manufacturing beef equation (Figure 3k). Some of the equations with MAPEs over 10% are not particularly important equations in terms of the model's overall structure. For example, the three equations for net capital investment all have MAPEs over 10%.

The Theil U statistic measures the ability with which the simulation predicted the changes in the actual value. The Theil U calculated is defined as:

$$U = \frac{\sum_{t=1}^{T} (A_t - S_t)^2}{\sum_{t=1}^{T} A_t^2}$$

where $U \equiv$ the value of the Theil U statistic.

If U = 0, then the simulation predicts perfectly the changes in the actual values. If U = 1, then the simulation predictions are no better than a naive no change model[37], i.e.

$$S_t = A_{t-1}.$$

[37] See Longmire and Watts (1981), p 21.

Table 29: Summary statistics from historical simulation.

Equation number	Dependent variable	Mean absolute percentage error (MAPE)	Theil U statistic (U)	Correlation coefficient (r)	$\bar{R}$-squared from estimated equation ($\bar{R}^2$)
1	KE	9.14	0.12	0.87	0.83
2	KHGT	10.79	0.15	0.77	0.61
3	KOS	13.90	0.15	0.29	0.58
4	QW	11.19	0.14	0.67	0.96
5	QM	7.70	0.10	0.82	0.82
6	QL	10.58	0.13	0.84	0.93
7	KD	9.20	0.12	0.39	0.56
8	KDH	13.46	0.16	0.79	0.62
9	QMLK	4.31	0.05	0.77	0.81
10	KBBC	4.79	0.05	1.00	0.71
11	KBH	6.07	0.06	0.99	0.95
12	KBC	5.56	0.06	0.99	0.76
13	KOB	4.58	0.05	1.00	0.76
14	QPB	8.43	0.10	0.84	0.85
15	QMB	49.99	0.44	0.51	0.96
16	SUSB	7.13	0.09	0.99	
17	SUD	8.45	0.11	0.49	
18	GYW	8.11	0.09	0.96	0.96
19	GYSM	5.62	0.06	0.96	0.91
20	GYB	11.81	0.13	0.86	0.89
21	SBGYO	14.86	0.13	0.92	0.82
22	SBGYTO	15.90	0.14	0.95	
23	GYSB	5.06	0.07	0.93	
24	SBE	5.54	0.07	0.94	0.96
25	SBNY	11.27	0.14	0.83	
26	GYD	3.23	0.05	0.98	0.95
27	DE	3.53	0.04	0.99	1.00
28	DNY	6.27	0.09	0.93	
29	GIL	13.60	0.14	0.61	0.52
30	RIL	2.21	0.03	0.99	
31	NIL	37.41	0.26	0.70	
32	CSKL	2.30	0.03	0.99	
33	GIB	8.88	0.13	0.70	0.26
34	RIB	0.73	0.01	1.00	
35	NIB	12.10	0.16	0.71	
36	CSKB	0.79	0.01	1.00	
37	GIM	7.68	0.09	0.94	0.94
38	RIM	1.33	0.02	1.00	
39	NIM	56.98	0.33	0.88	
40	CSKM	1.43	0.02	1.00	

Values of U greater than 1 are therefore indications that the simulation model predicts changes in the actual values worse than no change, naive forecasts.

Table 29 shows that the simulation results for this model produce very low Theil U statistics. All Theil U's are less than one, the largest Theil U is 0.44, again for QMB.

To confirm the favourable results produced by the MAPE and Theil U statistics, a simple correlation coefficient is also presented in Table 29. The correlation between the actual and simulated values of the dependent variables ranges from 0.29 to almost perfect correlation ($r = 1.00$). By comparing the correlation coefficients from the simulation, and the $\bar{R}$-squares from the estimated equations, it can be seen that the high $\bar{R}$-squares do not necessarily ensure high correlation coefficients. A dynamic simulation exposes an equation to data generated by the model, and to the extent that this data differs from that with which the equation was estimated, a better or worse fit to the dependent variable's historical values may result. The equations for 'other' sheep (KOS), dairy cows (KD) and manufacturing beef (QMB) are good examples of equations performing worse in a simulation context than when viewed in isolation. The beef herd equations (KBBC, KBH, KBC, and KOB) and the equations for land and buildings gross capital investment (GIL and GIB) conform to the historical data better in the simulation than when viewed in isolation.

Having presented the summary statistics, the discussion of the graphical analysis can proceed. Figure 3 presents graphically the actual and simulated values of some important dependent variables. The graphical analysis is useful for showing the errors between the actual and simulated values,

but because of the different scales used, is inferior to the summary statistics in making comparisons between equations. The advantage of the graphical analysis is that it enables an evaluation of the model's ability to correctly simulate the turning-points in the actual data.

Overall, Figure 3 shows that the majority of turning-points in the actual data series are reproduced. For example, in the graph showing breeding ewe numbers (Figure 3a), only the turning-point that occurred in 1971 is missed. For the ewe hoggets (Figure 3b), a major turning-point was missed in the previous year. Clearly, the impact of the missed turning-point for the ewe hoggets resulted, because of the model's dynamics, in the missed turning-point for the breeding ewes in the subsequent year. Also, Figure 3g shows that the missed turning-point for ewe numbers then caused another turning-point error, this time for wool production in 1971. This example clearly shows the compounding effects of errors in a deterministic and dynamic simulation model.

Figures 3d and 3q, graphing the simulation results for beef heifers and building capital investment, appear to show a good fit between the actual and generated data. However, both graphs show that important turning points are missed, and tend to be produced a year or two after the actual event. For beef heifers, this occurs following the major turning-point in 1975, and for building investment, the turning-points in 1970 and 1975. This inability to correctly anticipate the turning-points greatly limits the usefulness of these equations for forecasting and policy analysis.

The graphical analysis shows little evidence that the historical simulation results are beginning to diverge off the

FIGURE 3: Historical Simulation Results

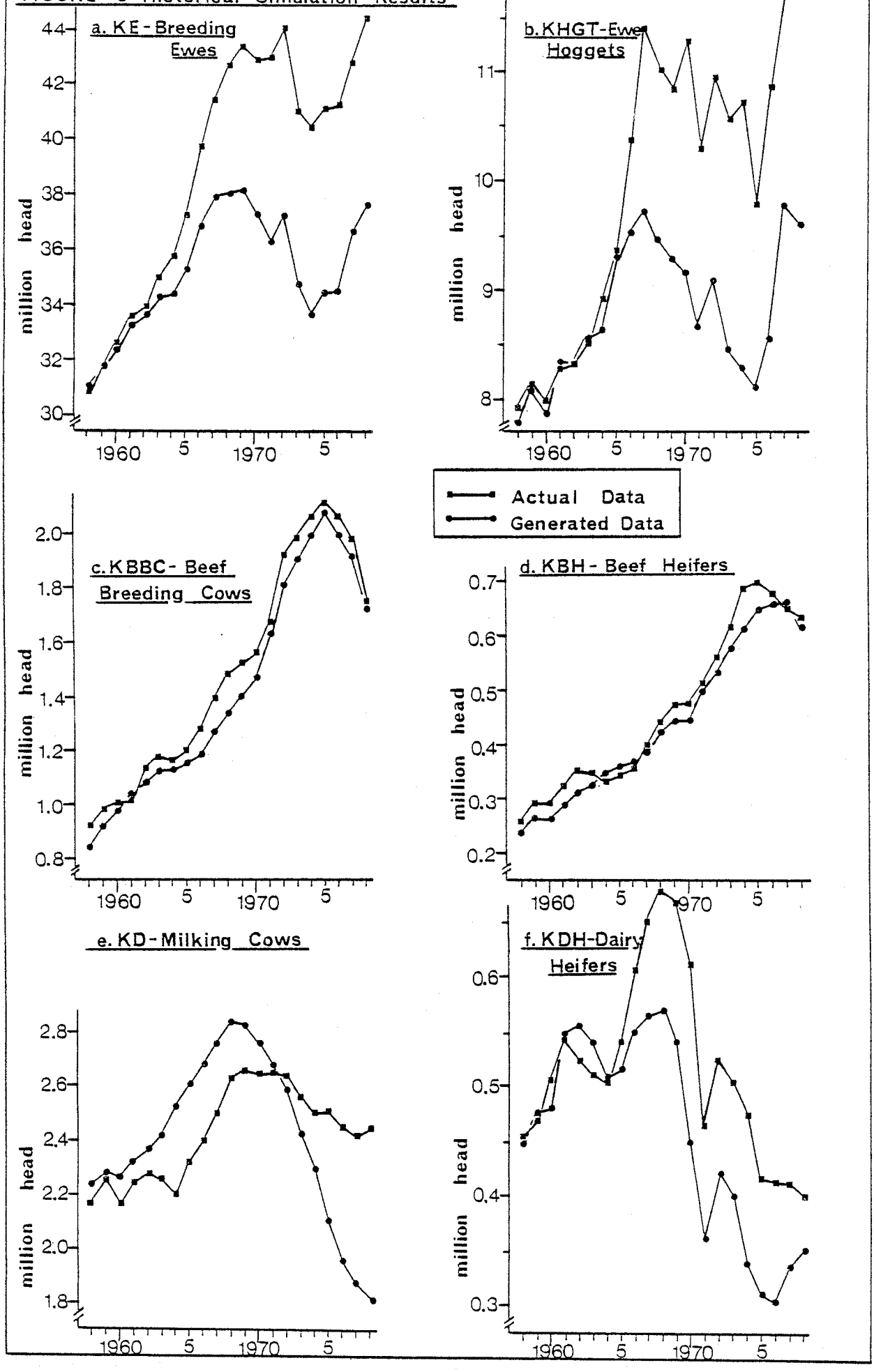


FIGURE 3 (continued)

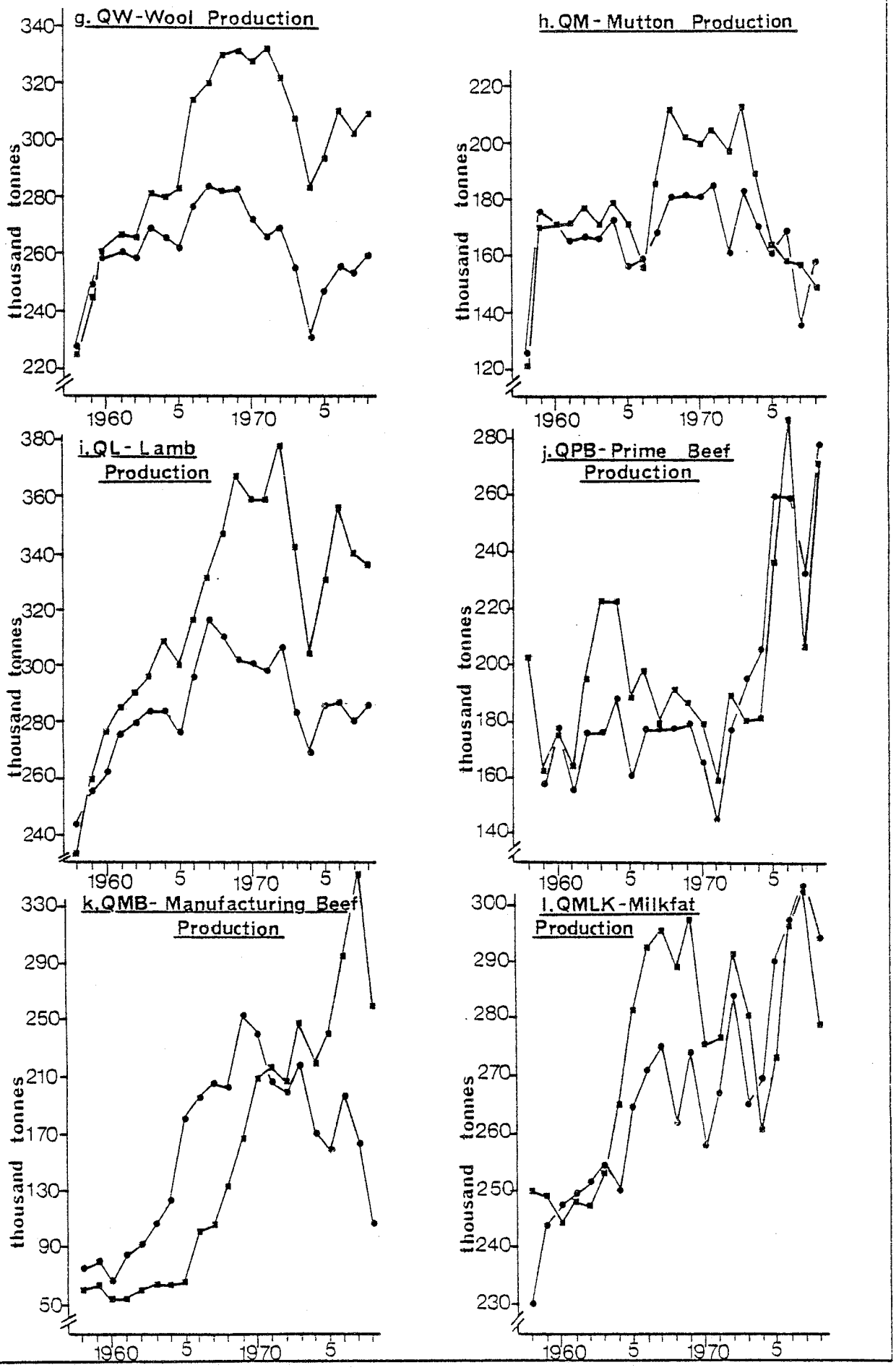
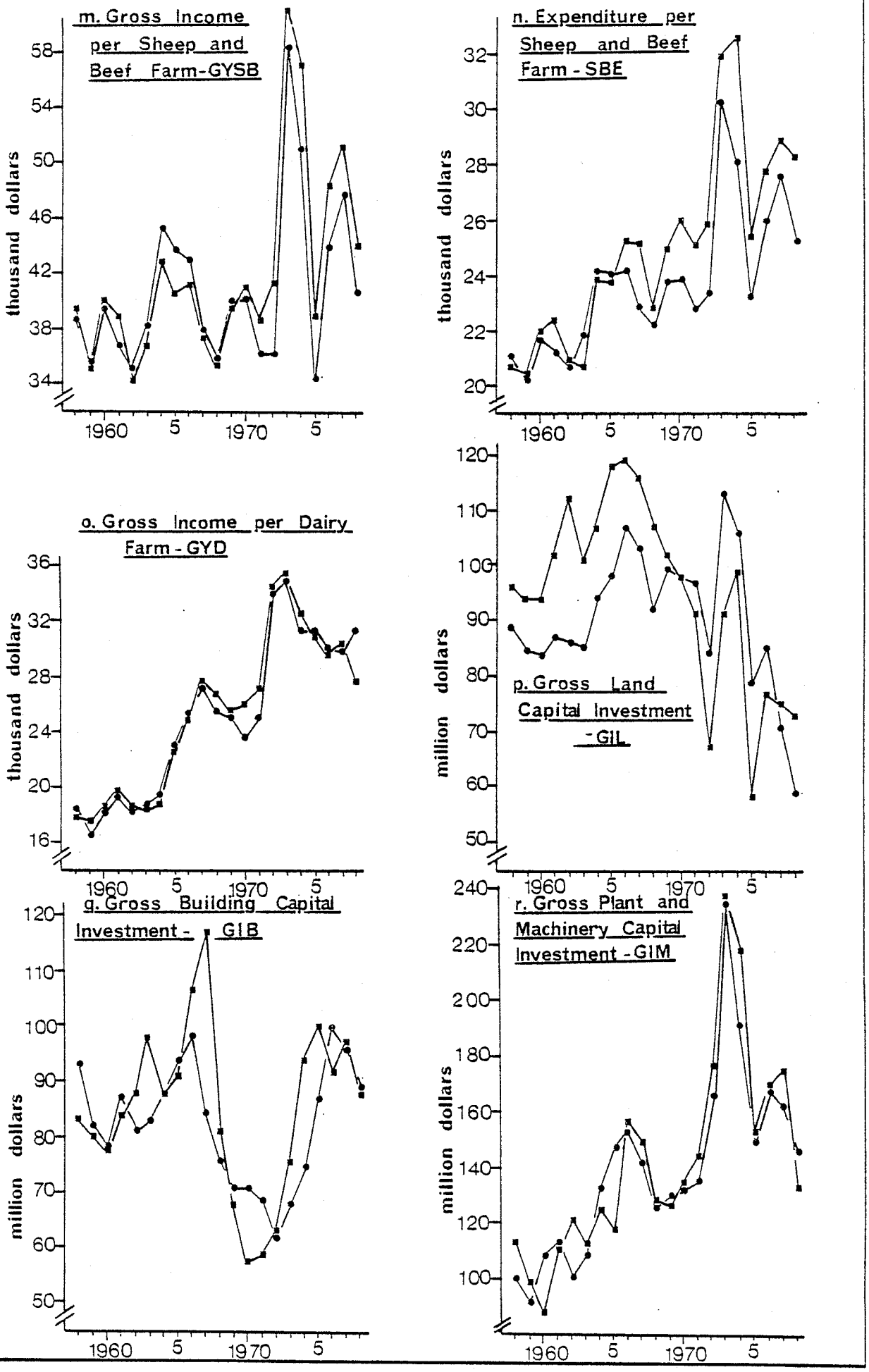


FIGURE 3 (continued)



historical time path for the variables. However, the graphs show that while most of the turning-points in the data are reproduced by the simulation, persistently large errors in the absolute levels of the dependent variables are often generated. This is caused by the compounding effect of errors generated by the simulation process. A good example of this is provided by Figures 3a and b for the sheep flock, and the subsequent effect of the errors shown in these graphs on the production equations shown in Figures g, h, and i. This graphical information, together with the Theil U results presented earlier, is perhaps an indication that the model predicts changes in the dependent variables better than their absolute values. This is not surprising when it is considered that many of the dependent variables in the estimated equations were in first difference form.[38]

When the model is used for forecasting, this problem with the accumulation of errors will not arise, since the values of lagged endogenous variables would be re-initialised with actual, rather than generated, data (provided only single-period forecasts are required).

The farm income and expenditure simulation results (Figures 3 m, n and o) show that the equations perform well when exposed to the influences of other equations in the model. The results obtained from the income equations ensure that the investment equations (Figures p, q, and r) whose values depend to a large degree on the level of gross income, fit in well with the multi-equation simulation framework.

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[38] All the livestock numbers, and one capital investment equation, were estimated in this way.

6.3 CONCLUSIONS

The historical simulation approach to evaluating the validity of the estimated model has shown that in terms of the summary statistics and the graphical analysis, the model performs reasonably well. Turning-points are usually predicted by the simulation results. Dynamically, individual equations in the model did not show any tendency to diverge away from the actual data.

The results generated by the current model are sufficiently encouraging to suggest that the effort required to improve the preliminary model developed by Laing and Zwart (1981) has not been wasted. A major advance has been the establishment of causal linkages between livestock numbers, farm production, gross farm income, and capital investment.

The direction of future research should include both further model development and the application of the model to forecasting and policy analysis. Possible model developments include the continued refinement of individual equation specifications, the extension of the current model so that farm prices, retail prices, domestic consumption and exports are determined endogenously, and the updating of data so that the estimation period is extended.

In its current form, the model seems well suited for analysing government policy affecting farm prices e.g. devaluation or Supplementary Minimum Prices (SMP's). An analysis of the dynamic properties of the model through the generation of dynamic elasticities would also yield valuable information for the participants in policy-making.

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APPENDIX I: LIST OF VARIABLES - DEFINITIONS AND SOURCES

A. Endogenous Variables

Sheep Numbers

1 KE — Number of breeding ewes, thousand head, June year.

2 KHGT — Number of ewe hoggets, thousand head, June year.

3 KOS — Number of other sheep, thousand head, June year.

from New Zealand Department of Statistics (various). Sheep returns. Wellington: Government Printer.

Sheep Production

4 QW — Quantity of wool produced, thousand tonnes, greasy basis, June year.

from New Zealand Wool Board (various). Annual report and statement of accounts. Wellington.

5 QM — Quantity of mutton produced, thousand tonnes, bone-in, June year.

6 QL — Quantity of lamb produced, thousand tonnes, bone-in, June year.

from New Zealand Department of Statistics (various). Monthly abstract of statistics. Wellington: Government Printer.

7 KD Number of dairy cows and heifers over two years old in milk or in calf, and one to two year old heifers, thousand head, June year.

8 KDH Number of dairy heifers, under one year old, and cows and heifers over two years old not in calf or in milk but intended for dairying, thousand head, June year.

from New Zealand Department of Statistics (various). Agriculture statistics. Wellington: Government Printer.

Note : Before 1971, data were collected on a January rather than a June year. Adjustment of the pre-1971 data was therefore necessary so that a consistent June year time series could be used for regression analysis.

9 QMLK Quantity of milkfat produced, including both milkfat processed by dairy factories, and town supply milk consumed, thousand tonnes, June year to 1961, thereafter the year ended May.

from New Zealand Dairy Board (various). Farm production report. Wellington.

10 KBBC Number of beef cows and heifers over two years old used for breeding, thousand head, June year.

11 KBH Number of one to two year old beef heifers, thousand head, June year.

12 KBC Number of less than one year old beef heifers, thousand head, June year.

13 KOB Number of beef cows and heifers over two years old not used for breeding, mixed age steers and bulls, and cull dairy cows, thousand head, June year.

from New Zealand Department of Statistics (various). Agriculture statistics. Wellington: Government Printer.

Note : Before 1971, data were collected on a January rather than a June year. Adjustment of the pre-1971 data was therefore necessary so that a consistent June year time series could be used for regression analysis.

14 QPB Quantity of prime beef produced, thousand tonnes, bone-in equivalent, June year.

15 QMB Quantity of manufacturing beef produced, thousand tonnes, bone-in equivalent, June year.

from Total beef and veal production. New Zealand Department of Statistics (various). Monthly abstract of statistics. Wellington: Government Printer.

from Export meat production. New Zealand Meat Producers' Board (various).

Export meat production. Unpublished on a June year, obtained through personal communication with the Board. The data were also converted from a shipping weight basis to

bone-in equivalents.

It was assumed that all manufacturing beef was exported. After calculating the manufacturing beef component of the export beef production, it was subtracted from the total beef and veal production data, producing prime beef production as a residual.

16 SUSB Number of sheep and beef cattle stock units, thousand stock units, June year.

17 SUD Number of dairy cattle stock units, thousand stock units, June year. Based on converting variables 1, 2, 3, 7, 8, 10, 11, 12, and 13 into stock units. The variables and their conversion factors into stock units are shown below:

Variable	Conversion Factor
KE	1.0
KHGT	0.7
KOS	0.7
KD	7.5
KDH	4.0
KBBC	6.0
KBH	4.5
KBC	3.5
KOB	5.0

18 GYW Gross income per sheep and beef farm derived from the sale of wool, dollars, June year.

19 GYSM Gross income per sheep and beef farm derived from the sale of sheepmeats, dollars, June year.

20 GYB Gross income per sheep and beef farm derived from the sale of beef, dollars, June year.

21 SBGYO Gross income per sheep and beef farm derived from other sources (e.g., cash crops, hay), dollars, June year.

22 SBGYTO Gross income per sheep and beef farm derived from other sources, adjusted for deposits and withdrawals from Wool Income Retention, and Income Equilisation Accounts, dollars, June year.

23 GYSB Total gross income per sheep and beef farm, dollars, June year. GYSB = GYW + GYSM + GYB + SBGYTO.

24 SBE Cash expenditure per sheep and beef farm, dollars, June year.

25 SBNY Available cash net income per sheep and beef farm, dollars, June year. SBNY = GYSB - SBE.

from New Zealand Meat and Wool Board's Economic Service (various).

Sheep and beef farm survey. Wellington.

Note : Data taken from 'all classes average', published since 1971. Pre-1971 data unpublished.

26 GYD Total gross income per dairy farm, dollars, financial year.

Note 1 : Income includes payments for milkfat, cull dairy cows, dairy beef, income equalisation deposits and withdrawals, and off-farm income.

Note 2 : Financial years for dairy farms are traditionally March, but increasingly are now kept on a May or June basis.

27 DE Total expenditure per dairy farm, dollars, financial year.

28 DNY Net Income per dairy farm, dollars, financial year. DNY = GYD-DE.

from New Zealand Dairy Board (various). An economic survey of factory supply dairy farms in New Zealand. Wellington.

Note : The survey began in 1964. To obtain earlier data, income data available from the New Zealand Department of Statistics was utilised. It was found that for years when the two series overlapped, a close correlation existed between the changes in the two data series. By calculating the percentage changes in the Department of Statistics data, and applying them to the Dairy Board data, available for 1964, pre-1964 data were generated.

see also

New Zealand Department of Statistics. Statistics of Incomes and Income Tax to 1978-79. Wellington: Government Printer.

29 GIL Gross capital expenditure on land, million dollars, June year.

from New Zealand Department of Statistics (various). Agriculture Statistics. Wellington: Government Printer.

Note : Data available from 1967. Johnson (1970) and Johnson and Hadfield (1971) provide capital expenditure data for land, buildings, and transport vehicles, plant and machinery from

1946-1969. After some adjustments, Johnson's (1970) data were used pre-1968.

see Johnson, R.W.M. 1970. Capital formation in New Zealand agriculture 1946-67. Agricultural Economics Research Unit, Research Report No. 65. Lincoln College, N.Z. 60 p.

Johnson, R.W.M.; Hadfield, S.M. 1971. Recent trends in capital formation in New Zealand agriculture 1964-69. Agricultural Economics Research Unit, Discussion Paper No. 20. Lincoln College, N.Z.

30 RIL Replacement capital expenditure on land, million dollars, June year.

Note : $RIL_t = \delta\ CSKL_{t-1}$

where t ≡ in year t

and δ *≡ the average replacement rate for capital expenditure on land, calculated as 1.2% from Johnson's (1970) estimates of gross and replacement investment, and the land capital stock. Therefore,* $\delta = 0.012$.

31 NIL Net capital expenditure on land, million dollars, June year. NIL = GIL-RIL.

32 CSKL Capital stock of land, million dollars, June year.

Note : base year capital stock of land calculated by Johnson (1970).

$CSKL_t = (1 - \delta)\ CSKL_{t-1} + GIL_t$

33 GIB Gross capital expenditure on buildings, million dollars, June year.

34 RIB Replacement capital expenditure on buildings, million dollars, June year.

Note : From Johnson's (1970) data, the average replacement rate for capital expenditure on buildings was calculated at 0.6%.

35 NIB Net capital expenditure on buildings, million dollars, June year.

36 CSKB Capital stock of buildings, million dollars, June year.

Note : Base year capital stock of buildings calculated by Johnson (1970).

37 GIM Gross capital expenditure on transport vehicles, plant and machinery, million dollars, June year.

38 RIM Replacement capital expenditure on transport vehicles, plant and machinery, million dollars, June year.

Note : From Johnson's (1970) data, the average replacement rate for capital expenditure on transport vehicles, plant and machinery was calculated at 9.1%.

39 NIM Net capital expenditure on transport vehicles, plant and machinery, million dollars, June year.

40 CSKM Capital stock of transport vehicles, plant and machinery, million dollars, June year.

Note : Base year capital stock of transport vehicles, plant and machinery calculated by Hussey and Philpott (1969).

see Hussey, D.D.; Philpott, B.P. 1969. Productivity and income of New Zealand Agriculture 1921-67. Agricultural Economics Research Unit, Research Report No. 59, Lincoln College, N.Z. 63 p.

B. Exogenous Variables

1 PW Wool price, cents per kilogram, average auction price, greasy wool, June year.

from New Zealand Wool Board (various). Annual report and statements of accounts. Wellington.

2 PL Lamb price, cents per kilogram, North Island schedule price for PM lamb (13-16 kg), December to May mid-month average, plus pelt and wool payments.

3 PM Mutton price, cents per kilogram, North Island schedule price for ML2 ewe (22.5-26 kg), January to June mid-month average, plus pelt and wool payments.

4 PPB Prime beef price, cents per kilogram, North Island schedule price for P1 steer (245-270 kg), January to June mid-month average.

5 PMB Manufacturing beef price, cents per kilogram, North Island schedule price for cow M (145-170 kg), February to June mid-month average.

from New Zealand Meat Producers' Board (various). Annual report and statement of accounts. Wellington.

and New Zealand Meat and Wool Board's Economic Service (various). Annual review of the sheep and beef industry. Wellington.

6 PD Milkfat price, cents per kilogram, includes both basic and end-of-season payments, May year.

from New Zealand Dairy Board. Annual report and statement of accounts. Wellington.

7 VPW Three year moving standard deviation of the wool price (PW).

8 VPB Three year moving standard deviation of the prime beef price (PPB).

9 VPD Three moving standard deviation of the milkfat price (PD).

10 WS Days of soil moisture deficit, weighted by the distribution of the sheep population, June year.

11 WB Days of soil moisture deficit, weighted by the distribution of the beef cattle population, June year.

12 WD Days of soil moisture deficit, weighted by the distribution of the dairy cattle population, June year.

from The New Zealand Meteorological Service, obtained from the New Zealand Meat and Wool Board's Economic Service, Wellington.

13 WRISB Wool income deposited/withdrawn from the Wool Proceeds Retention Scheme, dollars, June year.

14 IEASB Income placed in the income equalisation accounts, dollars, June year.

15 D Liabilities and reserves minus total liquid assets per sheep and beef farm, dollars, June year.

from New Zealand Meat and Wool Board's Economic Service (various).
Sheep and beef farm survey. Wellington.

16 PK^B Defined as the cost of building capital services index in the theoretical model, but in the regression analysis was defined as the first-year tax depreciation allowance for buildings (TAXB), percentage, March year.

17 PK^M Defined as the cost of transport vehicle, plant and machinery capital services index in the theoretical model, but in the regression analysis was defined as the first-year tax depreciation for plant and machinery (TAXM), percentage, March year.

from Sweet and Maxwell (N.Z.) Ltd (various).
Taxation tables Auckland.

18 PLAB Farm wage index, four quarter average, June year.

19 CPL Land farm capital price index, June year.

20 CPB Building farm capital price index, June year.

21 CPM Plant and machinery farm capital price index, June year.

22 XPI Meat and wool export price index, June year.
from New Zealand Department of Statistics (various).
Monthly abstract of statistics. Wellington: Government Printer.

23 PPBD Prices paid by dairyfarmers' index, May year.
from New Zealand Dairy Board (various).
Farm production report. Wellington.

24 PPBS Prices paid by sheepfarmers' index, January year.

25 PPTS Prices received by sheepfarmers' index, season (September for meat, June for wool).

26 STE Sheepfarmers' terms of exchange. PPTS ÷ PPBS.
from New Zealand Meat and Wool Board's Economic Service (various).
Annual review of the sheep and beef industry. Wellington.

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