THE NEW ZEALAND

PASTORAL LIVESTOCK SECTOR :

a preliminary econometric model

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Discussion Paper No. 54

Agricultural Economics Research Unit
Lincoln College

ISSN 0110-7720

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Lincoln College, Canterbury, N.Z.

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The overall policy of the Unit is set by a Policy Committee consisting of the Director, Deputy Director and appropriate Professors.

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PREFACE

This paper presents the methodology and results of an initial effort to develop an econometric model of the New Zealand livestock sector.

The work reported in this paper was commenced by Mr Laing whilst employed in the Ministry of Agriculture and Fisheries in Wellington. The work continued at Lincoln College where Mr Laing is carrying out postgraduate research under the supervision of Dr A Zwart, senior lecturer in the Department of Agricultural Economics and Marketing.

The model presented here is reported as a preliminary model. Although further work is progressing on the model in the Department, it is felt appropriate to record the results so far to enable a higher level of feedback to be facilitated to the authors than otherwise would be the case.

Financial assistance provided by the Ministry of Agriculture and Fisheries is gratefully acknowledged.

J. B. Dent
Director

SUMMARY

This paper reports on an investigation of the pastoral livestock sector[1] of New Zealand. The sector's recent history, and also New Zealand's, has been one of slow, and sometimes negative growth. As a result of the sector's importance, government intervention, in the interests of the country as a whole, has been widespread. This intervention has, however, been largely unco-ordinated.

A need is seen for the development of a formal model of the pastoral livestock sector. Such a model would both monitor the sector's performance and provide guidelines for intervention by Government. An econometric model is seen as a valuable aid in describing the sector's structure explicitly, predicting the future implications of current trends, and exploring the effects of alternative policies.

Section 1 backgrounds the pastoral livestock sector and identifies, in the light of national objectives, the problems it faces in contributing to national prosperity. It concludes with a discussion of how an econometric model will aid the investigation and solution of some of the pastoral sector's problems.

Section 2 develops a theoretical model of the pastoral sector which will be useful in analysing the problems described in Section 1.

Section 3 presents and discusses the results of estimated model equations and the final section presents the results from a validation exercise.

It should be noted that this report is of a preliminary nature and merely reports on the first round of estimation for the model.

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[1] The Pastoral Livestock Sector comprises the sheep, beef cattle and dairy cattle populations.

The results generated, however, suggest that the model has provided a reasonable estimate of the structure of the sector and that further research is needed.

SECTION 1

THE PASTORAL LIVESTOCK SECTOR

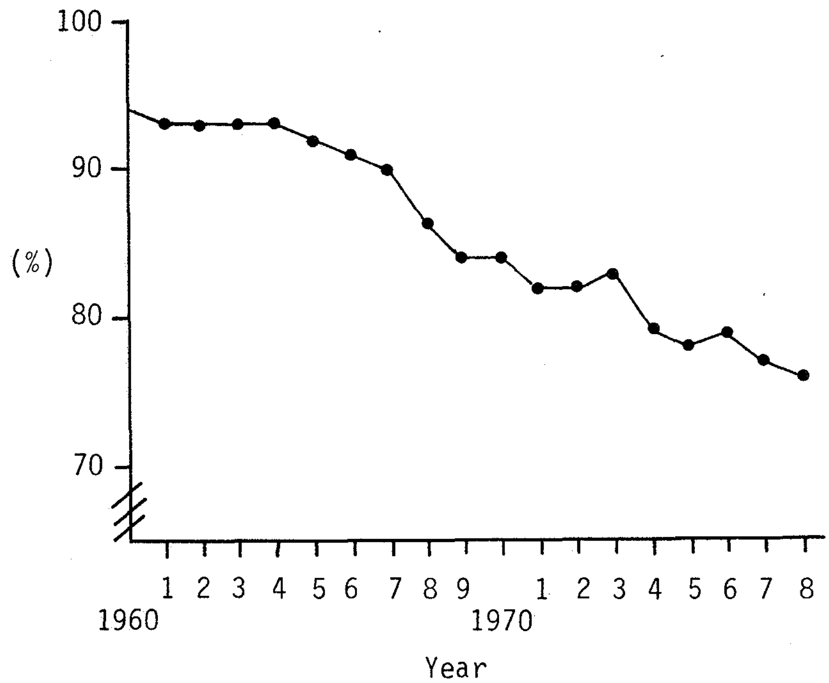
1.1 The Contribution of the Pastoral Livestock Sector to the New Zealand Economy

1.1.1 Exports

Historically, the pastoral sector has been of major importance to the New Zealand economy. New Zealand has always relied heavily on trade to stimulate its economic growth, and as Figure 1 shows, pastoral receipts have a dominant though declining role in contributing to export income.

FIGURE 1

Pastoral Receipts as a Percentage of Total Export Receipts, 1960-1978



Source: Reserve Bank of New Zealand, Bulletin

In real dollar terms (base year 1977), pastoral receipts have doubled over the 1960 to 1980 period, from $722 m. in 1960 to $1,416 m in 1978 and declined in their relative importance from 94 per cent of export receipts in 1960 to 76 per cent in 1978.

1.1.2 Economic Interaction

The pastoral sector's share of Gross National Product (GNP) has also declined markedly, along with the proportion of the workforce employed in the sector. However, while the conspicuous contribution of the pastoral sector to the New Zealand economy is declining, its continued value can be assessed by considering the sector's role in the total economy, and its relationships with other sectors.

In the Zanetti Report (Zanetti, 1975) the pastoral sector was described as the destabilising sector in the New Zealand economy. Three of the reasons given for this description are discussed below:

(i) Sector Interrelationships

Most measures of the contribution of the pastoral livestock sector only account for its "up to farm gate" contribution. The "farmgate to f.o.b." contribution of the sector is considerable when the role of the "input supplying" servicing industries (e.g. freezing works, wool scourers) are accounted for, not only in terms of employment generated but also in terms of demand by these sectors for the manufacturing sector's goods. The effect of any instability in the pastoral sector is magnified when it is passed on to the servicing industries. In part, this magnification is due to the capital intensiveness of many servicing industries. As the servicing industries tend to be capitalised to cope with periods of high demand for their services, periods of low demand (associated with low farm incomes) lead to a situation of overcapitalisation and reduced efficiency.

(ii) Market Prices

A second reason why the pastoral sector is a destabilising element in the New Zealand economy can be recognised by considering the dependence of internal price levels for farm products on the prices received for the products on overseas markets. Fluctuations in overseas prices are therefore transmitted to the domestic economy causing instability in the level of domestic economic activity. As internal price rises are not always matched by internal price falls (when overseas prices fall, i.e. a 'ratchet' effect), permanent disequilibrium can be experienced.

(iii) Multiplier Effect

The pastoral sector is also destabilising in that increases in overseas prices result in higher farm incomes and an associated increase in economic liquidity via the multiplier effect. In the past, this increased liquidity has been associated with a high propensity to increase demand for imports, thus negating the effects of increased export prices on the balance of payments.

The pastoral sector's decline in importance in the economy can be partially explained by its relative market power, having little ability to deflect cost increases in comparison with other sectors of the economy. The manufacturing sector is highly protected from overseas competition in comparison with the pastoral sector, which must absorb higher priced inputs from the manufacturing sector and then sell its own output on world markets.

1.1.3 Future

The future role of the pastoral sector has been discussed by many writers (e.g. Taylor, 1980; McLean, 1978; N.Z. Planning Council, 1978; and Zanetti, 1975), the consensus being that while the pastoral sector's contribution to the economy is declining, it still affords New Zealand great potential for achievement of national objectives (see Section 1.2). If growth objectives for sectors such as forestry, energy and manufacturing are to be achieved, then the pastoral sector must provide an increasing stream of exports in order to meet the foreign exchange requirements of a growing economy. Relegating the development of the pastoral sector to a secondary position in any development strategy for New Zealand will require the gloomy assumption that the present most important foreign exchange earner (which also has a low imported input demand) offers little future potential. This report presumes that such an assumption is unjustified, and so the problems of the pastoral sector are worth discussing in the light of achieving national objectives.

Section 1.2 reviews the objectives of New Zealand and the pastoral sector and Section 1.3 presents a discussion of the problems in the sector that inhibit the achievement of these objectives. Section 1.4 then discusses the need for an explicit model of the pastoral sector and the role that such a model could play in planning and policy analysis.

1.2 New Zealand and the Pastoral Livestock Sector : Objectives

Ian McLean's, "The Future for New Zealand Agriculture", states that New Zealand's economic management has been directed towards the objectives of:

(i) full employment,
(ii) low rates of inflation,
(iii) maintaining or extending the welfare system,
(iv) retaining and extending access for New Zealand's exports,
(v) developing manufacturing,
(vi) maintaining a mixed economy (free market plus planning), and
(vii) a moderate rate of economic growth.

These intermediate objectives are important because they aid the achievement of what might be described as "national ultimate objectives", such as maximising the nation's welfare, both economic and non-economic, and achieving a fair distribution of that welfare, (see Schickle, Ch. 3 and 4).

McLean then takes the agricultural sector and seeks to identify its objectives. He concludes that to gain any clear indication of what New Zealand's agricultural objectives have been one must first look at the policies that have been initiated. Since agricultural policy objectives are seldom stated explicitly, the chances of ad hoc and contradictory policy making are increased. However, McLean lists four perceived objectives of policy in the agricultural sector.

(i) Greater stability in prices received.
(ii) Reasonable stability in farm incomes.
(iii) As much growth as possible within the constraints imposed by the style of economic management.

(iv) Minimum disturbance to existing institutional arrangements, especially if major interest groups are opposed to specific changes.

The Zanetti Report includes an additional agricultural objective:

(v) orientation of the pastoral sector to overseas market forces.

It can be seen that the agricultural objectives (except for (iv) are by and large compatible with the objectives of New Zealand as a whole, so that the achievement of the agricultural objectives should contribute to the achievement of the national objectives. The first three objectives, stable prices and incomes, and growth, deal directly with the role the pastoral sector plays in earning export income. By taking the instability out of farming and thereby encouraging growth in production, the extra foreign exchange gained can be used to finance growth in G.N.P. (see Maughan, 1977). The fifth objective modifies the first three, in that it seeks to ensure long term competitiveness on overseas markets so that long term foreign exchange earnings are protected.

1.3 The Achievement of Agricultural Objectives

The degree of achievement of agricultural objectives can be assessed by a brief survey of important statistics over the last two decades.

1.3.1 Prices, Incomes, Investment

The first point that is clear is that prices received by farmers have fluctuated markedly (Figure 2). This is reflected in the terms of exchange (Figure 3). Unstable prices have been transformed into variable farm incomes (Figure 4),especially since 1974. Also, non-farm incomes have risen steadily and in the 1970's have been consistently higher than farm incomes. It is considered that variable incomes have led to variable investment by farmers in the pastoral sector (Figure 5).

1.3.2 Stock Numbers

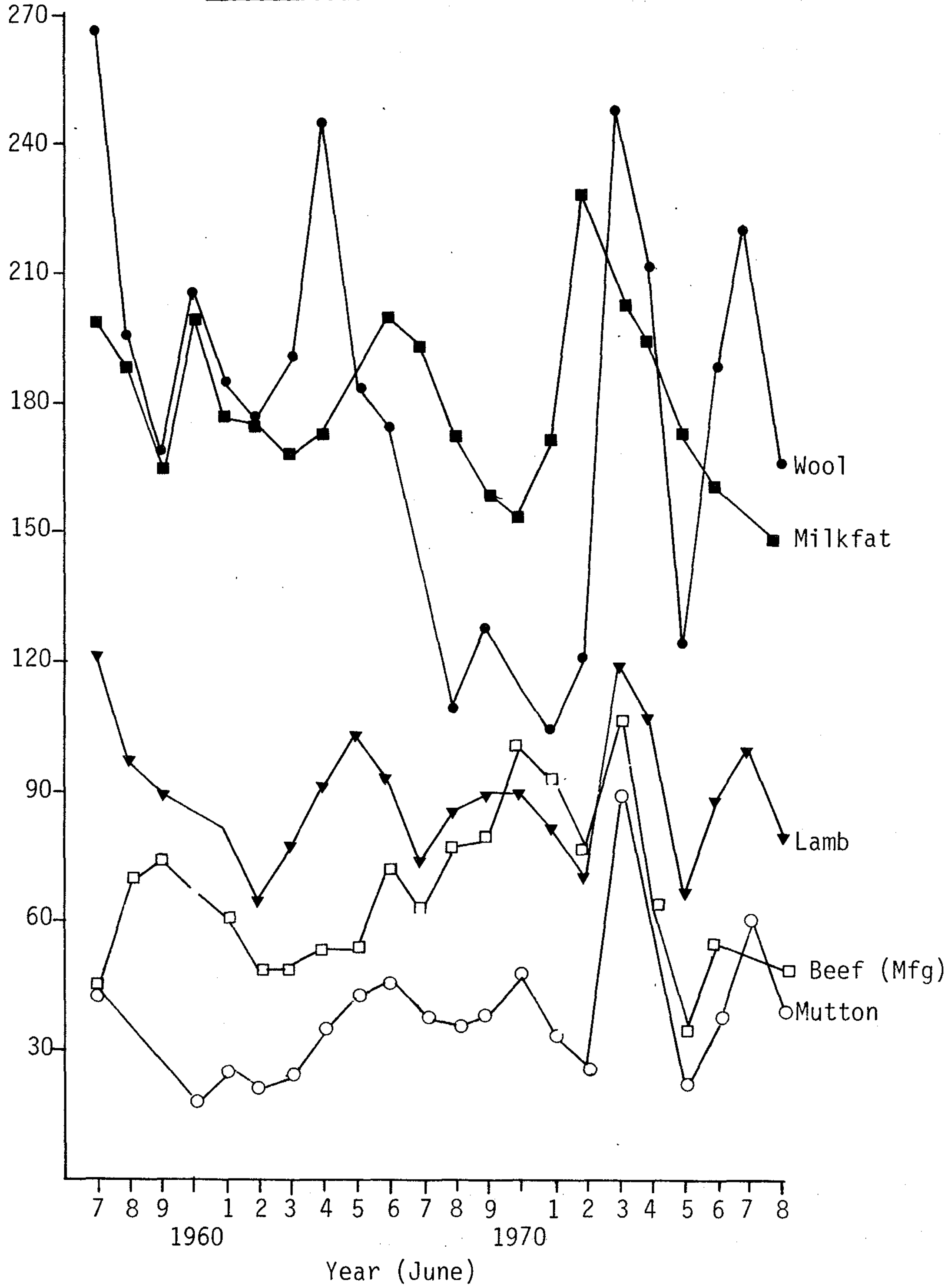
Stock numbers rose consistently throughout the 1960's but during the 1970's the trend was interrupted, (Figure 6). Sheep numbers fell throughout the early 1970's, interrupted only by a large rise in 1972, this rise due mainly to a Livestock Incentive Grant given to farmers in that year. Since 1977, sheep numbers have increased again, probably in response to the Livestock Incentive Scheme, announced in 1976. Beef cattle numbers grew substantially in the early 1970's, but have been falling since 1975 (Figure 7). Dairy cattle numbers have declined almost continually throughout the 1970's, probably due to uncertainty over markets for dairy products, and also the rise in horticultural activity in dairying areas (Figure 8).

1.3.3 Exports, Balance of Payments, National Income

The halting of livestock growth trends which had been sustained throughout the 1960's has had important consequences for the growth rates of exports and of National Income. Figure 9 shows that pastoral export growth has usually been at a slower rate than that for total exports, and when exports fall, pastoral exports fall to a greater extent than non-pastoral exports. In the 1970's export growth rates have not been at 1960's levels, except for a large increase in exports in 1976. However, this only made up for the fall in exports in 1974. Therefore, as a

FIGURE 2

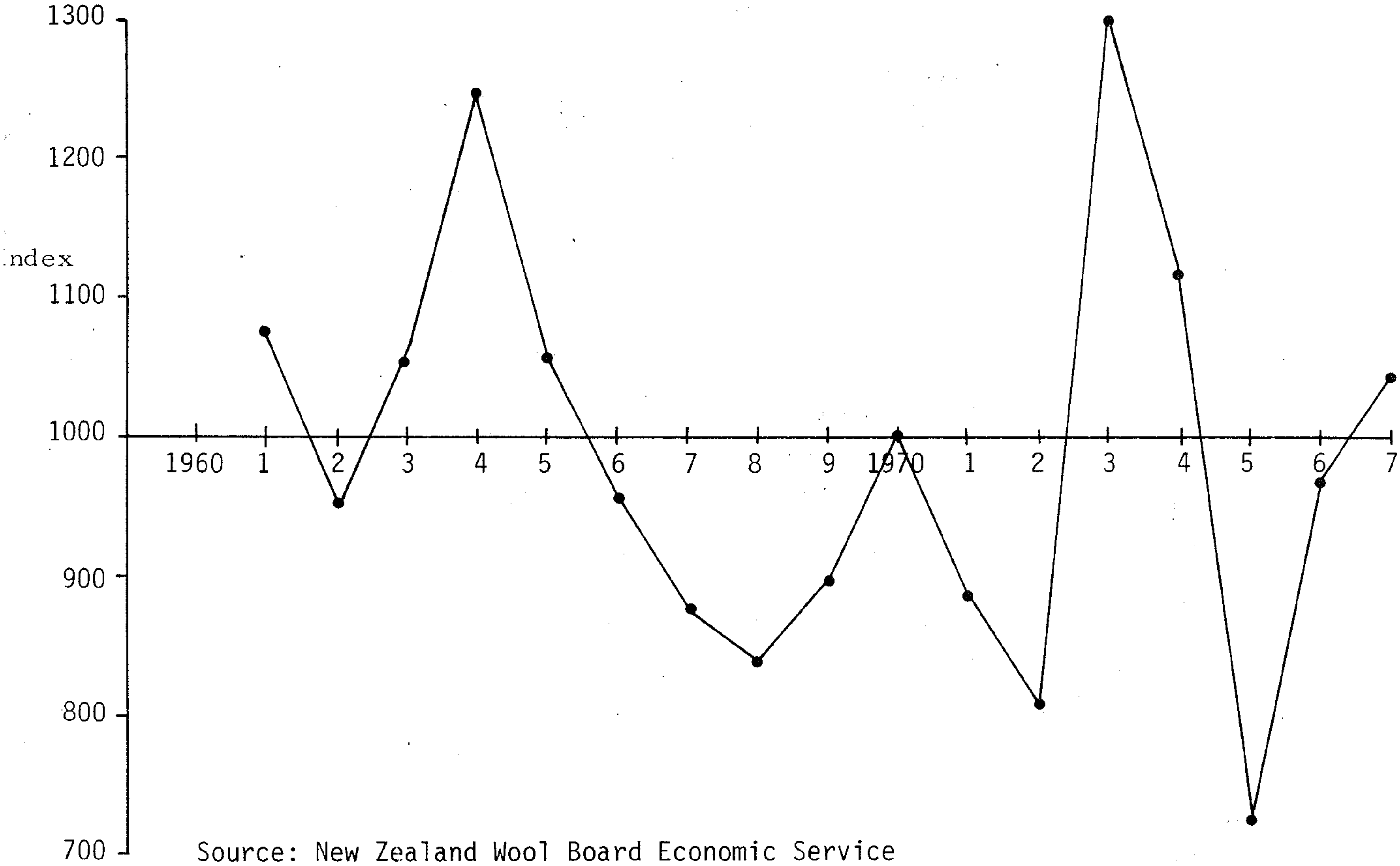
Prices Received by Farmers, Cents/Kg. (Real $ 1977)
1957-1978



Source: New Zealand Meat and Wool Board's Economic Service, New Zealand Dairy Board.

FIGURE 3

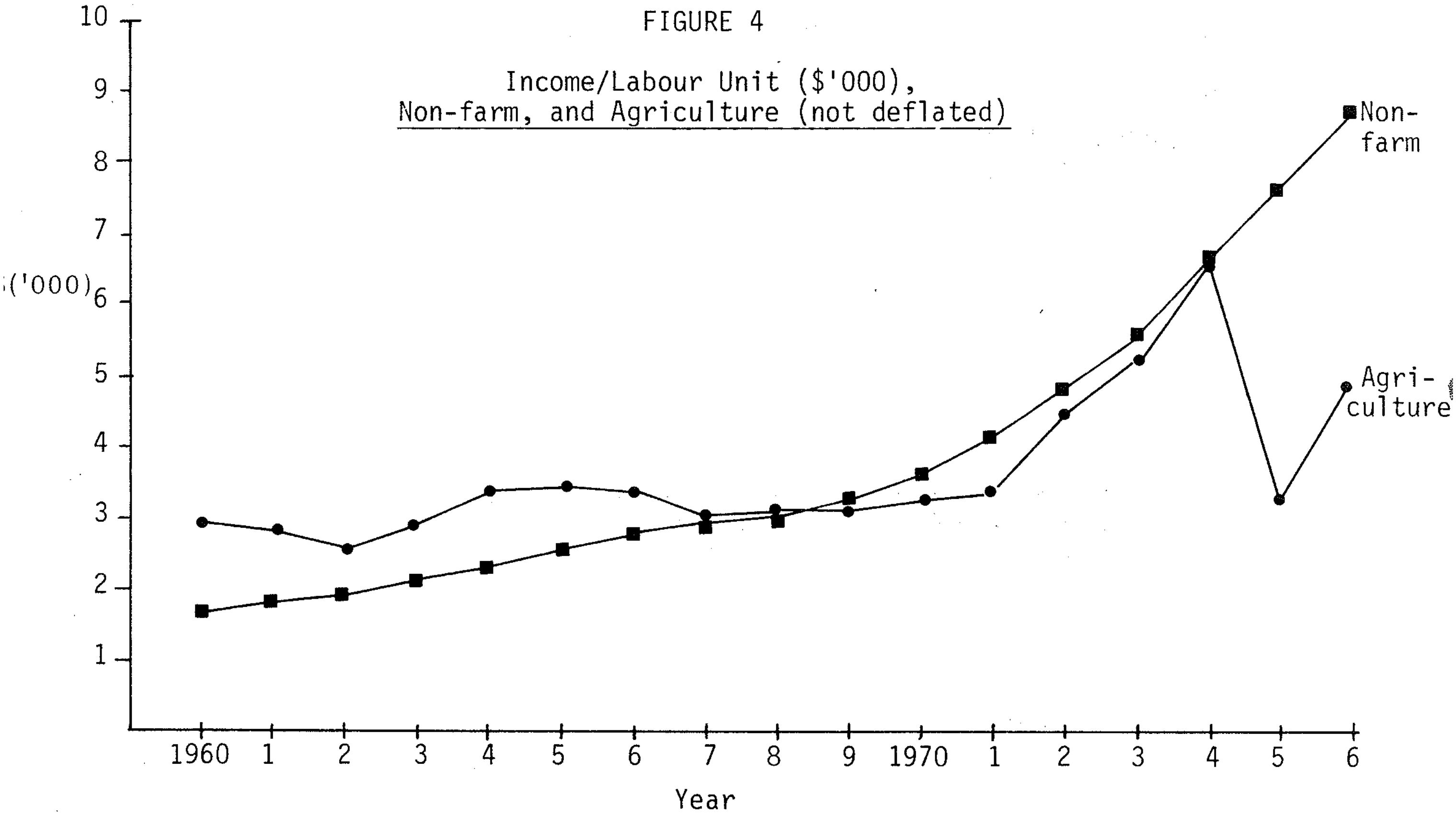
Sheep Farmers' Terms of Exchange (1970 = 1000)



Source: New Zealand Wool Board Economic Service

FIGURE 4

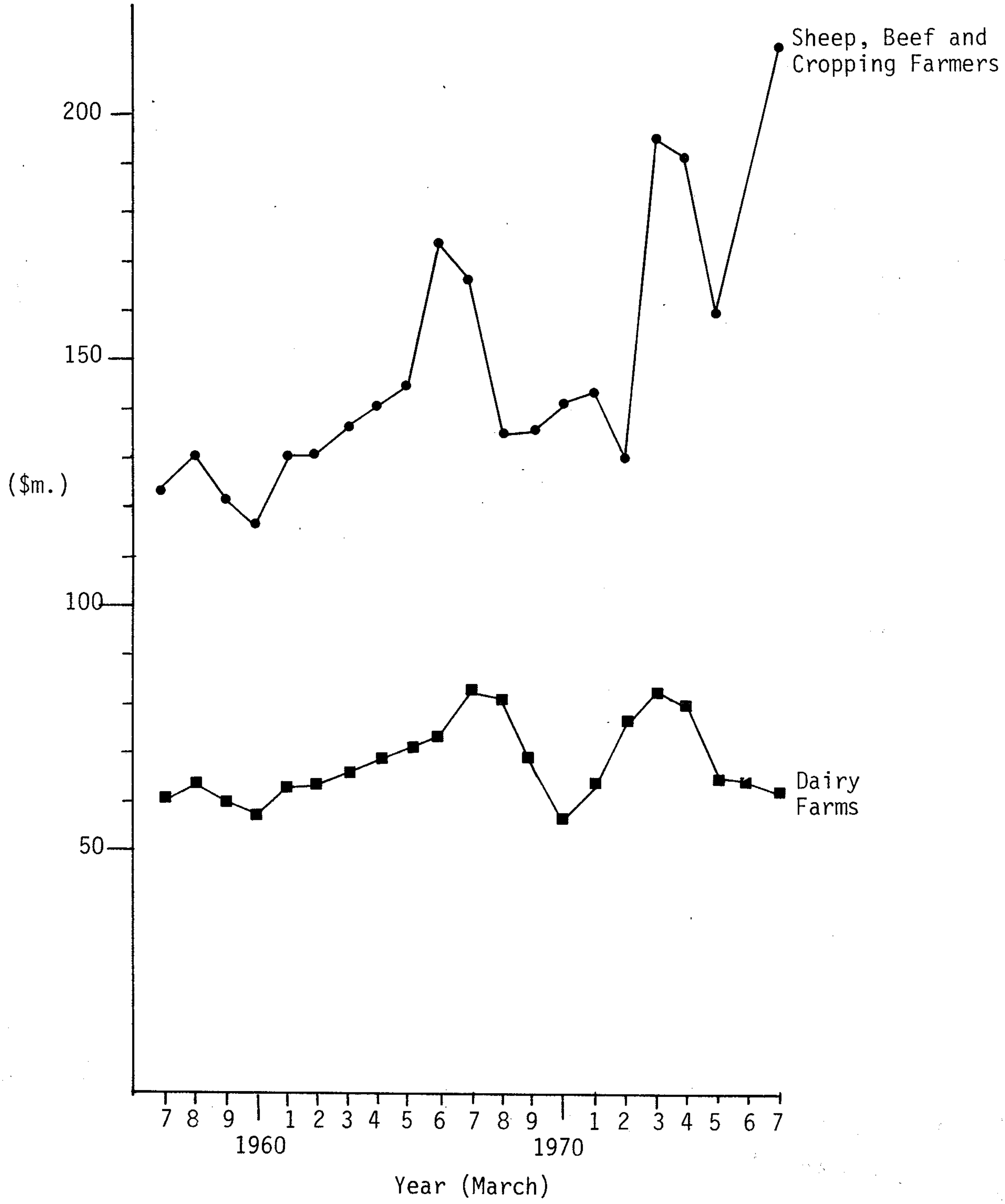
Income/Labour Unit ($'000),
Non-farm, and Agriculture (not deflated)



Source: Johnson (1977)

FIGURE 5

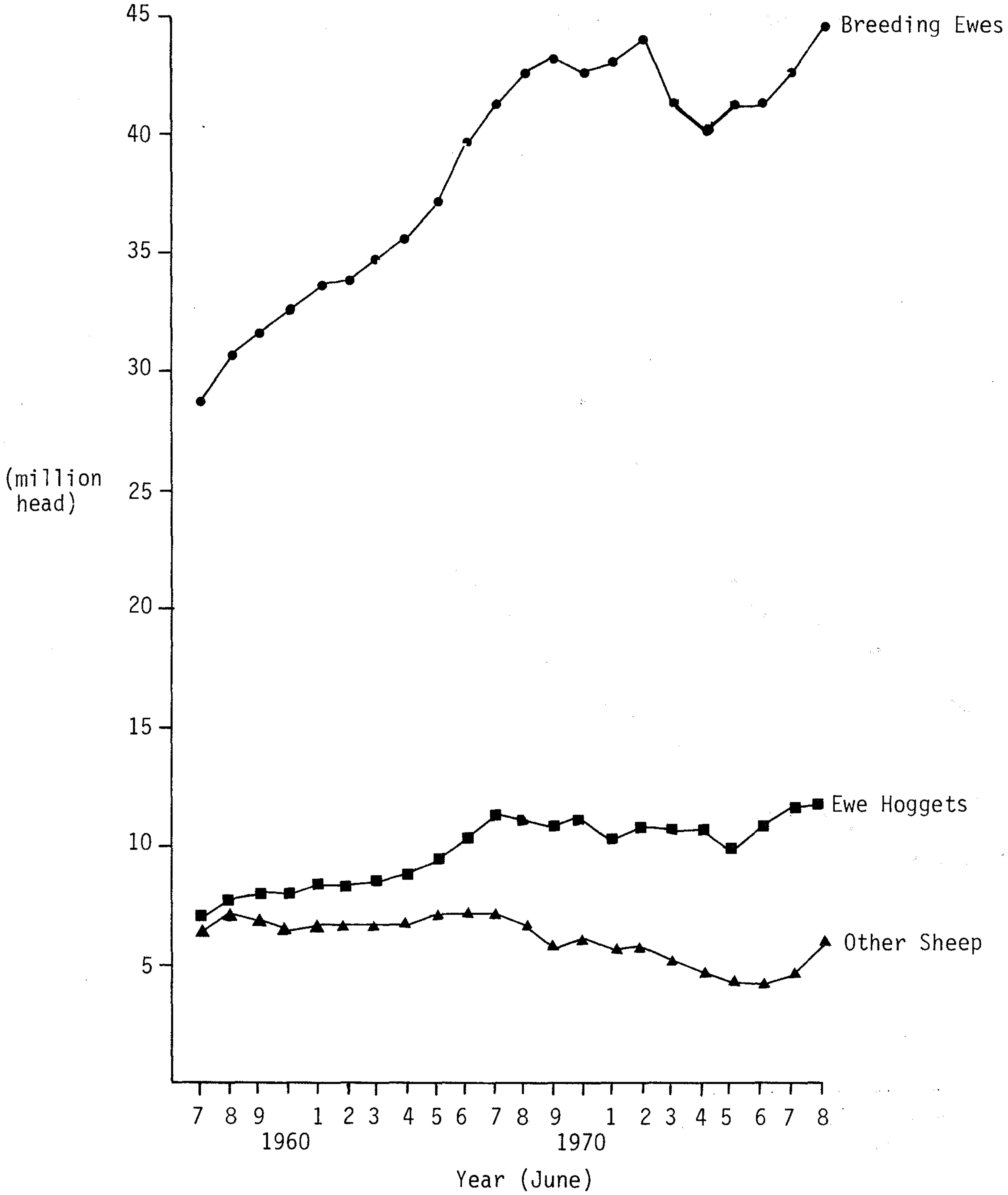
Gross Investment in Land, Buildings, and Plant ($ million), 1957-1977



Source: Johnson (1978)

FIGURE 6

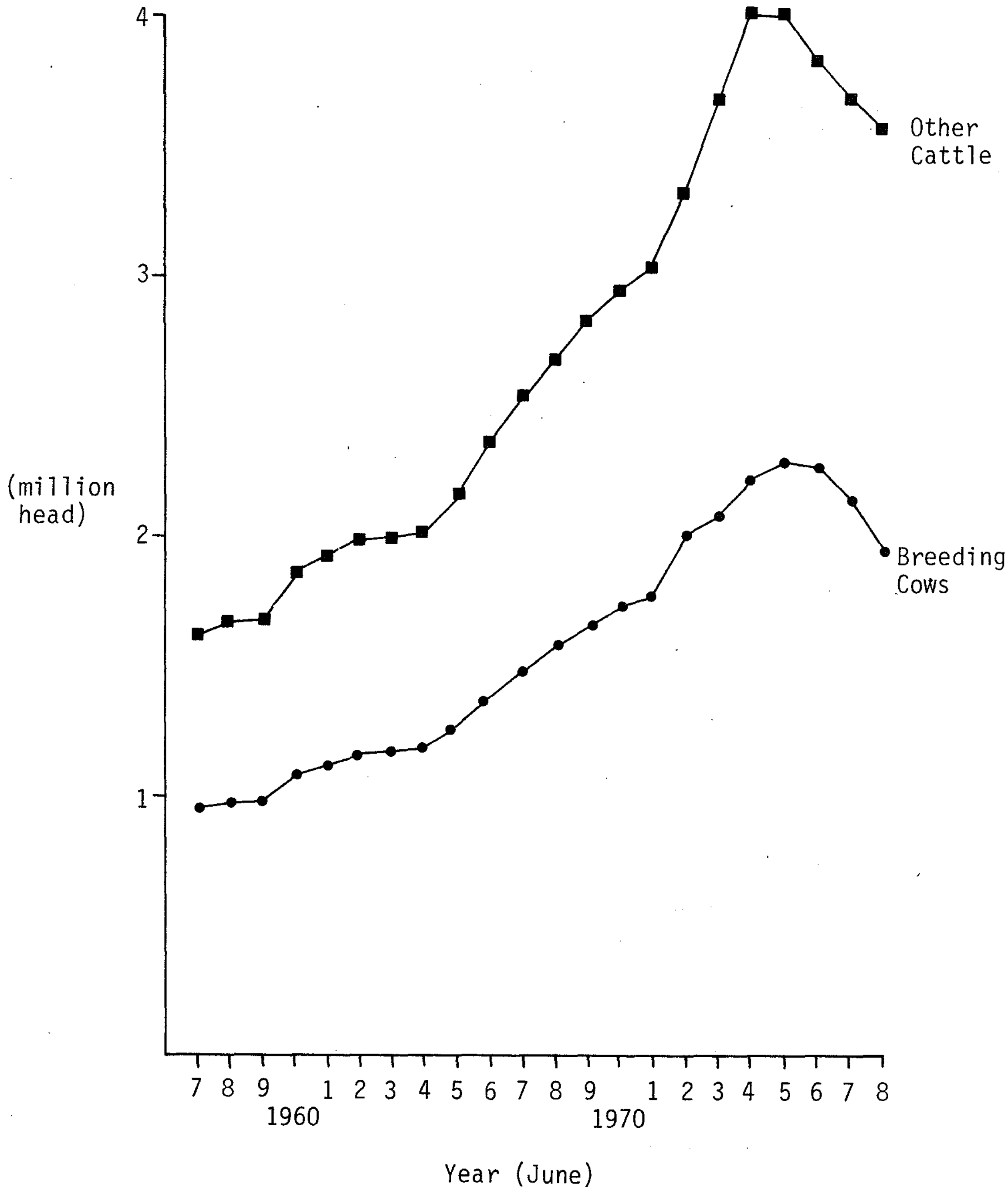
Sheep Numbers (million), 1957-1978



Source: New Zealand Department of Statistics

FIGURE 7

Beef Cattle Numbers (million head), 1957-1978



Source: New Zealand Department of Statistics

FIGURE 8

Dairy Cattle Numbers (Million head), 1957-1978

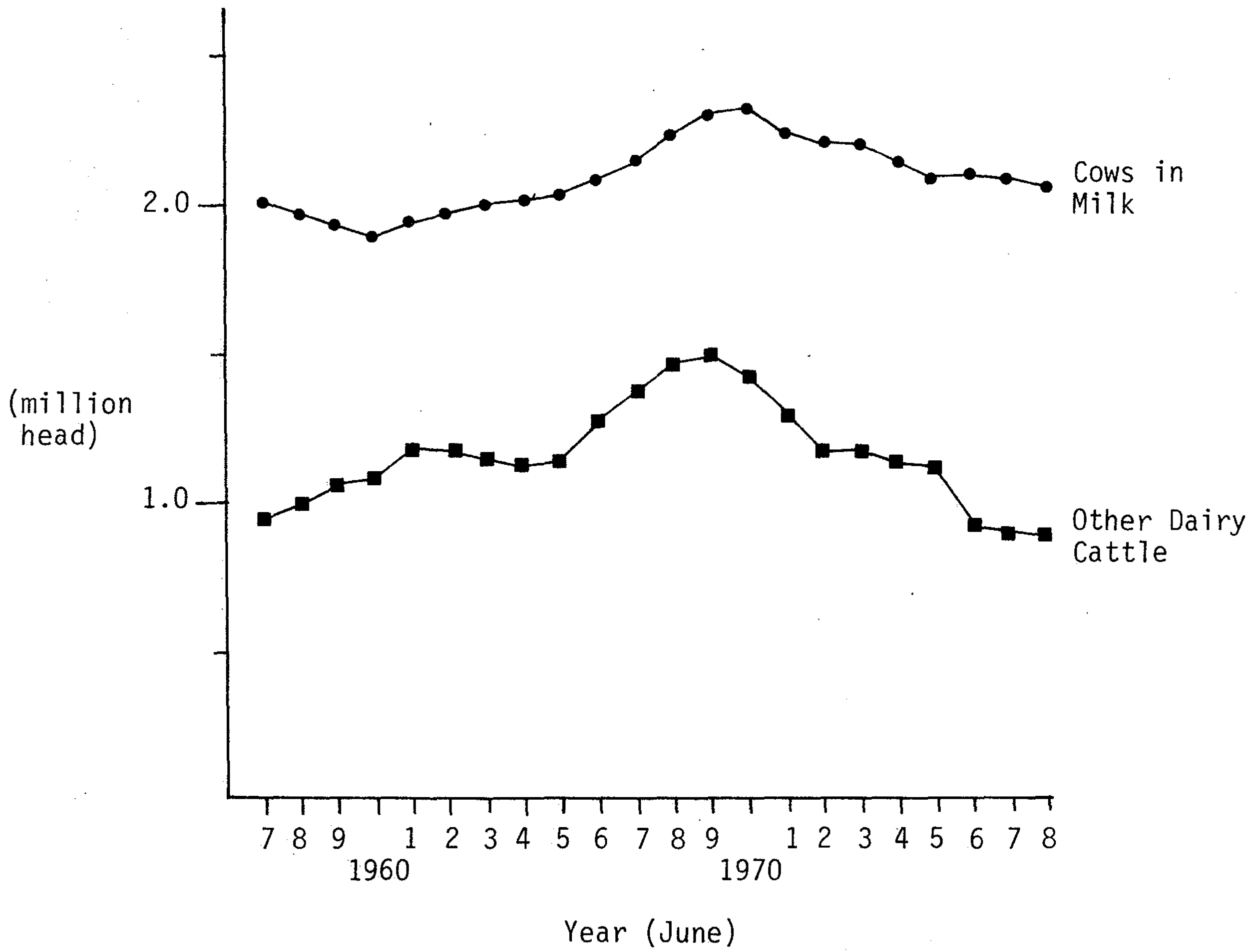
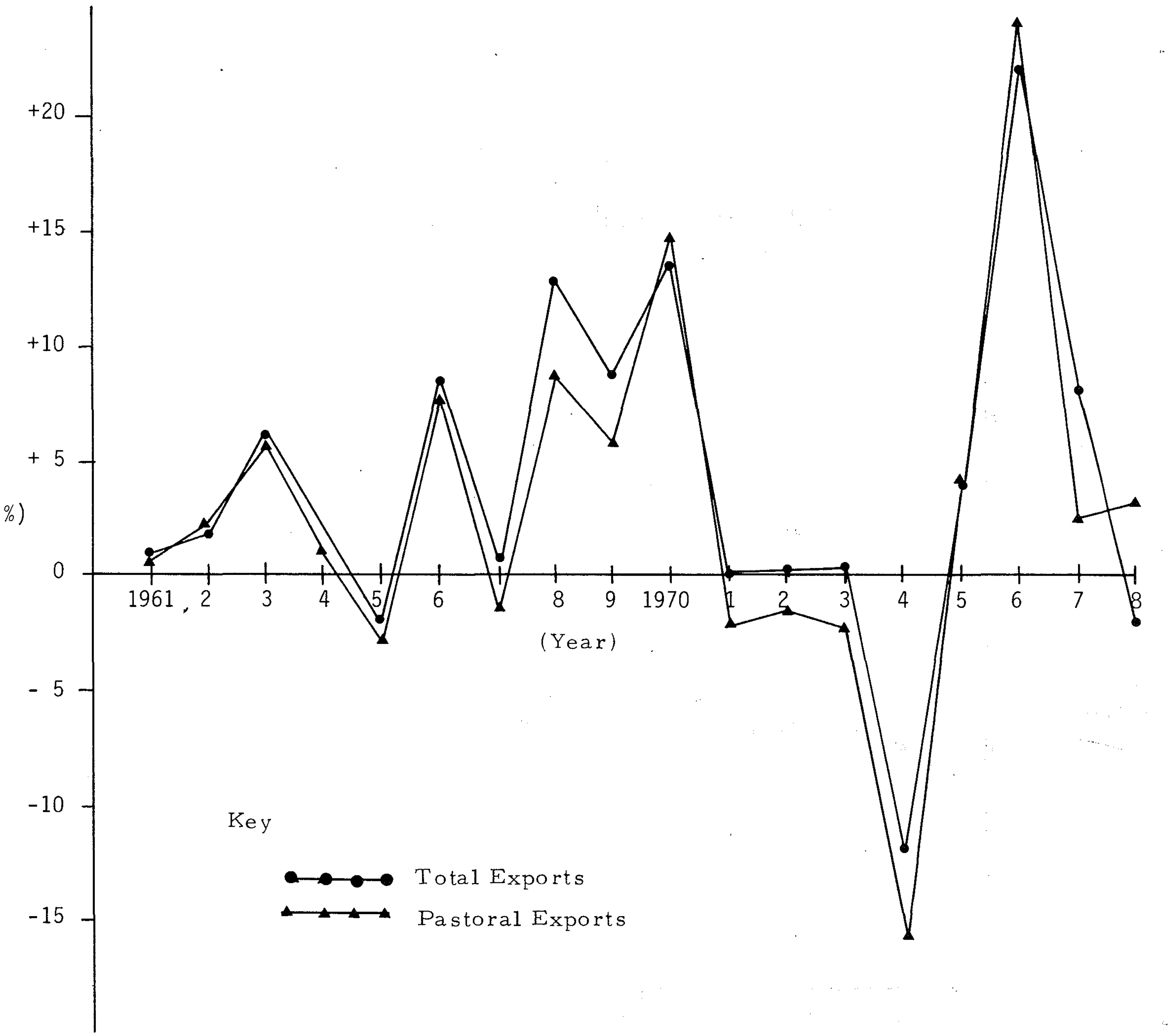


FIGURE 9

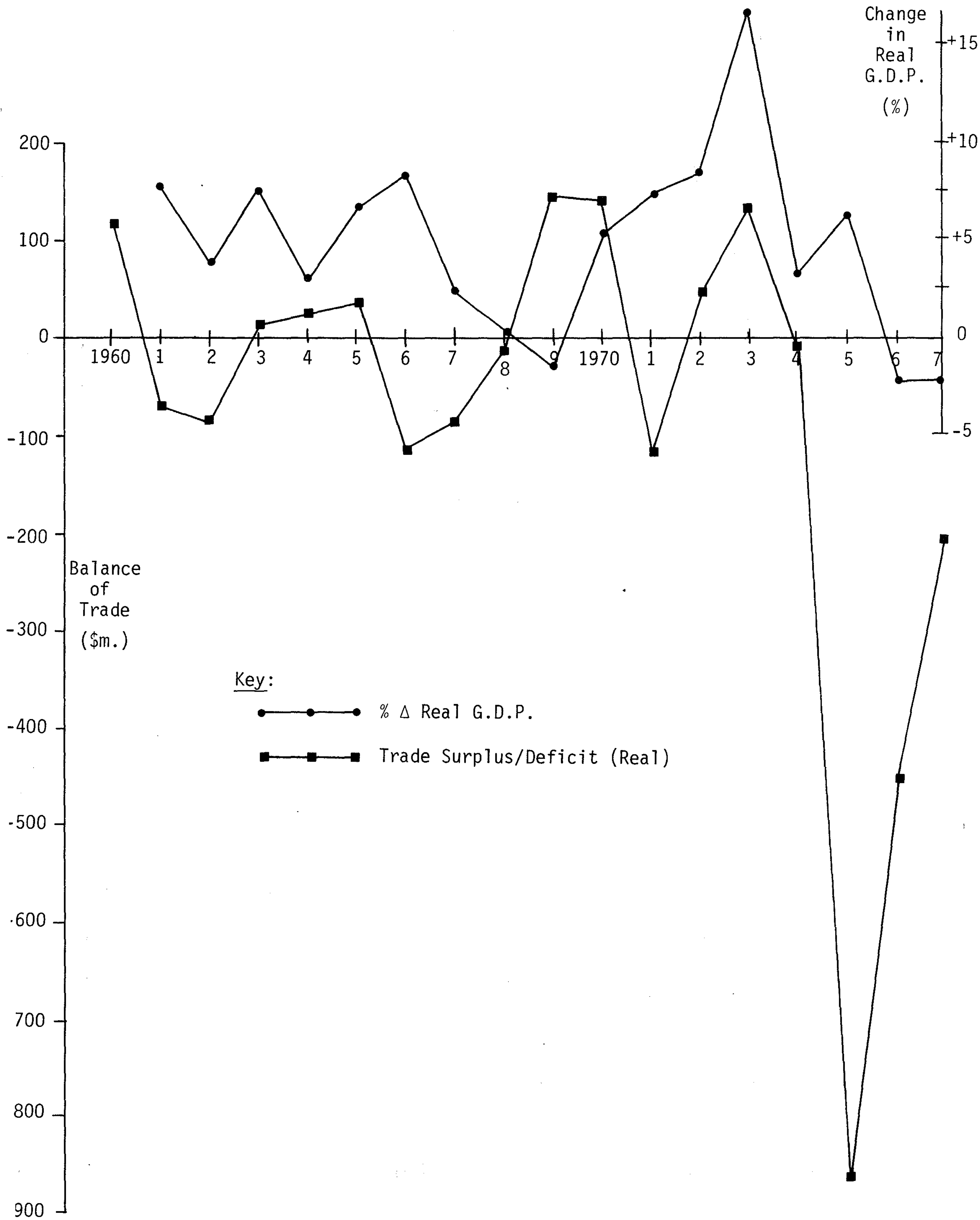
Growth Rates of Pastoral and Total Exports (%)



Source: Reserve Bank Bulletin

FIGURE 10

Balance of Trade ($m), Change in Real GDP (%)



Source: New Zealand Department of Statistics

result of the fluctuating rate of export growth, pastoral export receipts at the end of the 1970's are still at the same level as at the start of the decade. The table below summarises this (Table 1). As exports have not been growing consistently the tendency has been for New Zealand to incur trade deficits in recent years (see Figure 10). As New Zealand's G.N.P. growth depends upon the trade result, we would expect a close correlation between the trade deficit/surplus and economic growth. This is borne out by Figure 10. It would seem that the relationship is a lagged one, the lag being one period.

TABLE 1

Pastoral Export Receipts

Year	$m (real 1971 $)
1960	668.0
1970	1001.0
1978	1015.0

Source: Reserve Bank Bulletin

To conclude, it can be restated that the achievement of the agricultural sector's objectives will determine to a large extent the potential for achieving national objectives. Agricultural objectives of more stable prices and incomes, and output growth have not been achieved, even though the objective of market orientation has partly been achieved.

1.4 The Need for a Model of the Pastoral Livestock Sector

So far many of the problem areas and objectives of the pastoral livestock sector have been discussed. In particular three points can be reiterated:

(i) The cost of instability: The pastoral sector was seen as a destabilising sector in the New Zealand economy, bringing with it many costs of instability, both to the farming and the off-farm sectors.

(ii) The need for increased pastoral production: Many national objectives will only be achieved if the farming sector increases production available for export. The present trends in production are not facilitating the needed higher rate of economic growth.

(iii) The need for the pastoral sector to stay internationally competitive: To be able to respond to trends in overseas agricultural prices, the pastoral sector must remain market orientated. However, short term trends must be isolated from long term trends in order to stop misallocation of resources.

The following discussion identifies how the development of an explicit model of the pastoral livestock sector will contribute to the analysis and solution of sectoral problems and objectives discussed earlier.

(i) Structure Model building will enable the more explicit identification of the "pasture-to-market" production and marketing flows. The pastoral sector is large in size and complex in operation, so a model that describes internal and external linkages between price, supply and demand, and foreign trade and the domestic market will be valuable to individuals and institutions making decisions affecting agriculture. There is often a tendency for decision makers in a sector to develop their own 'notional'model of the structure and conduct of the sector, and especially that section of the sector which is of the most importance to themselves.

The development of a more formal model can provide a new and alternative framework for considering this structure which can allow the individuals to re-assess their own decision making framework.

(ii) Monitoring The model will be useful in monitoring the pastoral sector, with a view to protecting the industry's productive power. The model should be built around important indicators of the vitality of the sector, e.g.

(a) the flow of produce through to export.
(b) current trends in livestock numbers and their performance in relation to past and potential productivity.
(c) current and recent history of the movements in product prices, farm costs, farming incomes and investment.

A model built in such a way could be used as an early warning system, reducing the need for and possibility of ad hoc and hasty decision making. Not only would the model indicate potential weakness and problem areas within the industry, but it could also suggest or test potential solutions.

The need for such a model has been recognised for a number of years. In 1974 the Report of the Commission of Inquiry into the Meat Industry stated,

"... because of the lagged nature of the relationship of stock numbers to farm investment it is important for Government to be able to detect early warning signs and take remedial action if stock numbers in New Zealand are to be built up sufficiently to supply the earnings this country will need to sustain a high level of business and industrial activity and a steadily rising standard of living."

(paragraph 751)

Also in the same year, in an address to the Electoral Committee of the New Zealand Meat Producers' Board, Mr F. L. Ward, in relation to the input and production gap in farming, said that,

"... The farming industry can profit by a greater understanding at planning levels, of the effect of this production lag."

Perhaps the strongest supporter of a sectoral model came with the publication of the Zanetti Report in 1975 (Report of the Farm Incomes Advisory Committee), but so far nothing has been done to develop an aggregate model based on farming indicators, as the report suggested.

(iii) Decision Making A model will not only provide a valuable structure in which the pastoral livestock sector may be discussed ((i) above) and also be used as a tool for analysing trends and acting as a warning system (ii) above), but it will also encourage the development of rational decision making by co-ordinating policy making toward the achievement of targets. Setting targets and trying to forecast future livestock numbers or production seems to be a favourite past-time of planning organisations. Unfortunately, precisely how these targets are to be achieved, the justification for assumptions about growth rates, and the consistency and merits of various proposed policies are seldom explained or investigated very deeply. In doing so, the fact that the various objectives of economic policy are unlikely to be entirely compatible is concealed. Of the objectives listed in 1.2, there is an obvious conflict between stabilising prices paid to farmers, and maintaining the market-orientation of the agricultural sector. Understanding the behavioural relationships within the livestock sector will enable these types of conflicts to be more easily identified and acknowledged in decision making.

The National Development Conference (N.D.C.) in 1968 set target growth rates for agricultural production at 3 per cent per annum, but as Professor Philpott remarked at the Lincoln College Farming Conference in 1975, the achieved rate was 0 per cent (Philpott, 1975). In 1975 when the Commission of Inquiry into the Meat Industry asked for estimates of livestock numbers in ten years time, only the Ministry of Agriculture and Fisheries (M.A.F.) was prepared to hazard a guess (see Table 2).

The M.A.F. had also been involved in forecasting in 1972 through their involvement with the Agricultural Production Council (A.P.C.) of the N.D.C. The A.P.C. set up a Meat Forecasting Working Party which recommended as a priority the development of long term forecasting models by the M.A.F.

TABLE 2

M.A.F. Forecasts of Stock Numbers

(million head)

	1972-73	1983-84 Low	1983-84 Med.	1983-84 High
Total Ewe Equivalents	104	115	145	165
Total Sheep	61	63	80	100
Dairy Cows in Milk	2.2	2.0	2.5	3.0
Total Beef Cattle	5.6	8.5	10.6	12.0

Source: Report of the Commission of Inquiry into the Meat Industry (1975).

The forecasts would be short term (1 year) and long term (10 year time scale with reviews every three years), and used for long term planning. Nothing seems to have been done about the recommendation as far as model building, although forecasts were made using the combined wisdom of the M.A.F. advisory officers.

The latest effort in establishing targets and forecasting has been made by the New Zealand Planning Council (N.Z.P.C.), who claim that a three per cent per annum real growth rate in G.N.P. is necessary for New Zealand.[1] The target will be achieved if "the economy is made more efficient" and "the government takes action on vital issues confronting New Zealand" (e.g. tax reform, employment, etc.). They allow for a real growth rate in

[1] Since this report was written the AGROW campaign was initiated. Given two growth rates, a continuation of current growth and an 'optimistic' growth rate, export receipts from agriculture are expected to rise by either 29 per cent or 51 per cent by 1989/90 compared with 1979/80. Such estimates are probably reflections of industry aspirations rather than any rigorous analysis.

traditional exports (mainly pastoral) of 2 per cent per annum in calculating their three per cent G.N.P. growth rate. Two questions arise, can this growth rate be achieved and is a higher rate of growth possible?

The above discussion has briefly outlined the need for, and the value of developing an econometric model of the New Zealand livestock sector. The following sections of this paper outline and estimate such a model.

SECTION 2

THEORETICAL MODEL OF THE PASTORAL LIVESTOCK SECTOR

2.1 Introduction

It has been shown that a model formulated in terms of the important indicators in the livestock sector would be useful, both descriptively, and for decision making centred around national and sectoral objectives. Previous models of the pastoral livestock sector have been attempted, but usually only in terms of aggregate stock numbers (Woodford and Woods, 1978) or in terms of one class of stock (Rayner, 1968). Another livestock numbers model (Rowe, 1956) dealt with economic factors only and assumed climatic factors were unimportant.

The pastoral livestock sector has been defined in terms of sheep, beef cattle and dairy cattle populations, and so comprises the bulk of New Zealand's traditional primary production sector. In modelling this sector from 'pasture-to-market', account should be taken of variables such as stock numbers, production, consumption, exports, stocks, overseas prices, schedule prices, retail prices, and farmers' incomes and investment decisions. In the theoretical model at least, all these can be described as endogenous variables, or variables whose values are determined within the model. The choice of exogenous variables, or variables determined independently of the model, is wide and can include variables such as costs, foreign exchange rates, population, national income, weather (climatic influences) and government policy. The choice of what is endogenous or exogenous is necessarily an arbitrary one. For example, government policy could easily be thought of as an endogenous variable, dependent on the performance of the livestock sector.

Having identified the need for a model and having described its principal components, it would be useful, in discussing the theoretical specification of the model, to take a diagrammatical preview of the model's structure. Figure 11 presents a schematic representation of the model and its major components.

The variables which are encircled represent what are considered to be the major endogenous variables within the sector. The remaining variables and the arrows indicate the direction of causality in the model. It can be seen that the major exogenous influence on the sector is assumed to be the export prices for the major commodities. These influence the supply side of the sector through the farmers' price expectations and hence the level of output in later periods. On the demand side the export prices are important in determining the local retail prices because local uses must compete with export uses for the product. These supply and demand effects then work through the sector to determine the export availability which is a residual (assuming exogenous stocks) from the production and local consumption decisions.

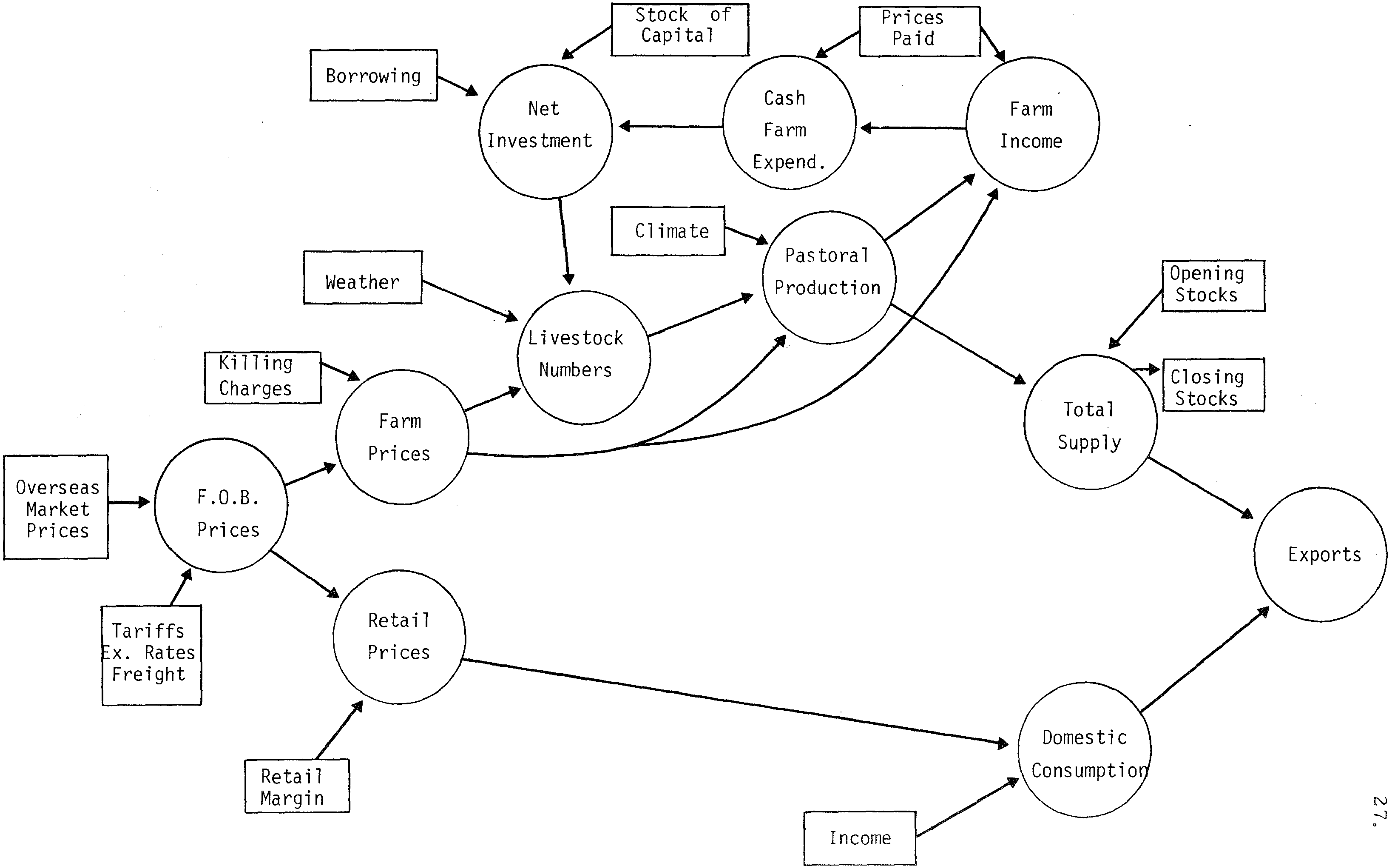
Given this very general outline the model can be discussed conveniently under the following six headings:

(i) Prices.
(ii) Stock numbers.
(iii) Production and stocks (supply).
(iv) Consumption (demand).
(v) Exports.
(vi) Investment.

A special note will also be made about the role of government policy in the model.

FIGURE 11

Overview of Theoretical Model



2.2 Prices

In general, it can be assumed that the price reigning in an overseas market is not influenced by New Zealand's available supply of exports. This would be especially true for beef, mutton and dairy products, although perhaps less true for lamb and wool, e.g. Meatmark intervention by the Meat Board in the U.K. lamb market, and Wool Board intervention in local auction markets. However, we will assume that overseas market prices are a function of internal market forces operating in that country and in other importing or exporting countries. The c.i.f. overseas price facing New Zealand is the overseas market price, adjusted for market subsidies or taxes, and border tariffs and levies. The overseas price expressed f.o.b. in New Zealand currency is determined by insurance and freight costs, and the exchange rate.

The price actually received by New Zealand farmers (schedule price for meat, guaranteed price for dairy farmers) is the f.o.b. New Zealand price adjusted for processing of the product, internal cartage, port handling, and sometimes government (or producer board) policy, e.g. price stabilisation schemes, production guidance by altering the 'proper' schedule price, or 'evening' of returns from different products.

Prices paid to farmers generally set the price New Zealand processors, wholesalers and consumers must pay for products similar to, or derived from, exported products. The consumer price is related to the farmers' price through processing, transport and marketing costs (including mark-up), plus the effect of government policy, e.g. subsidies and price control. Also, at the retail level, the price of one product is influenced by its relative price in comparison to complementary or competitive goods. Retailers often engage in price averaging over time in order to smooth the retail price they offer; however, in an annual model less evidence of this is expected.

To summarise,

$$p^{os} = f_1 \text{ (Overseas Market Forces)}$$

$$p^{os}_{cif} = f_2 \text{ (}P^{os}\text{, Tariffs, Market Subsidies/Sales Taxes)}$$

$$p^{NZ}_{fob} = f_3 \text{ (}p^{os}_{cif}\text{, Exchange Rate, Insurance, Freight)}$$

$$p^{NZ}_{Sch} = f_4 \text{ (}p^{NZ}_{fob}\text{, Costs, Policy)}$$

$$P_R = f_5 \text{ (}P^{NZ}_{Sch}\text{, Marketing Margin, PC, Policy).}$$

where p^{os} = overseas market price in foreign currency

p^{os}_{cif} = overseas market price in foreign currency c.i.f.

P^{NZ}_{fob} = overseas price expressed f.o.b. New Zealand.

P^{NZ}_{Sch} = prices paid to farmers

P_R = Retail prices

PC = Prices of competitive or complementary goods.

2.3 Stock Numbers

The pastoral livestock sector comprises three major groupings of stock: sheep, beef cattle and dairy cattle. Within each group the stock can be further subdivided into breeding stock and non-breeding stock, although for dairy cattle the subdivision is better described as "cows in milk" and "other dairy cattle". Because of the availability of data, the sheep flock can be subdivided into "breeding ewes", "ewe hoggets" and "other sheep".

2.3.1 Theoretical Framework

For estimation purposes, the stock number equations will be estimated with the dependent variable being the change in livestock numbers between years rather than the absolute level of stock numbers in each year. This is done in order to explain the annual change in stock numbers in terms of an adjustment model (Labys, p.39). The assumption behind the adjustment form of the estimations is that for any period, producers have a desired level of livestock numbers. Mathematically,

$$q_t^* = a_0 + a_1 p_t^* + a_2 z_t \qquad (1)$$

where q_t^* = desired level of livestock numbers

p_t^* = expected future return from livestock

t = current time period

z_t = other variables

a_0, a_1, a_2 = parameters

By assuming that stock numbers cannot change immediately in response to new economic conditions so as to reach the desired level for the period, dynamic adjustment is introduced. The actual change in stock numbers is only a fraction (δ) of the desired adjustment required to reach planned livestock levels (q_t^*).

i.e. $q_t - q_{t-1} = \delta (q_t^* - q_{t-1})$ (2)

q_t^* is not directly observable (being an expectation) and so must be eliminated from (2) for the equation to be estimated. This can be done by substituting (1) into (2).

$$q_t - q_{t-1} = \delta (a_0 + a_1 p_t^* + a_2 z_t - q_{t-1}) \qquad (3)$$

$$q_t - q_{t-1} = \delta a_o + \delta a_1 p_t^* + \delta a_2 z_t - \delta q_{t-1}$$

p_t^* is also unobservable and so must be removed by making further assumptions about how the farmer forms his price expectations. In this model, we have assumed that price expectations are formed by the two most recent pieces of price information available to the farmer at the time when decisions about livestock numbers are being made. Most decisions about livestock numbers on sheep and beef farms are made over the summer and into the autumn, as it is at these times when breeding decisions must be made. Therefore, for sheep and beef farmers we have assumed the relevant prices to be current and one year lagged prices. (Although the current price is a June year price, most of the current year's price information will be known when decisions are made for breeding.) For dairy farmers, the relevant prices are one and two year lagged prices, the difference being due to the way in which dairy cattle statistics are collected (see 2.3.3).

The adjustment model can therefore be stated as:

$$q_t - q_{t-1} = \delta a_0 + \delta a_1 p_t + \delta a_2 z_t - \delta q_{t-1}$$

2.3.2 The Adjustment Model and Non-Breeding Stock

The applicability of the adjustment model to the breeding and milking stock has been justified on the assumption that farmers have a desired breeding stock level, to which the present level of breeding stock numbers is adjusted.

It is assumed in this model that the desired level of non-breeding stock is determined as a consequence of decisions made in the breeding herd. Given that the farmer has decided on the level of breeding stock he desires to carry, he must then adjust the level of replacement breeding stock in order to ensure the availability of replacements to maintain his breeding stock. Other categories of stock must also be adjusted as a consequence of breeding decisions, so that the farm's "stock portfolio" is balanced at desired and consistent levels. Thus, the adjustment model can be justified for non-breeding stock by assuming that the actual change in non-breeding animals is only some fraction of the desired change that would be consistent with decisions made in the breeding stock. This implies that the partial adjustment mechanism which operates at the breeding stock level will also apply to non-breeding stock although possibly in a different manner.

2.3.3 Beef Cattle Numbers

The specification of the beef cattle equations will, to a large extent, reflect the biological and managerial principles that underlie changes in stock numbers.

Stock sales and routine culling from the herd because of age, infertility or sickness, plus the usual proportion of on-farm deaths means that the herd in one period is some proportion of the herd in the previous period:

$$KB_t = \gamma KB_{t-1}$$

$$KOB_t = \alpha KOB_{t-1}$$

where KB_t = current numbers of breeding cattle

KOB_t = current numbers of other cattle

and γ, α = total retention.

The components of the beef cattle herd are related to each other quite closely. The breeding herd's offspring supply the replacements for the 'other beef' herd, and the 'other beef' herd supply replacement breeding stock for the breeding herd. Thus, the current level of breeding stock determines to some extent the future level of 'other beef' and vice versa, i.e.

$$KB_t = \delta KOB_{t-1}$$

$$KOB_t = \beta KB_{t-1}$$

where δ and β represent some long term replacement rate.

The equations are being estimated in difference form, so the relevant variables are DKB_t and $DKOB_t$ (the change in beef breeding cows: $DKB_t = KB_t - KB_{t-1}$, and the change in 'other beef' cattle: $DKOB_t = KOB_t - KOB_{t-1}$). The change in 'other beef' cattle is the net effect of the level of 'other beef' in the previous period potentially available to be retained (or lost to the breeding herd) and the numbers of breeding animals in the previous period, reflecting the potential number of available replacement stock to enter into the 'other beef' herd. Also, the actual change in breeding cow numbers will be important, as it describes the change in demand for replacements in the current period. In other words, the actual change in the 'other beef' herd is also a function of the adjustment in the breeding herd to the desired breeding herd size. Therefore, when the change in breeding herd numbers is negative, less demand for replacement stock exists. As Figure 12 shows, changes in breeding herd numbers tend to be magnified in the 'other beef' herd as it adjusts to levels that will enable it to supply the breeding herd with a stable supply of replacements. For example, big increases in the breeding herd lead to even greater increases in 'other beef' as more young stock are retained to make up for the current and future demand for replacements from the breeding herd.

To summarise,

$$DKOB_t = f\,(DKB_t,\ KB_{t-1},\ KOB_{t-1}).$$

For similar reasons, the change in the breeding herd is a function of the numbers of breeding stock and the numbers of 'other beef' in the previous period; however, the breeding herd change is not determined by the current change in 'other beef' numbers. The direction of causality, as has been explained, is the other way round. It is assumed that farmers make adjustment decisions based on their desired levels of breeding stock, and that adjustments in the 'other beef' herd flow from that decision.

The change in 'other beef' can be included in the equation, but in a lagged form. Using this specification, $DKOB_{t-1}$ can be said to represent the changing potential of the replacement herd to satisfy potential changes in demand for replacements by the breeding herd, e.g. if 'other beef' fell in the current period, they would be less able to satisfy an increased demand for replacements in the future. This would occur if the breeding herd was being maintained by retaining older cows which are usually culled, while at the same time less young stock were being retained for future admission to the breeding herd.

Therefore,

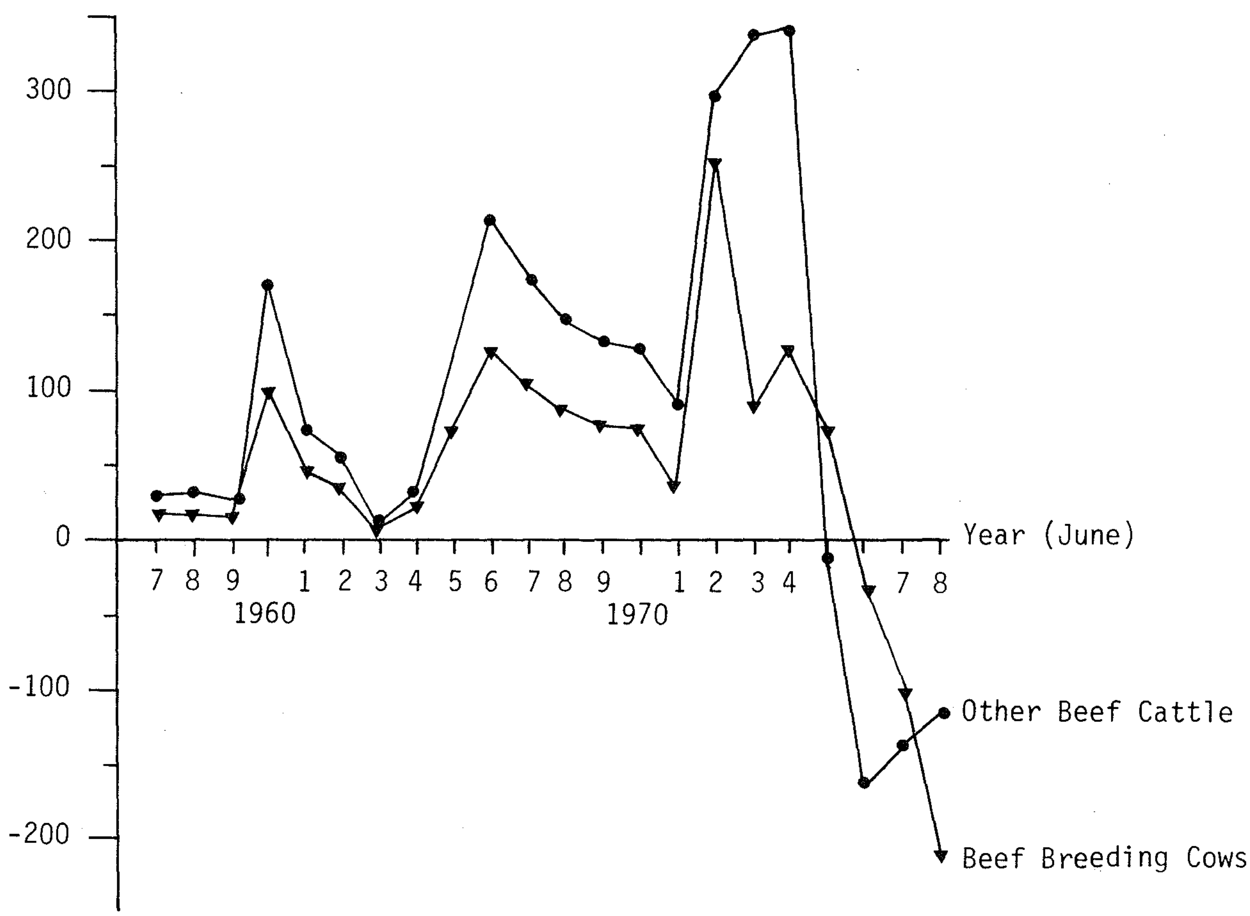
$$DKB_t = f\,(DKOB_{t-1},\ KB_{t-1},\ KOB_{t-1}).$$

Changes in beef cattle numbers will also be influenced by prices paid to farmers for prime and manufacturing beef. Prime beef prices can be assumed to represent the future returns from breeding and potential breeding stock, whereas manufacturing beef prices can represent a 'salvage' value to the producer for the immediate slaughter of breeding stock. Returns from competitive enterprises can be represented by an aggregate sheep price, representing returns from mutton, lamb and wool. Risk can be included in the specification of the equation through a variable (representing) reflecting the variance in returns to the beef enterprise. For this model, a three period moving standard deviation of schedule beef prices was calculated to represent risk.

The effect of climatic changes on cattle numbers can be represented by the annual number of days of soil moisture deficit. Soil moisture deficit reflects a level of moisture in the soil that inhibits grass growth. The level of investment on sheep farms, both current and past, will presumably affect the potential level of both breeding and non-breeding stock and hence is included in each of the estimated functions.

FIGURE 12

Change in Beef Cattle Numbers ('000 head), 1957-1978



Source: New Zealand Department of Statistics

Finally, the effects of government policy can be assessed through the use of a dummy variable. Two government policies can be assessed in the livestock number equations through dummy variables. Firstly, the Livestock Incentive Grants of 1972, and secondly, the Livestock Incentive Scheme of 1976. The effects of the second scheme were noticed in 1977 and 1978, while the first scheme, because of its nature as a grant, saw an immediate response (see Figures 6 and 7).

The specifications of the beef cattle equations are therefore:

$$DKB_t = f_1\,(KB_{t-1}, KOB_{t-1}, DKOB_{t-1}, PPB_t, PPB_{t-1}, VPB_t, PMB_t, PSS_t, PSS_{t-1}, WB_t, SBINV, GIS)$$

$$DKOB = f_2\,(KOB_{t-1}, KB_{t-1}, DKB_t, PPB_t, PPB_{t-1}, VPB_t, PMB_t, PSS_t, PSS_{t-1}, WB_t, SBINV, GIS).$$

where PPB, PMB = schedule price of prime and manufacturing beef

VPB = 3 period moving standard deviation of an aggregate beef price (PB), made up of a combination of the prime and manufacturing schedule prices, weighted by production of prime and manufacturing beef in total beef production.

WB = days of soil moisture deficit (weighted by geographic location of beef cattle population).

SBINV = investment in the sheep and beef sector (lagged two years).

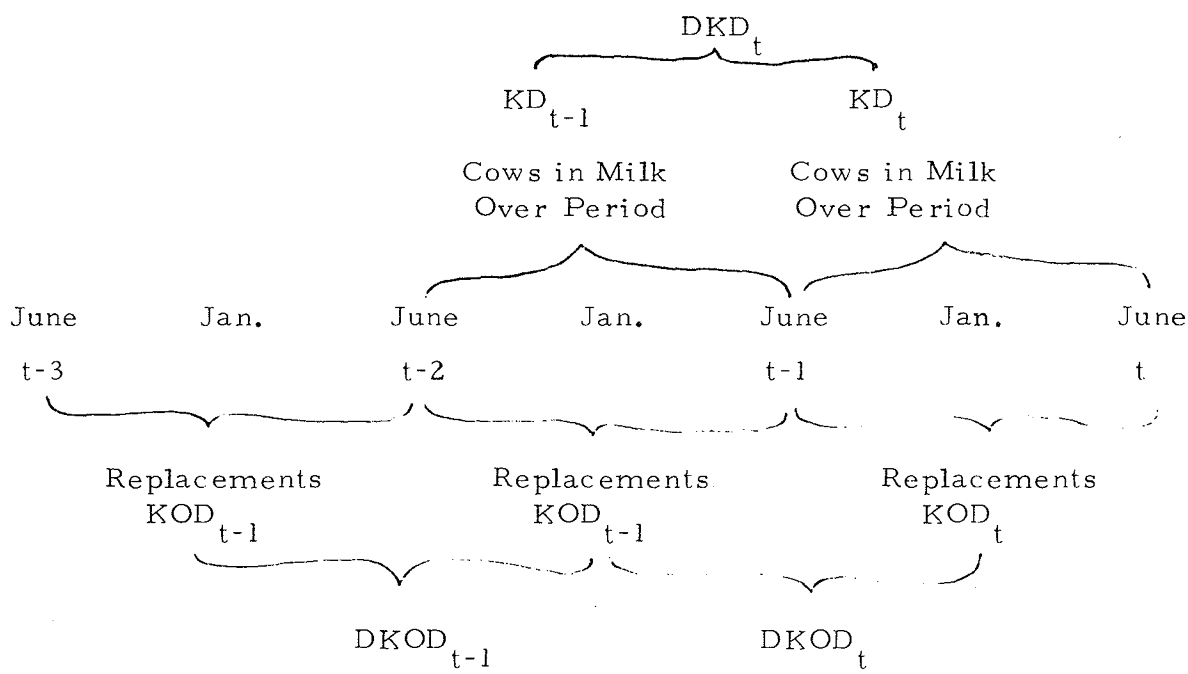
GIS = government intervention in the sheep and beef sector.

PSS = an aggregate sheep return, based on wool, lamb, and mutton prices.

2.3.4 Dairy Cattle

Under the definition used by the Department of Statistics, the category "dairy cows in milk" (KD) accounts for all dairy cows which are in milk at any time between 1 July and 30 June, although the survey is carried out in January. "Other dairy cattle" (KOD) comprise mainly dairy heifers (85%, see Appendix I). Dairy cattle intended for beef are included under 'other beef'. The method of collection of data influences the lags put on some variables in the two dairy cattle equations, although the actual specification of the equations are of a similar format to the beef cattle equations.

The following simple diagram will help explain the lags involved in the specification of the equations and the timing of the surveys:



DKD_t represents the change in the number of dairy cows that will be milked at any time in the current year from those milked at any time in the previous year. The fact that a cow will be milking in the current year is a consequence of decisions made atmating in the previous year. Therefore DKD_t is influenced by the number of replacements available during the previous year, and also the change in the number of available replacements in the previous year, as it is this trend in available replacements that will spill over into the current milking herd.

$$DKD_t = f(DKOD_{t-1}, KD_{t-1}, KOD_{t-1})$$

where DKD_t = change in the number of milking animals ($KD_t - KD_{t-1}$)

KD_t = number of milking cows

KOD_t = number of 'other dairy' cows

KD_{t-1} is included in the equation to represent the annual wastage rate of milking cows.

$DKOD_t$ is determined by the number of cows mated in the previous period[2], the number of replacements in the previous period (only a certain proportion move into the milking herd), and the change in the number of milking cows, as this reflects the changing demand forheifers when mating decisions were made in the previous period. This change in demand is only known when the number of cows coming into milk in the current period is known.

Therefore,

$$DKOD_t = f(DKD_t, KOD_{t-1}, KD_t)$$

As for the beef equations, prices, risk, climate, investment and government policy variables will also be important.

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2 Only known whenthe number of cows coming into milk in the current period is known.

To summarise:

$$DKD_t = f(DKOD_{t-1}, KD_{t-1}, PDD_t . PDD_{t-1}, VPD_{t-1}, PMB_{t-1}, WD_{t-1}, DINV, GIS)$$

$$DKOD_t = f(DKD_t, KOD_{t-1}, KD_t, PDD_t, PDD_{t-1}, VPD_t, WD_t, DINV, GIS).$$

where:

PDD = milkfat payout

VPD = three period moving standard deviation of the total milkfat price

PMB = manufacturing beef schedule price

WD = days of soil moisture deficit weighted by dairy cattle population

DINV = investment on dairy farms (lagged two years)

GIS = government intervention.

Note the lags on the price in the equation, reflecting the information the farmer has at the time when the decision to mate is made.

2.3.5 Sheep Flock Numbers

The three sheep flock equations will have similar specifications as in the beef equations except the relevant price data will be different. Once again the basis for the specifications is to assume that it is the size of the breeding ewe flock and adjustments to its desired size that determine adjustments in hogget and 'other sheep' populations.

The equation specifications are:

$$DKE_t = f(KE_{t-1}, KHGT_{t-1}, DKHGT_{t-1}, PSS_t, PSS_{t-1}, VPSS_t, PB_t, PB_{t-1}, WS_t, SBINV, GIS).$$

where:

DKE = change in breeding ewe numbers ($KE_t - KE_{t-1}$)

KE = number of breeding ewes

KHGT = number of ewe hoggets

DKHGT = change in the number of ewe hoggets

PSS = an aggregate sheep return, based on wool, lamb, and mutton returns

VPSS = three period moving standard deviation of PSS

PB = an aggregate beef price, based onprime and manufacturing beef schedules

WS = days of soil moisture deficit, weighted by sheep population

SBINV = investment in the sheep and beef sector

GIS = government intervention.

$$DKHGT_t = f(KHGT_{t-1}, KE_{t-1}, DKE_t, PSS_t, PSS_{t-1}, PLS_t, PB_t, PB_{t-1}, VPSS_t, WS_t, SBINV, GIS).$$

where PLS = schedule lamb price, representing in this case the option to slaughter the ewe hogget as a lamb.

In this function it should be noted that the variable PSS is included to represent the potential future returns from a ewe hogget.

$$DKOS_t = f(KOS_{t-1}, KE_{t-1}, DKE_t, PWS_t, PWS_{t-1}, PLS_t, VPSS_t, PPB_t, PPB_{t-1}, WS_t, SBINV, GIS).$$

where:

PWS = average wool auction price, representing the future returns from non-breeding animals.

DKOS = change in 'other sheep' numbers ($KOS_t - KOS_{t-1}$)

KOS = numbers of 'other sheep'

PPB = schedule price of prime beef, representing the competition between young beef cattle and young wethers.

In this function PLS represents the option to slaughter the wether hoggets which are included in KOS_t as lambs.

2.4 Production and Stocks

An objective of the model is to incorporate the major products that originate from the pastoral livestock sector into the model framework. The major products from the sector are prime and manufacturing beef, milkfat, mutton, lamb and wool. Total supply is the sum of opening stocks and production (assuming no imports). Stocks are assumed to be exogenous.

The equation specifications for prime beef, manufacturing beef and mutton production should be fairly similar, as each results from the slaughtering of one or more categories of stock previously accounted for in the livestock number equations. Thus the amount of these meats produced will be determined largely by the number of potential stock available for slaughtering at the start of the period and the actual change in the number of stock over the period. The flow of meat production from these sectors can be considered to be made up of two components. The first is a 'culling' effect which represents the normal slaughter of mature stock. This effect is a function of the absolute number of stock. The second effect results from the desire of the producer to change the level of stock numbers. This effect is thus a function of the change in livestock numbers over the particular year. As in the stock number equations, price expectations and climatic factors are included in the specifications, as well as the variable investment, to represent the effect of investment not only on stock numbers, but also on per head production.

Therefore a general equation would be:

Quantity of Meat = (Livestock numbers in period t-1, Change in livestock numbers in period t, Price expectations for enterprise and competitive enterprises, Investment, Climate.)

More specifically,

$$QPB_t = f(DKOB_t, KOB_{t-1}, PPB_t, PPB_{t-1}, WB_t, PLS_t, SBINV).$$

where QPB = quantity of prime beef produced ('000 t).

$$QMB_t = f(KBBB_{t-1}, DKBB_t, KD_{t-1}, PPB_t, PPB_{t-1}, PMB_t, PSS_t, PDD_{t-1}, PDD_t, PDD_{t-1}, WB_t, SBINV).$$

where:

QMB = quantity of manufacturing beef produced ('000 t)

KBBB = KB + KOB

DKBB = DKB + DKOB

$$QM_t = f(KE_{t-1}, DKE_t, KOS_{t-1}, PSS_t, PSS_{t-1}, PPB_t, PPB_{t-1}, WS_t, SBINV).$$

where QM = quantity of mutton produced ('000 t).

Products such as milkfat, wool and lamb have a different form of response, however, as they represent an annual 'crop' from dairy cattle, sheep and breeding ewes respectively. They are mainly dependent on the number of animals at the start of the period, plus price expectations, investment and climate.

$$QL_t = f(KE_{t-1}, KOS_{t-1}, PLS_t, PMS_t, PMS_{t-1}, PWS_t, PWS_{t-1}, WS, SBINV).$$

where QL = quantity of lamb produced ('000 t)

PMS = mutton schedule price

KOS_{t-1} is included in the equation as some of last season's lambs are always held over and slaughtered late in the season (as shown by slaughter statistics). Although hardly a lamb at almost a year old it would seem that statistically some are classified as lambs.

It should be noted that mutton and wool schedule prices are included to represent future returns from lambs, compared to PLS, the present return from immediate slaughter.

$$QMLK_t = f(KD_t, KOD_{t-1}, PDD_t, PMB_t, WD_t, DINV)$$

where:

QMLK = quantity of milkfat produced ('000 t)

In this equation KOD_{t-1} will be used to represent the number of young stock coming into the milking herd. A high number of young stock in the herd would lower average productivity in the herd.

Current dairy and manufacturing beef prices have been included in the specifications under the assumption that low current milkfat payments could lead to earlier drying off of the herd, as could high beef prices.

$$QW_t = f(KE_{t-1}, KHGT_{t-1}, KOS_{t-1}, WS_t, SBINV, PWS_t, PMS_t, PLS_t)$$

where QW = quantity of wool produced ('000 t).

2.5 Consumption

2.5.1 Domestic Consumption

Consumer demand theory explains commodity demand in terms of a static relationship. Demand is a function of the price of the commodity, the prices of substitutes and complementary goods, and income. In order to include a dynamic element into the demand equations in this model, a one period lagged demand is incorporated into the equation specification in order to take account of habit formation, i.e. changes in demand in response to price changes is not instantaneous. Both Nerlove and Koyk (Labys, 1973) derive similar specifications in order to make allowances for differences in short and long-run demand adjustments towards some long run equilibrium.

The estimated equation is of the general form:

$$c_{it} = \delta a_0 + (1 - \delta)c_{it-1} + \delta a_i y_t + \delta a_2 p_{it} + \delta a_3 p_{jt} + u_t$$

where c_{it} = consumption of good i in period t.

y_t = income in period t.

p_{it} = price of good i in period t.

p_{jt} = prices of complementary and competitive goods in period t.

u_t = random error term.

a_0, a_1, a_2, a_3 = coefficients.

δ = adjustment coefficient.

In this model, four consumption equations will be estimated, being per capita consumption of beef and veal, mutton, lamb and pork. Pork is included as it is of considerable importance in total meat consumption (see Figure 13).

The specifications of these equations will be as follows:

$CBV_t = f(PCY_t, PRBP_t, PRM_t, PRP_t, CBV_{t-1})$

$CM_t = f(PCY_t, PRBP_t, PRM_t, PRP_t, CM_{t-1})$

$CL_t = f(PCY_t, PRBP_t, PRM_t, PRP_t, CL_{t-1})$

$CP_t = f(PCY_t, PRBP_t, PRM_t, PRP_t, CP_t)$.

where:

CBV_t = per capita consumption of beef and veal (kg).

CM_t = per capita consumption of mutton (kg).

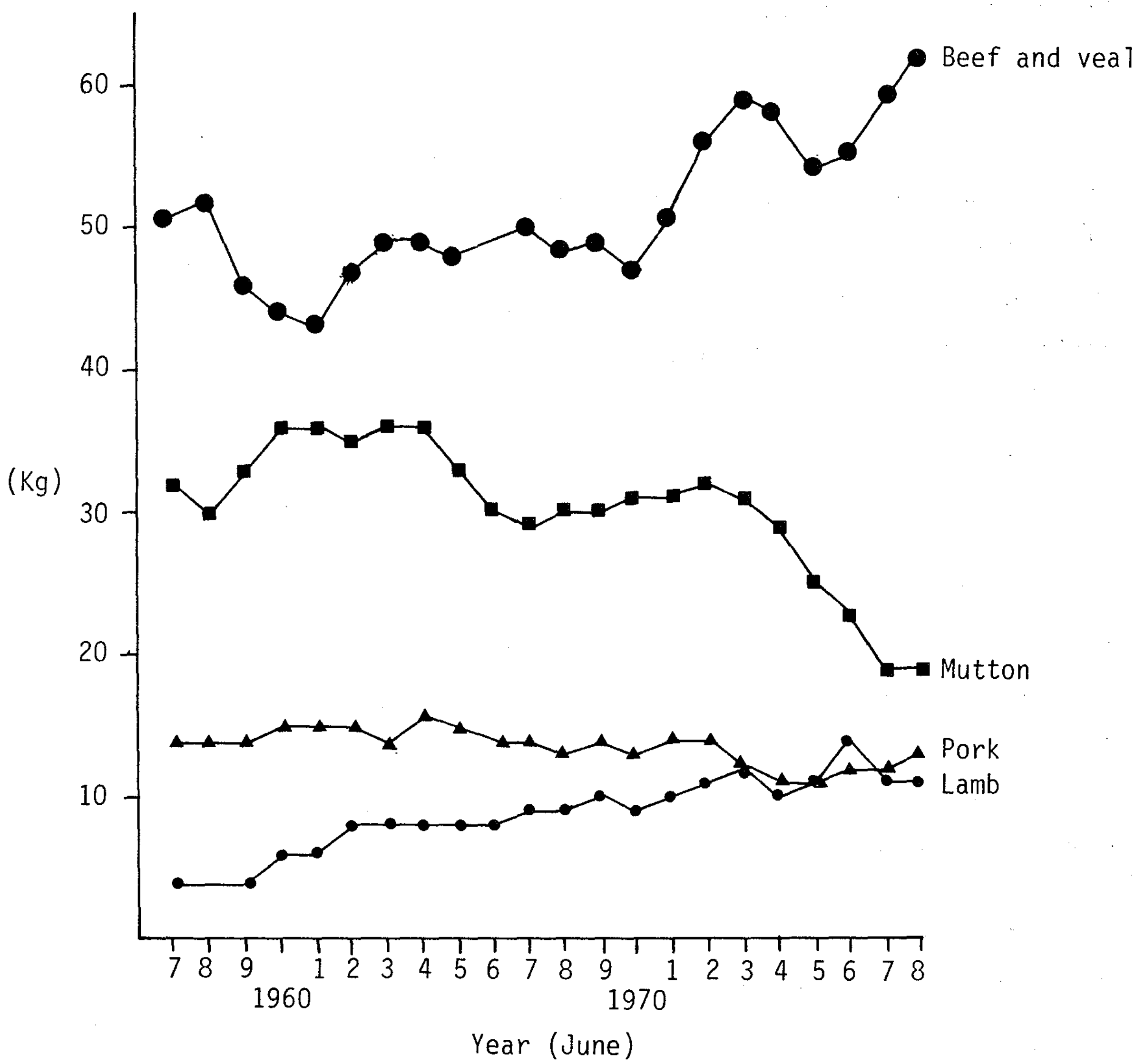
CL_t = per capita consumption of lamb (kg)

CP_t = per capita consumption of pork (kg).

PCY_t = per capita income ($).

FIGURE 13

Per Capita Consumption of Beef, Mutton, Lamb, and Pork (kilograms), 1957-1978



Source: New Zealand Department of Statistics

PRM = retail price of mutton.

PRBP = retail price of beef.

PRP = retail price of pork.

It should be noted that no lamb retail price is available to be included in the model. However, the mutton price (actually a hogget price) will be useful in accounting for lamb price movements.

At this stage of model development local consumption functions have not been estimated for products such as wool and dairy products. The complexity of the local demand structure for these products would introduce unnecessary complications at this stage, but it is envisaged that they would be incorporated in later versions of the model.

2.5.2 Exports

As can be seen from Figure 11, exports are considered to be a residual item. Although most of the pastoral production is exported, New Zealand consumers are able to buy as much as they want at the ruling market price. Also, as noted before, available exports from New Zealand do not influence overseas market prices significantly.

Therefore, the equation that links stocks, production, domestic consumption and exports is the identity:

EXPORTS = OPENING STOCK + PRODUCTION - CONSUMPTION - CLOSING STOCKS.

2.6 Investment

The role of investment in farming has been identified by many writers as an important determinant of stock numbers and agricultural output (see Walsh, 1979; Ward, 1974; Davison, 1976; Taylor, 1979; Woodford and Woods, 1979; Johnson, 1978).

One of the problems that arises when discussing investment is the difficulty in defining what constitutes investment. Obviously, net investment on capital goods, comprising net capital expenditure on land, buildings, plant and livestock should be classed as investment.

However, current working expenditure on farms also has an element of investment in it if it adds to the future productivity of the farm. This is especially true of inputs such as fertiliser, lime, animal health expenditure, sprays, fencing and repairs and maintenance, which are often counted as current working expenses when in fact they are, to at least some degree, development expenses. Also, it has been noted by Walsh (1979) that of total current working expenditure, the most variable proportion are those development type expenses, which have the ability to increase production through improved livestock performance. Taylor (1979) notes that for a given percentage change in gross income, fertiliser and repairs and maintenance expenditures change to a greater degree than total expenditure. Thus this category of development expense is clearly dependent upon income.

Johnson (1978) has shown that of expenditure on capital goods, expenditure on land and buildings is reasonably stable, but plant and livestock expenditure is more variable. Expenditure on plant seems to exhibit evidence of the effects of a cycle, with periods of little investment followed by periods of high investment as old plant wears out or becomes obsolete. Therefore, we can say that for net capital expenditure on land, buildings and plant, the important determinant would be the level of capital stock already available, the rate of technological change, and of course, farmer incomes. (Johnson (1978) estimates that 86 per cent of farming expenditure is financed out of current income).

We have seen that actual farm investment is made up of capital expenditures and working expenditures, and that most of investment is financed out of current incomes. Farm incomes are primarily determined by production, prices, costs and government policy (e.g. tax policy, income equalisation schemes). The remaining investment money must be borrowed. Mathematically, the discussion can be summarised in the following form:

Farm Incomes	= f(Output, Terms of Exchange, Policy)
Cash Farm Expenditure	= f(Farm Incomes, Stock of Capital, Technology, Terms of Exchange, Policy)
Net Investment	= f(Cash Farm Expenditure, Borrowing).

Of course, major problems exist in trying to develop the investment part of the model. Firstly, there will be the inevitable problems in finding reliable data. Secondly, there is the problem of incorporating investment into the rest of the model. Investment involves expending current income on both material and capital inputs, to effect, in the long and short run, both increases in stock numbers and in per head performance. Having said that investment has both a current and a lagged effect, it must also be noted that little evidence exists as to just what the lags should be.

At this stage, the model experiments with two very simple variables that are expected to reflect investment and its effect on stock numbers and output. Firstly, gross investment in land, plant, buildings and development (taken from Johnson, 1978) is considered. Two measures of gross investment will be used; SBINV to represent investment on sheep and beef farms, and DINV, to represent gross investment on dairy farms. A two period lag is placed on SBINV in the model, while a one period or no lag is placed on DINV, reflecting the greater capital intensity in dairying. Secondly, total fertiliser sales (FERT) will be used as an investment indicator.

To summarise, investment in the model will be considered at this stage of model development to be exogenous, and will be represented by the variables SBINV, DINV and FERT.

2.7 The Role of Government Policy in the Theoretical Model

Mention has been made several times in the preceding discussion of the use of variables to account for government involvement in the pastoral livestock sector. In the theoretical model it was thought to be important that the interface of government policy and the sector be brought out quite clearly, as the model itself must be built for the analysis of policy.

Government or producer board intervention has been more frequent in recent years as the outline of major policy initiatives set out below shows.

(i) Farm Price Policy - exchange policy, devaluations, revaluations of 1967, 1971, 1973.
- schedule intervention:

(a) Meat: 1955 minimum price scheme initiated
1972 Meat Board intervention in lamb market

	1974	Meat Board buys mutton, beef and lamb
	1975	Meat Board guarantees export beef schedule. Government makes supplementary payments on lamb
	1976	Government and producer boards set minimum and trigger prices
	1978	Supplementary Minimum Price Scheme
(b) Wool:	Pre 1974	Buying and selling at auction
	1974	Flexible market intervention policy introduced
	1975	Supplementary payments by government
	1976	Minimum prices set by government and producer boards
	1978	Supplementary minimum price scheme

(ii) Retail Price Policy - short term price freezes of 1969-1974. Sheepmeats subsidy 1973.

(iii) Stock Numbers Policy

1972	Stock Retention Incentive Scheme - grant
1976	Livestock Incentive Scheme

(iv) Investment - taxation policy

1931	Introduction of phosphatic fertiliser subsidy
1965	Farm Income Equalisation Scheme Further Input Subsidies
1970	Agricultural Assistance Fund established
1971	Supplementary Finance Scheme to provide loans to sheep farmers
1973	Farm Income Stabilisation Scheme
1974	Seasonal Finance Support Scheme
1978	Land Development Encouragement Loans

The frequency of government intervention can be regarded as a measure of the sector's importance and instability. However, intervention measures, at least up to 1976, have been characterised by their ad hoc nature, in response to largely short term phenomena.

The model outline (Figure 11) shows that policy instituted in one part of the sector will automatically have repercussions in other areas. The impact of policy actions tend to flow throughout the whole pastoral sector.

Obviously, the empirical model estimated cannot explicitly reproduce all government policy over the period of estimation, as much of the policy response is embedded in collected data. This is especially true of price data. Clearly, the estimated model's greatest value in terms of government policy will be to analyse future policy, especially alternative policies, e.g. exchange rate changes, deficiency payments, or investment grants as policies to achieve a given objective (e.g. increasing production by a certain percentage).

In the estimated model, some existing government policies will be accounted for using dummy variables. For the stocknumbers equations dummy variables will be put on 1972, 1977 and 1978 to represent the effects of the livestock grants and the Livestock Incentive Scheme. On the retail price equations, dummy variables will be put on the period 1969-1974, although since the price freezes in these years were only in operation for a few months at a time, the significance of the price freezes on annual data might be negligible. However, the consumer subsidies on sheepmeats in 1973 should have had more effect on retail prices.

SECTION 3

ESTIMATION OF THE MODEL

3.1 Introduction

The estimated model contains nineteen structural equations: seven stock number, six production, four consumption and two retail price equations. All prices up to retail prices have been considered exogenous. As mentioned in other sections, investment and stocks are also considered exogenous.

The system of equations is recursive and so ordinary least squares (O.L.S.) can be used to estimate the equations. The Time Series Processor (T.S.P.) computer package was used for the computing.

The results will now be presented and discussed, but first, it is important to note that many of the equations contain insignificant variables that could be eliminated on statistical grounds. However, most have been included for the purposes of this study, in order to show fully the results from using the model specification developed in Section 2. Some variables, however, have been excluded to ease the problems caused by a lack of degrees of freedom in certain equations.

Data series have been collected for the period 1957-1978, the period of estimation for the model. (In some cases fewer observations have been collected, hence estimation is over a smaller time period). All price data have been deflated by appropriate indicies (Base 1977 = 1000). Price variables have an S, D, or C as the final letter in their variable name, reflecting that they have been deflated by the prices paid by sheep farmers index, the prices paid by dairy farmers index, or by the consumers price index, respectively. All variables are defined in Appendix II.

3.2 Livestock Number Equations

3.2.1 Beef Breeding Cows

Dependent Variable: DKB

Independent Variables[1]	Estimated Coefficient	T Statistic[2]
KB_{t-1}	-0.01	-0.21
PPBS	-2.43	-0.69
$PPBS_{t-1}$	3.73	1.74
PMBS	2.91	1.16
VPBS	-5.34	-1.91
PSS	5.97	1.10
PSS_{t-1}	0.08	0.02
WB	-1.29	-0.95
$DKOB_{t-1}$	0.08	0.55
C	-272.28	-1.25

R-squared = 0.81 $\bar{R}$-squared = 0.65

Durbin-Watson Statistic = 2.51

Number of Observations = 21

Mean of Dependent Variable = 47.06

F-statistic (9., 11.) = 5.08

1 Unless otherwise stated variables are current period.

2 The significance of the individual t statistics is not reported but as a general guide a t value greater than 1.30 is significant at the 90 per cent level and $t \geq 1.8$ is significant at the 95 per cent level.

This equation differs from the theoretical specification in two respects. Firstly, the variable KOB_{t-1} is omitted due to the almost perfect correlation between itself and KB_{t-1}. The second difference is the absence of investment and policy variables. In alternative estimates of this relationship it was shown that policy variables had no significant impact on the estimate and that investment variables were insignificant and of a theoretically incorrect sign.

In general the function is not satisfactory as many of the variables are not significant even though they may have the correct sign. The major variables appear to be the price of beef which has a negative impact in the first period, but a positive effect in the longer run, the variability of beef prices which suggests that producers decrease the number of beef cows when prices are variable, and the weather variable which suggests that producers reduce cow numbers during dry weather conditions. Other variables such as those associated with sheep production appear to have inconsistent signs.

Although the laggel level of breeding cows (KB_{t-1}) has a coefficient which is insignificant and close to zero it is still potentially important in understanding the structure of the industry. Because the dependent variable in the equation is the change in the number of cows, this implies that the adjustment coefficient in the theoretical model is also close to zero (see Section 2.3).

3.2.2 'Other Beef' Cattle

Dependent Variable: DKOB

Independent Variables	Estimated Coefficient	T-Statistic
KOB_{t-1}	-0.62	-2.25
KB_{t-1}	1.09	2.15
DKB	1.25	7.24
PPBS	3.76	2.96
PMBS	-1.66	-1.46
VPBS	0.09	0.05
PSS_{t-1}	8.91	2.88
WB	2.93	3.08
C	-464.30	-3.88

R-squared = 0.95 $\bar{R}$-squared = 0.92

Durbin-Watson Statistic = 1.85

Number of Observations = 22

Mean of Dependent Variable = 89.64

F-statistic (8., 13.) = 32.71

This equation appears to be more satisfactory in that the degree of explanation is higher and more of the estimated coefficients are significant and consistent with the theoretical model.

Many of the expected coefficients are opposite in sign to those found in the previous equation. This is caused by the interchange between the two categories. For instance, a change which would cause a decrease in the breeding herd such as dry weather, good sheep prices, or a short run increase in beef prices, may cause an increase in the number of other beef. This could be due to the fact that heifers can be retained in the beef herd rather than being added to the breeding cow herd.

In general, however, the significance of the variable DKB would suggest that increases in the breeding herd cause increases in the number of other beef on hand at the end of the year. This is presumably due to the influx of calves which are produced during the year.

From the above discussion it can be seen that it is extremely difficult to provide a simple explanation of the coefficients in this equation. This is caused by the wide range of age-groups and types of stock which are included in the 'other beef' variable.

An alternative equation presented below demonstrates that investment in fertiliser may have some impact on the number of beef cattle. The overall explanation, however, is only marginally better than the previous estimate.

Dependent Variable: DKOB

Independent Variables	Estimated Coefficient	T-Statistic
KOB_{t-1}	-0.28	-0.71
KB_{t-1}	0.40	0.52
DKB	1.23	7.14
PPBS	2.91	2.04
PMBS	-1.14	-0.95
VPBS	1.80	0.74
PSS_{t-1}	5.81	1.47
WB	2.72	2.87
FERT	0.08	1.22
C	-351.70	-2.35

R-squared = 0.96 $\bar{R}$-squared = 0.93

Durbin-Watson Statistic = 1.67

Number of Observations = 22

Mean of Dependent Variable = 89.64

F-statistic (9., 12.) = 30.32

3.2.3 Dairy Cattle in Milk

Dependent Variable: DKD

Independent Variables	Estimated Coefficient	T-Statistic
KD_{t-1}	-0.31	-2.68
KOD_{t-1}	0.34	4.76
$DKOD_{t-1}$	0.21	2.32
PDD_{t-1}	0.70	1.97
$PMBD_{t-1}$	-1.78	-4.20
WD_{t-1}	-0.24	0.41
GIS	42.34	1.96
FERT	0.05	2.59
C	147.53	0.85

R-squared = 0.88 $\bar{R}$-squared = 0.79

Durbin-Watson Statistic = 2.34

Number of Observations = 20

Mean of Dependent Variable = 4.30

F-statistic (8., 11.) = 10.14

The equation is a satisfactory one, the only difference from the theoretical specification being the omission of PDD_{t-2}, which proved very insignificant.

Note that both the policy (GIS) and the investment variable (FERT) have proved significant (investment reflected by DINV did not prove very significant). All the variables incorporated in this function have signs which are consistent with the theoretical model.

3.2.4 Other Dairy Cattle

Of all the estimated equations this is the least successful. Most of the coefficients have the correct sign but many lack any real significance. $\bar{R}^2$ is only 0.43, while the Durbin-Watson statistic is very low, indicating autocorrelation among the error terms. This is often caused by the omission of important variables, and yet policy and investment variables were both used, but proved very insignificant.

Dependent Variable: DKOD

Independent Variables	Estimated Coefficient	T-Statistic
KOD_{t-1}	-0.10	-0.66
KD	-0.08	-0.39
DKD	0.88	2.73
PDD	0.00	0.00
PDD_{t-1}	1.53	1.80
VPDD	-0.40	-0.20
WD	-1.59	-1.24
C	31.81	0.09

R-squared = 0.63 $\bar{R}$-squared = 0.43

Durbin-Watson Statistic = 1.30

Number of Observations = 21

Mean of Dependent Variable = -3.37

F-statistic (7., 13.) = 3.13

The sign of KOD_{t-1} is almost zero, representing an implied adjustment coefficient of 1 in the adjustment model (see Section 2.3). The change in KD, (DKD) should have a negative sign, as it represents the demand for replacements from the previous period that will be milked in the current period. However, the almost zero coefficient on KD_t, which was supposed to represent the number of stock coming into the replacement herd, suggests that DKD_t might reflect the inflow of heifers to a greater extent than it does the loss of stock to the breeding herd.

The sign of WD is negative, in contrast to the sign on WB in the equation for 'other beef'. It would seem that weather is more critical for a dairy farmers total carrying capacity in that he cannot readily switch stock between the milking and non-milking herd.

3.2.5 Breeding Ewes

Dependent Variable: DKE

Independent Variables	Estimated Coefficient	T-Statistic
KE_{t-1}	-0.02	-0.13
$KHGT_{t-1}$	0.11	0.21
$DKHGT_{t-1}$	0.42	1.33
PSS	71.63	1.69
PSS_{t-1}	37.87	1.13
VPSS	-301.36	-4.38
PBS	-24.25	-1.98
WS	-47.81	-3.71
GIS	952.59	2.64
$SBINV_{t-2}$	9.98	1.21
C	632.80	0.28

R-squared = 0.92 $\bar{R}$-squared = 0.85

Durbin-Watson Statistic = 2.30

Number of Observations = 21

Mean of Dependent Variable = 743.59

F-statistic (10., 10.) = 12.20

The estimated equation for the breeding ewe population is a satisfactory one. All signs are as expected, with policy and the gross investment variable (lagged two periods) being significant.

The only variable omitted from the original specification is PBS_{t-1} which, together with PBS in the equation above, was to represent the price expectations for the beef enterprise. It was omitted, due to the significance of GIS and SBINV which also form a part of the producers longer term response.

Mention must be made of the correlation between $KHGT_{t-1}$ and KE_{t-1} of -.95. The equation was run without $KHGT_{t-1}$, but this only biased KE_{t-1} to the extent that it became positive. At least by including them, recognition has been made of the different effects of $KHGT_{t-1}$ and KE_{t-1}. Once again though, the coefficient on KE_{t-1} is almost zero, suggesting an implied coefficient in the adjustment model of almost 1.

3.2.6 Ewe Hoggets

Dependent Variable: DKHGT

Independent Variables	Estimated Coefficient	T-Statistic
$KHGT_{t-1}$	-0.64	-2.42
KE_{t-1}	0.29	4.03
$\dot{D}KE$	0.15	1.11
PSS	169.89	2.86
PSS_{t-1}	72.44	2.54
PLS	-43.31	-2.49
PBS	18.13	2.14
PBS_{t-1}	-18.99	-2.46
WS	-21.17	-1.67
C	-5766.56	-3.88

R-squared = 0.82 $\bar{R}$-squared = 0.68

Durbin-Watson Statistic = 2.77

Number of Observations = 22

Mean of Dependent Variable = 236.52

F-statistic (9., 12.) = 5.88

As in the breeding ewe equation, a good fit has been obtained, although the $\bar{R}^2$ is low because of the number of insignificant variables. Policy and investment variables were insignificant when they were entered into the equation, but most of the other variables have signs which were consistent with the theoretical development.

3.2.7 Other Sheep

Dependent Variable: DKOS

Independent Variables	Estimated Coefficient	T-Statistic
KOS_{t-1}	-0.16	-1.26
DKE	-0.06	-0.34
KE_{t-1}	0.04	1.35
PWS_{t-1}	12.36	5.43
PLS	-18.74	-3.13
VPSS	-83.26	-2.03
PPBS	27.29	2.88
$PPBS_{t-1}$	-28.47	-4.69
WS	-1.79	-0.18
GIS	597.81	2.05
C	-613.27	-0.45

R-squared = 0.88 $\bar{R}$-squared = 0.77

Durbin-Watson Statistic = 2.55

Number of Observations = 22

Mean of Dependent Variable = -36.15

F-statistic (10., 11) = 7.91

The 'other sheep' equation is also quite a reasonable one, with an F test significant at the 1 per cent level and an $\bar{R}^2 = 0.77$, although this could be increased through the omission of some insignificant variables (e.g. DKE_t and WS).

The signs of PPBS and $PPBS_{t-1}$ are interesting. It would be expected that both should be negative, as they represent the alternative enterprise of running young beef stock instead of young wether hoggets, which comprise 40 per cent of 'other sheep'. Perhaps the negative sign on $PPBS_{t-1}$ reflects this and the positive sign on $PPBS_t$ the effect of more ewe hoggets in the 'other sheep' category as the profitability of beef increases. In any event the net effect of prime beef prices on 'other sheep' is negligible, as the coefficients on $PPBS_t$ and $PPBS_{t-1}$ cancel each other out in the long run.

The investment variable SBINV showed some significance when included in the equation, although the F test fell and $\bar{R}^2$ was the same.

Unexpectedly, the sign on SBINV was negative, implying that increases in investment have different effects on different classes of sheep. The fact that it showed some significance means more research into the investment part of the equation is required. The results of this alternative specification are presented on the following page.

Dependent Variable: DKOS

Independent Variable	Estimated Coefficient	T-Statistic
KOS_{t-1}	-0.20	-1.49
DKE	-0.02	-0.10
KE_{t-1}	0.06	1.75
PWS_{t-1}	11.87	5.17
PLS	-18.38	-3.09
VPSS	-73.86	-1.78
PPBS	22.84	2.23
$PPBS_{t-1}$	-29.26	-4.83
WS	-0.43	-0.04
GIS	450.13	1.41
$SBINV_{t-1}$	-5.67	-1.10
C	-106.05	-0.07

R-squared = 0.89 $\bar{R}$-squared = 0.77

Durbin-Watson Statistic = 2.72

Number of Observations = 22

Mean of Dependent Variable = -36.15

F-statistic (11., 10.) = 7.44

3.3 Production Equations

3.3.1 Prime Beef

Dependent Variable: QPB

Independent Variables	Estimated Coefficient	T-Statistic
DKOB	0.03	0.50
KOB_{t-1}	0.01	1.09
PPBS	-0.85	-2.28
$PPBS_{t-1}$	-1.10	-2.30
WB	0.69	1.89
PLS	-0.59	-1.76
FERT	0.03	1.70
C	288.40	7.22

R-squared = 0.84 $\bar{R}$-squared = 0.75

Durbin-Watson Statistic = 1.70

Number of Observations = 22

Mean of Dependent Variable = 199.50

F-statistic (7., 14.) = 10.24

Two features of the prime beef production equation are interesting. First, the lack of significance of stock numbers in determining the quantity of prime beef, and secondly, the signs on the prime beef variables ($PPBS_t$ and $PPBS_{t-1}$).

In 1978, over 30 per cent of prime beef came from the category 'other beef', being either ox or heifer beef. Therefore, we would expect some relationship between the change in 'other beef' numbers and the amount of prime beef produced. The reason why no relationship is found could be explained by looking at the signs on the schedule prime beef prices ($PPBS_t$ and $PPBS_{t-1}$), both at first glance unexpectedly negative. However, when it is considered that 40 per cent of KOB is made up of heifers, and that prime beef production is made up of both steers and heifer beef, an answer is forthcoming.

A producer has the option of either slaughtering heifers or retaining them for the breeding herd. It could be assumed that slaughtering of heifers would be more variable than that of steer slaughtering where no option exists, except perhaps that of growing the steers out to bigger weights. As future returns from a heifer retained for breeding purposes is determined by the expected return from the offspring they produce, high beef prices would lead to less heifers being slaughtered. Thus, the most variable part of prime beef production would be heifer beef. High prime beef prices, in the short run at least, would decrease the quantity of prime beef produced.

The sign on the weather variable, WB, is positive, indicating that lack of grass growth increases the number of animals classified as prime beef being slaughtered. It would have been expected that the sign on this variable would be negative indicating that the animals slaughtered would kill out at lower weights. The investment variable, fertiliser sales (FERT), appears to have a positive relationship with the amount of prime beef available.

3.3.2 Manufacturing Beef

Dependent Variable: QMB

Independent Variables	Estimated Coefficient	T-Statistic
$KBBB_{t-1}$	0.03	12.77
DKBB	-0.08	-1.53
KD_{t-1}	0.01	0.48
PPBS	-1.65	-1.69
PMBS	2.38	4.09
PSS	0.87	0.72
PDD	0.37	0.94
WB	-0.74	-1.85
$SBINV_{t-1}$	-0.82	-2.28
C	-176.39	-1.78

R-squared = 0.98 $\bar{R}$-squared = 0.97

Durbin-Watson Statistic = 2.33

Number of Observations = 22

Mean of Dependent Variable = 149.77

F-statistic (9., 12.) = 69.54

In contrast to the prime beef equation, livestock numbers are the most important determinant of manufacturing beef production, reflecting the annual nature of culling. The weather variable in this equation is negative which indicates that the culled animals' weights suffer in dry weather.

The investment variable which is significant in this case is SBINV. While a positive sign would have been expected, the negative sign might reflect the overall improvement in stock quality that comes about when investment increases, reflected in better quality meat being produced and being graded subsequently as prime.

3.3.3 Wool

Dependent Variable: QW

Independent Variables	Estimated Coefficient	T-Statistic
KEH_{t-1}	0.01	14.69
KOS_{t-1}	0.01	3.82
WS	-0.47	-2.00
C	-20.74	-0.74

R-squared = 0.93 $\bar{R}$-squared = 0.92

Durbin-Watson Statistic = 1.63

Number of Observations = 22

Mean of Dependent Variable = 292.13

F-statistic (3., 18.) = 83.49

A simple regression using stock numbers and weather was run first, as for wool the number of stock in the previous period to a large extent determine current wool production. Due to multcollinearity between KE_{t-1} and $KHGT_{t-1}$, they were added together to form one variable, KEH_{t-1}.

As the results above show, the regression explained much of the variation in wool production.

An alternative equation, which included product prices, improves the overall fit marginally ($\bar{R}^2$ increase to 0.94), but the Durbin-Watson is improved greatly. Wool (PW_t) and Mutton (PM_t) prices have the expected signs and indicate the form of a possible short term response.

Dependent Variable: QW

Independent Variables	Estimated Coefficient	T-Statistic
KEH_{t-1}	0.01	8.24
KOS_{t-1}	0.01	4.54
WS	-0.63	-2.39
PWS	0.19	1.95
PMS	-0.63	-1.85
PLS	0.07	0.26
C	-121.50	-1.90

R-squared = 0.95 $\bar{R}$-squared = 0.94

Durbin-Watson Statistic = 2.00

Number of Observations = 22

Mean of Dependent Variable = 292.13

F-statistic (6., 15.) = 52.47

3.3.4 Lamb

Dependent Variable: QL

Independent Variables	Estimated Coefficient	T-Statistic
KE_{t-1}	0.01	18.90
$KHOS_{t-1}$	0.00	1.55
PLS	0.03	0.17
PMS	-0.79	-4.62
PMS_{t-1}	-0.42	-4.48
PWS	0.18	3.61
PWS_{t-1}	-0.06	-1.56
WS	-0.66	-5.07
C	-49.07	-1.37

R-squared = 0.99 $\bar{R}$-squared = 0.99

Durbin-Watson Statistic = 2.05

Number of Observations = 22

Mean of Dependent Variable = 315.08

F-statistic (8., 13.) = 296.33

As hypothesised, it is stock numbers that largely determine the quantity of lamb produced. The number of breeding ewes in the period preceding the current period is the main determinant, plus the combined total of ewe hoggets and other sheep (KHGT + KOS = KHOS).

High mutton prices decrease the quantity of lamb available, as do high wool prices, representing the future value of retaining lambs rather than slaughtering them. Adverse weather conditions decrease lamb carcase weight, and so lead to a fall in lamb production. As would be expected investment variables were not found to be important at this advanced stage of the production chain.

3.3.5 Mutton

Dependent Variable: QM

Independent Variables	Estimated Coefficient	T-Statistic
KE_{t-1}	0.00	2.76
DKE	-0.01	-1.99
KOS_{t-1}	0.01	4.96
PSS_{t-1}	-1.11	-1.84
$PPBS_{t-1}$	0.45	2.85
WS	0.01	0.03
C	11.30	0.27

R-squared = 0.91 $\bar{R}$-squared = 0.88

Durbin-Watson Statistic = 2.49

Number of Observations = 22

Mean of Dependent Variable = 175.38

F-statistic (6., 15.) = 25.65

Mutton production is also largely a function of stock numbers. High price expectations about sheep returns will cause a fall in mutton production, while high beef prices will increase it, as a higher ewe slaughter rate occurs to make way for beef. Only lagged price variables are included, as current price variables proved to be insignificant.

Weather is shown to have no effect on mutton production, although it is possible that the practically zero coefficient is the net effect of increased ewes slaughtered due to dry weather conditions, and the drop in their body weight due to the same conditions.

Fertiliser sales (FERT) showed up as having some significance in a second regression (see following page). Its effect on mutton production is minimal and negative, the negative sign due most probably to the increased availability of feed due to the application of fertiliser, therefore the pressure to sell older ewes is less. However, a positive effect from fertiliser application, might also have been expected, because of the increasing per head productivity.

Dependent Variable: QM

Independent Variables	Estimated Coefficient	T-Statistic
KE_{t-1}	0.00	2.67
DKE	-0.01	-2.12
KOS_{t-1}	0.01	4.50
PSS_{t-1}	-0.86	-1.33
$PPBS_{t-1}$	0.44	2.18
WS	0.04	0.13
FERT	-0.01	-1.00
C	-2.49	-0.06

R-squared = 0.92 $\bar{R}$-squared = 0.88

Durbin-Watson Statistic = 2.69

Number of Observations = 22

F-statistic (7., 14.) = 22.14

3.3.6 Milkfat

Dependent Variable: QMLK

Independent Variables	Estimated Coefficient	T-Statistic
KD	0.24	7.49
KOD_{t-1}	-0.10	-4.15
PDD	0.07	0.59
PMBD	-0.26	-1.60
WD	-0.69	-3.32
C	-105.97	-1.92

R-squared = 0.80 R-squared = 0.74

Durbin-Watson Statistic = 1.21

Number of Observations = 21

Mean of Dependent Variable = 274.02

F-statistic (5., 15.) = 12.50

The previous equation is a reasonable estimation of milkfat production from dairy cattle. The milkfat, being derived from factory supply herds, is mainly determined by the number of cows in milk (KD), the number of replacements that could have entered the herd in the current period (KOD) and price expectations.

KOD_{t-1} has a negative sign, reflecting the lower average production from younger dairy stock. PDD is a good indicator of the incentive to milk cows longer before drying off, and PMBD the value of immediate slaughter.

Adverse weather conditions exert a significant negative influence through lower per cow production. Investment variables did not show up as being important.

The low Durbin- Watson statistic indicates that autocorrelation exists in the residuals of the equation. The residuals follow the trend of actual production. In order to eliminate this autocorrelation, another variable was included, the lagged dependent variable, $QMLK_{t-1}$. Actual milkfat production has not varied much in over twenty years, therefore it was felt that the previous year's production was a good indicator of what the current level of milkfat could be expected to be.

The re-estimated equation has improved the $\bar{R}^2$, the F test, and the Durbin-Watson. It must be remembered, however, that estimates of the Durbin-Watson statistic are biased in equations where lagged dependent variables are present. To overcome this problem the 'h' statistic is estimated and confirms the fact that there is no significant autocorrelation.

Dependent Variable: QMLK

Independent Variables	Estimated Coefficient	T-Statistic
KD	0.15	3.41
$QMLK_{t-1}$	0.47	2.81
KOD_{t-1}	-0.06	-2.72
PDD	0.09	0.93
PMBD	-0.25	-1.88
WD	-0.71	-4.13
C	-77.88	-1.67

R-squared = 0.88 $\bar{R}$-squared = 0.83

Durbin-Watson Statistic = 1.82 h-statistic = 0.65

Number of Observations = 21

Mean of Dependent Variable = 274.02

F-statistic (6., 14.) = 16.52

3.4 Retail Prices

Two retail price equations have been estimated for beef and for mutton. Due to the lack of retail price data, a lamb equation could not be estimated.

3.4.1 Beef Retail Price

Dependent Variable: PRBPC

Independent Variables	Estimated Coefficient	T-Statistic
PPBS	1.20	10.15
WAGE	-0.00	-0.18
PMS	-0.01	-0.04
PRPC	0.57	6.26
GRP	-24.05	-2.07
C	-12.14	-0.75

R-squared = 0.95 $\bar{R}$-squared = 0.94

Durbin-Watson Statistic = 1.59

Number of Observations = 22

Mean of Dependent Variable = 212.24

F-statistic (5., 16.) = 63.53

As would be expected, the schedule price of prime beef is the main determinant of the prime beef price. Intervening costs to retail, as shown by the real wage price index (WAGE) are not a significant determinant of the beef retail price.

The mutton schedule price and the pork retail price have been included to represent the cost to the retailer of alternative meats. The beef margin can then be set in relation to these other meats, and averaging could take place. In the equation above, the mutton schedule price proves insignificant, but the pork price is very significant. It would seem that beef and pork retail prices are set to maintain the competitive relationship between them. If pork prices move up, so do beef prices to maintain the price differential between them.

Dummy variables for the price freeze period (1969-1974) did not prove significant. However, GRP in the above equation is a dummy variable in 1973, when the sheepmeats subsidy scheme was used. In association with the price freeze of that year it appears to have held beef prices down, as well as mutton and lamb prices.

3.4.2 Mutton Retail Price

Dependent Variable: PRMC

Independent Variable	Estimated Coefficient	T-Statistic
PPBS	0.07	0.62
WAGE	0.01	1.40
PMS	0.57	3.60
PRPC	0.16	1.79
GRP	-35.83	-3.09
C	70.55	4.37

R-squared = 0.80　　　$\bar{R}$-squared = 0.72

Durbin-Watson Statistic = 1.20

Number of Observations = 22

Mean of Dependent Variable = 141.12

F-statistic (5., 16.) = 12.70

The mutton retail price is determined largely by the schedule price and also, to some extent, by the marketing costs (represented by WAGE).

Beef schedule prices can be seen to be insignificant in determining the mutton retail price. The pork retail price exerts a positive influence on the mutton price. This could be evidence of averaging, i.e. to hold down the pork increase in price the mutton retail price is increased to make a wider margin on mutton sales. The sheepmeats subsidy of 1973 (GRP) shows the expected effect of holding prices down.

3.5 Consumption

The equations that follow are estimates of per capita demand for beef, mutton, lamb and pork. As can be seen from Figure 13, beef comprises the highest proportion of per capita meat consumption in New Zealand. Mutton consumption has declined continuously throughout the 1970's, giving way especially to lamb, and probably also to chicken consumption, which although not graphed, has risen sharply throughout the last decade.

3.5.1 Per Capita Beef Consumption

Dependent Variable: CBV

Independent Variables	Estimated Coefficient	T-Statistic
PCY	0.00	2.69
PRBPC	-0.04	-1.26
PRMC	0.09	1.37
PRPC	-0.05	-1.02
CBV_{t-1}	0.43	1.92
C	17.95	2.26

R-squared = 0.80 $\bar{R}$-squared = 0.73

Durbin-Watson Statistic = 1.11

Number of Observations = 21

Mean of Dependent Variable = 50.68

F-statistic (5., 15.) = 12.03

The function is not entirely satisfactory. Although most of the signs are correct, much of the fit is due to the lagged dependent variable. Due to the lack of any great significance of the other variables (except per capita incomes (PCY)), the fitted graph tends to track the actual with a one period lag.

The Durbin-Watson statistic is low, and in this equation, it could signify that a non-linear equation specification could be more appropriate.

3.5.2 Per Capita Mutton Consumption

Dependent Variable: CM

Independent Variables	Estimated Coefficient	T-Statistic
PCY	-0.00	-4.34
PRBPC	0.09	6.76
PRMC	-0.12	-4.60
PRPC	-0.02	-1.30
CM_{t-1}	0.47	5.06
C	30.56	6.08

R-squared = 0.97 $\bar{R}$-squared = 0.96
Durbin-Watson Statistic = 1.43
Number of Observations = 21
Mean of Dependent Variable = 30.70
F-statistic (5., 15.) = 88.85

Mutton has traditionally been the second ranked meat in terms of consumption per capita. Of the four meats, mutton is the cheapest and tends to be regarded as inferior to beef, pork or lamb in New Zealanders' preferences. The equation depicts this well, with the negative sign on per capita incomes, i.e. as consumerincomes rise, mutton consumption decreases.

Again, the Durbin-Watson statistic is low, and the pork price shows an unexpected sign.

3.5.3 Per Capita Lamb Consumption

Dependent Variable: CL

Independent Variable	Estimated Coefficient	T-Statistic
PCY	0.00	3.73
PRBPC	-0.00	-0.05
RPMC	-0.06	-2.72
PRPC	-0.01	-0.52
CL_{t-1}	0.19	0.94
C	3.95	1.77

R-squared = 0.92 $\bar{R}$-squared = 0.90

Durbin-Watson Statistic = 1.96

Number of Observations = 21

Mean of Dependent Variable = 8.62

F-statistic (5., 15.) = 35.78

A reasonable fit has been obtained for the lamb equation. The retail price of pork again exhibits an unexpected sign, as does the beef retail price (PRBPC), although they are insignificant. In contrast to mutton, lamb consumption increases with income.

It should be noted that the retail price of mutton is used as a substitute for the lamb price in this function. This is caused by the lack of data on lamb prices. The implicit assumption involved is that the lamb and mutton prices move together. The significance of the mutton price variable in this equation would suggest that this is in fact the case.

3.5.4 Per Capita Pork Consumption

Dependent Variable: CP

Independent Variables	Estimated Coefficient	T-Statistic
PCY	0.00	0.55
PRBPC	0.01	0.96
PRMC	-0.01	-0.93
PRPC	-0.04	-3.33
CP_{t-1}	0.17	1.01
C	20.49	5.53

R-squared = 0.88 $\bar{R}$-squared = 0.84
Durbin-Watson Statistic = 2.12
Number of Observations = 21
Mean of Dependent Variable = 13.68
F-statistic (5., 15.) = 22.59

Pork consumption has varied little over the last twenty years (see Figure 13), reaching a high of about 16 kg/capita in 1964, and a low of about 11 kg/capita in 1975. The average over the last twenty years is 13.7 kg/capita. Variation in consumption is largely accounted for by changes in the pork retail price. The income effect is positive, but very insignificant, which is unexpected.

The sign on the retail price of mutton is also unexpected, although it can possibly be justified when the relative importance of mutton and pork in the consumers budget is considered. Mutton consumption, usually well over double that of pork consumption, can be considered more of a staple food than pork. Therefore, when the mutton retail price increases, more of the consumers food dollar must be spent on the staple food, at the expense of luxury-type goods.

SECTION 4

VALIDATION OF THE MODEL

4.1 Introduction

The previous section of this paper has reported and briefly discussed the nineteen behavioural equations which have been estimated in the preliminary version of this model. Whilst the individual equation results and their associated statistics give an indication of the validity of specific equations they are no indication of the overall validity of the model. In a dynamic recursive model such as that developed in this study, a weakness in an individual equation can have implications for the model as a whole. In this section the results of an historical simulation are presented in an attempt to validate the performance of the model. Such a simulation is also useful in understanding and verifying the dynamic characteristics of the model.

An additional six identities which estimate the total consumption and exports of beef, lamb and mutton were added to the nineteen estimated relationships and the model was simulated over the period (1959-1977) using actual levels of the exogenous variables. (A complete list of exogenous and endogenous variable names are provided in Appendix II.) Lagged endogenous variables were determined from previous period model solutions. This form of simulation is a particularly harsh test of the model's ability to capture the dynamic characteristics of the pastoral economy as any errors in early periods of the simulation can be compounded in later periods.

There are a wide range of possible tests and measures which can be used to validate a model and assess its value for forecasting and policy analysis (Labys, 1973), but at this stage of model development it is sufficient to consider the most widely used statistical measures as well as a graphical analysis of the results. The graphical analysis is particularly important in that it can assist in identifying patterns in residuals or particular time periods which may be causing problems in a number of the relationships. It is also useful in assessing the model's ability to predict turning points which is difficult to do using statistical measures.

4.2 Results

Table 3 presents the statistical measures of the accuracy of the model in predicting the changes in the endogenous variables over this period. The particular measures used include the Theil U statistic which is calculated from the following formula:

$$U = \frac{{}_n\Sigma(A_t - P_t)^2}{{}_n\Sigma A_t}$$

where: P_t is the change in the predicted value of the endogenous variable in period t,

and A_t is the change in the actual value of the same variable in period t.

This statistic in its simplest form provides a measure of the discrepency between the actual and predicted values and has a range of values from zero to infinity. A Theil U value of zero represents perfect prediction while a value of one is equivalent to a constant value forecast (i.e. $P_t = k$). A second common measure is the mean absolute percentage error which provides an estimate of the average error size estimated by the model.

The final column in Table 3 presents the $\bar{R}^2$ from the original estimating equation. Although some of the variables in the simulation are measured in absolute terms rather than the first differences which are used in the estimated functions, these statistics provide a measure of the types of errors which are present in a dynamic simulation.

The results in Table 3 show that many of the endogenous variables are predicted with reasonable accuracy, but there are some obvious sources of error. The dairy cow inventory equations appear to be the major problem, with U coefficients of greater than one and absolute average errors of 25 and 55 per cent respectively. The errors from these relationships can be seen to be compounded in other variables such as the production of manufacturing beef and milk.

The other inventory functions, however, appear to provide reasonable predictions even though the fit of the original functions would not appear to be that satisfactory (e.g. $\bar{R}^2$ of 0.65 for beef and 0.68 for Hoggets).

The retail prices are also predicted with reasonable accuracy and the only other major source of errors appears to be the consumption functions. It is surprising that the consumption functions have predicted poorly as the original estimates appeared reasonably good. The errors introduced by the consumption functions have an impact on the export predictions, especially for mutton where domestic consumption is a major percentage of total production. The accuracy of the predictions of total beef exports is undoubtedly affected by the dairy variables' influence on manufacturing beef production. These results show clearly how errors can be compounded in a dynamic recursive model. These considerations are extremely important when the resultant variables, such as exports, are of major importance to policy makers.

TABLE 3

MEASURES OF ACCURACY OF THE SIMULATION

(1959 - 1977)

Variable	Theil 'U' Coefficient	Mean Absolute Percentage Error	$\bar{R}^2$ From Estimated Equation
KB	0.41	3.4	0.65
KOB	0.52	3.4	0.92
KD	1.55	24.4	0.79
KOD	1.06	54.9	0.43
KE	0.28	0.9	0.85
KHGT	0.63	4.7	0.68
KOS	0.50	4.9	0.77
QPB	0.58	5.9	0.75
QMB	1.12	15.8	0.97
QW	0.73	2.0	0.94
QL	0.27	1.6	0.99
QM	0.94	4.8	0.88
QMLK	1.28	21.7	0.83
PRBPC	0.38	2.2	0.94
PRMC	0.50	3.1	0.72
CBV	0.86	4.9	0.73
CM	0.71	5.0	0.96
CL	1.02	10.7	0.90
CP	0.68	2.8	0.84
TCBV	0.87	5.8	-
TCM	0.85	6.8	-
TCL	1.62	15.2	-
TCP	1.33	4.8	-
XBV	1.52	12.6	-
XM	2.37	24.2	-
XL	0.89	5.5	-

A graphical analysis shows the inaccuracies in the model even more clearly (The graphs are presented in Appendix III.). It can be seen that the predicted values of dairy cow numbers are too high and the errors are compounding over time. The obvious effects on the other variables can also be seen. Other than this, however, there do not appear to be any major dynamic problems with the model as all the major variables track well and the predictions do not deteriorate in the later periods. One problem which can be seen in the graphical analysis is the tendancy for some of the variables to have biased predictions. These can be seen in the inventory functions for beef, hoggets and other sheep. One cause of such errors is the fact that these functions are estimated in first difference form and an error in the starting point can be continued over a number of years. Although a statistical measure cannot be provided easily, it can be seen from the graphs that the major turning points in most of the variables have been predicted with reasonable accuracy. The most crucial test of the model's forecasting ability, however, must depend on its ability to predict the time path of the variables outside of the estimation period.

4.3 Conclusions

In general, the simulation results have shown that the model of the New Zealand pastoral sector has provided reasonable predictions of the major endogenous variables over the estimation periods.

There is a considerable amount of work required, however, before the model would be in a suitable form for forecasting and policy analysis. Obvious difficulties can be seen in the form of the dairy inventory and meat consumption functions and the elements of the investment relationships have not been clearly specified.

Further work is also required in the testing of such a model to determine the dynamic properties of the model and the consistency of the dynamic multipliers.

These preliminary results are sufficiently promising, however, to warrant a considerable amount of further research into the development of such a model.

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APPENDICES

APPENDIX I

Profile of Livestock Numbers

Beef Cows at 30 June 1976 (000 hd)

		'000	%
KB:	Beef Cows (>2 yrs) used for breeding	2,058	91
	Beef Cows (>2 yrs) not used for breeding	199	9
		2,257	100
KOB:	Heifers 1-2 years	675	18*
	Heifer Calves <1 year	788	21
	Cull Dairy Cows	53	1
		1,516	40
	Steers and Non Breeding Bulls		
	- > 2 y.o.	581	15
	- 1-2 y.o.	765	20
	- < 1 y.o.	812	21
		2,158	56
	Breeding Bulls Mixed Age	156	4
		3,830	100

* 25% bred from (172,000)
75% not bred from (503,000)

Dairy Cattle at 31 January 1971

			'000	%
KD:	Cows in Milk		2,239	100
		TOTAL	2,239	100
KOD:	Heifers Not Yet in Milk		79	6
	Cows Intended for Dairying		20	2
	Heifers 1-2 (In-calf or not)		558	43
	Heifers < 1 yr		551	42
	Bulls		92	7
			1,300	100

Sheep at 30 June 1977

		'000	%
KE:	Total Breeding Ewes	42,782	100
		42,782	100
KHGT:	Ewe Hoggets	11,738	100
		11,738	100
KOS:	Wether Hoggets	1,989	43
	Ram Hoggets	314	7
	Rams, 2 th and over	877	19
	Other Sheep	1,405	31
		4,585	100

APPENDIX II

Variable Names and Definitions

Abbreviations

ASDS	-	Agricultural Statistics, Department of Statistics.
MAS	-	Monthly Abstracts of Statistics.
NZMPB	-	New Zealand Meat Producers Board.
NZWB	-	New Zealand Wool Board.
NZDB	-	New Zealand Dairy Board.
D.S.	-	Department of Statistics.
NZMWBES	-	New Zealand Meat and Wool Boards Economic Service.

Variable Name	Definition	Source/Comment
Endogenous Variables		
KB	Beef Breeding Cows ('000 hd)	ASDS, 1957-1971 January Years adjusted to June Years. 1972-1978 June Years.
KOB	Other Beef Cattle ('000 hd)	ASDS.
KD	Dairy Cows in Milk ('000 hd)	ASDS, January Years but measures Dairy cows in milk over the July-June period.
KOD	Other Dairy Cattle ('000 hd)	ASDS, Dairy Cattle intended for beef production included in KOB.
KE	Breeding Ewes ('000 hd)	ASDS, June Year.
KHGT	Ewe Hoggets ('000 hd)	ASDS, June Year.
KOS	Other Sheep ('000 hd)	ASDS, June Year.
QPB	Quantity of Prime Beef Produced ('000 t, bone-in)	NZMPB, June Year.

QMB	Quantity of Manufacturing Beef Produced ('000 t, bone-in)	NZMPB, June Year.
QM	Quantity of Mutton Produced ('000 t, bone-in)	MAS, June Year.
QL	Quantity of Lamb Produced ('000 t, bone-in)	MAS, June Year.
QW	Quantity of Wool Produced ('000 t, greasy)	NZWB, June Year.
QMLK	Quantity of Milkfat Produced ('000 t)	NZDB, Farm Production Report. Milkfat Processed by Dairy Factories, June Year to 1961, May Year since 1962.
PRBPC	Retail Price of Prime Beef (c/kg)	D.S. Prices, Wages and Labour, average of four-quarters ending June.
PRMC	Retail Price of Mutton (c/kg)	D.S. Prices, Wages and Labour, average of four-quarters ending June.
CBV	Per Capita* Consumption of Beef and Veal (kg)	MAS, June Year.
CM	Per Capita* Consumption of Mutton (kg)	MAS, June Year.
CL	Per Capita* Consumption of Lamb (kg)	MAS, June Year.
CP	Per Capita* Consumption of Pork (kg)	MAS, June Year.
		* Per Capita = Total N.Z. Consumption : popn.
TCBV	Total Consumption of Beef and Veal ('000 t, bone-in)	MAS, June Year.
TCM	Total Consumption of Mutton ('000 t, bone-in)	MAS, June Year.
TCL	Total Consumption of Lamb ('000 t, bone-in)	MAS, June Year.

TCP	Total Consumption of Pork ('000 t, bone-in)	MAS, June Year.
XBV	Exports of Beef and Veal ('000 t, product weight)	NZMPB, June Year.
XM	Exports of Mutton ('000 t, product weight)	NZMPB, June Year.
XL	Exports of Lamb ('000 t, product weight)	NZMPB, June Year.

Exogenous Variables

STBV	Change in Stocks of Beef and Veal ('000 t, product weight)	NZMPB, June Year.
STM	Change in Stocks of Mutton ('000 t, product weight)	NZMPB, June Year.
STL	Change in Stocks of Lamb ('000 t, product weight)	NZMPB, June Year.
CIS	Index of Prices Paid by Sheep Farmers	NZMWBES.
CID	Index of Prices Paid by Dairy Farmers	NZDB, Farm Production Report.
WAGE	Adult Male Wage Index	MAS.
CPI	Consumers Price Index	MAS.
PD	Milkfat price paid to Dairy Farmers for Wholemilk (c/kg)	NZDB, May Year.
PPB	Schedule Price for Prime Beef (c/kg)	NZMPB, Average mid-month schedule for P.1. Steer, Year ended June.
PMB	Schedule Price for Manufacturing Beef (c/kg)	NZMP, Average of February-June mid-month schedule for boner cow.

PM	Schedule Price for Ewe Mutton (c/kg)	NZMPB, Average of January-June mid-month schedule.
PL	Schedule Price for Lamb (c/kg)	NZMPB, Average of December-May mid-month schedule.
PW	Average Auction Price for Wool (c/kg, greasy)	NZWB.
PS	An aggregate sheep return based on lamb, mutton and wool prices	
WS	Days of Soil Moisture Deficit (weighted by sheep population)	N.Z. Meteorological Service.
WD	Days of Soil Moisture Deficit (weighted by dairy cattle population)	N.Z. Meteorological Service.
WB	Days of Soil Moisture Deficit (weighted by beef cattle population)	N.Z. Meteorological Service.
C	Intercept term	

APPENDIX III

GRAPHICAL ANALYSIS

The following Figures present the actual and predicted values of the endogenous variables in the model for the period (1959-1979).

FIGURE 14

KB - BEEF BREEDING COWS

('000 hd)

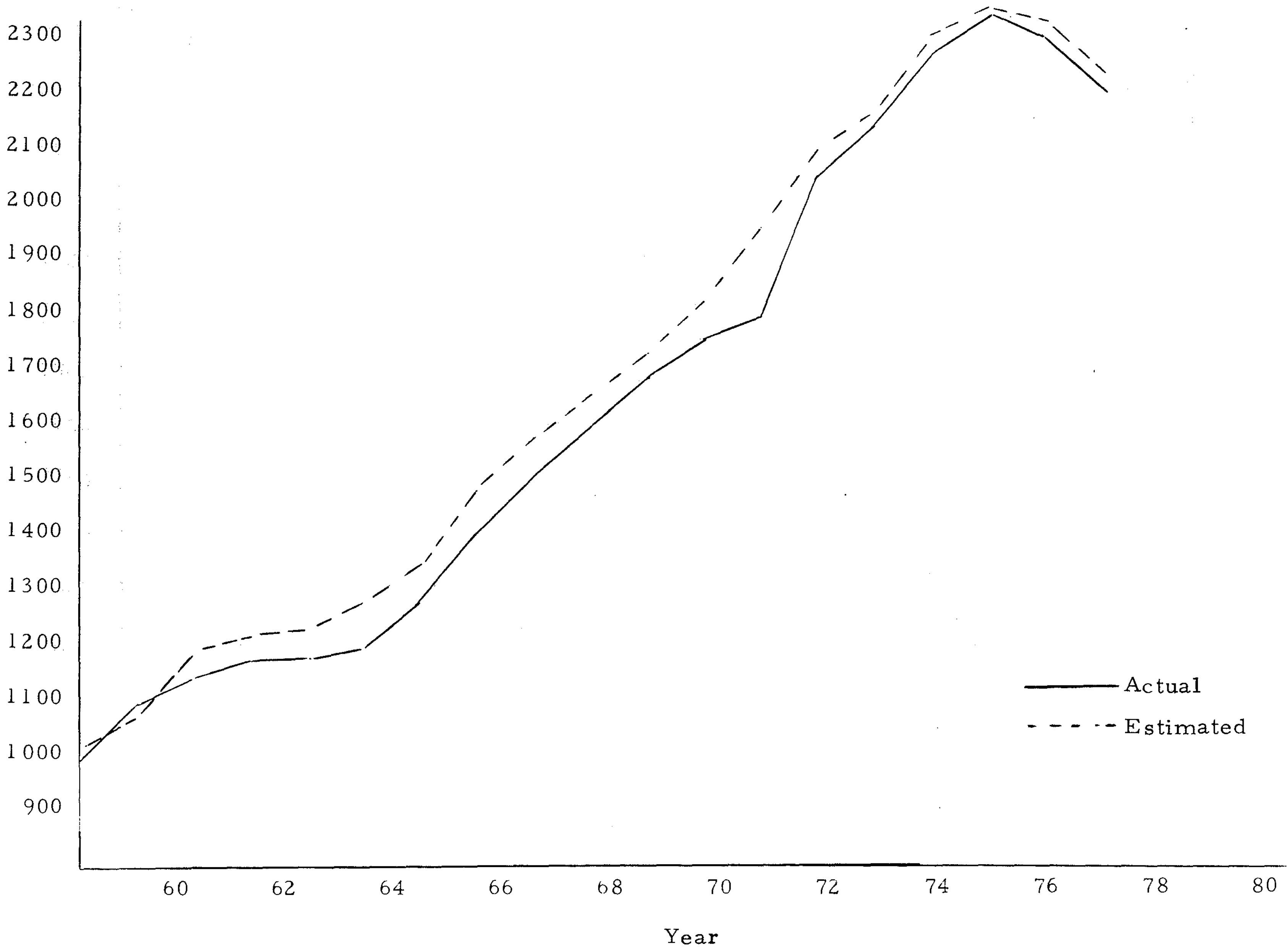


FIGURE 15

KOB - OTHER BEEF CATTLE

('000 hd)

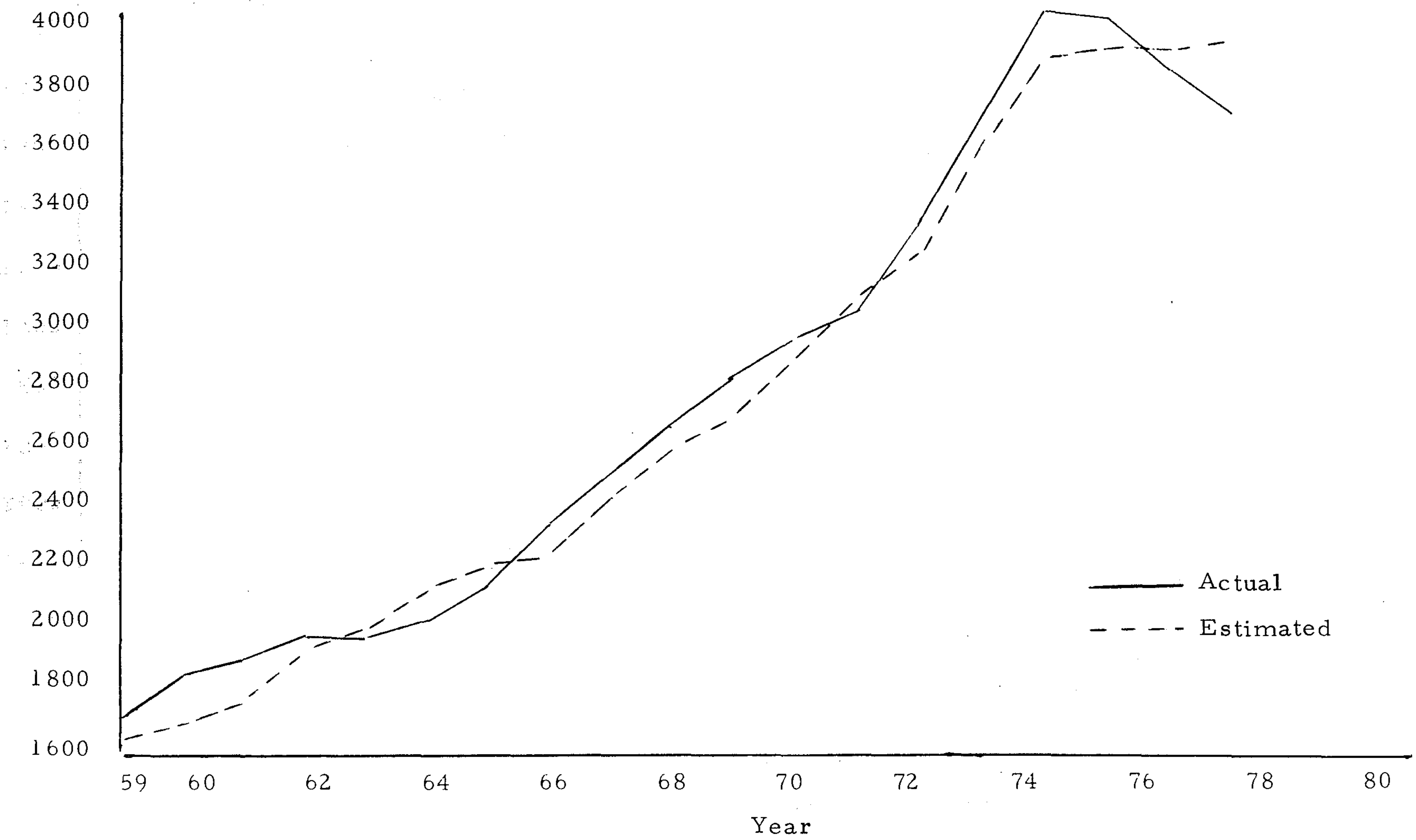


FIGURE 16

KD - DAIRY COWS IN MILK

('000 hd)

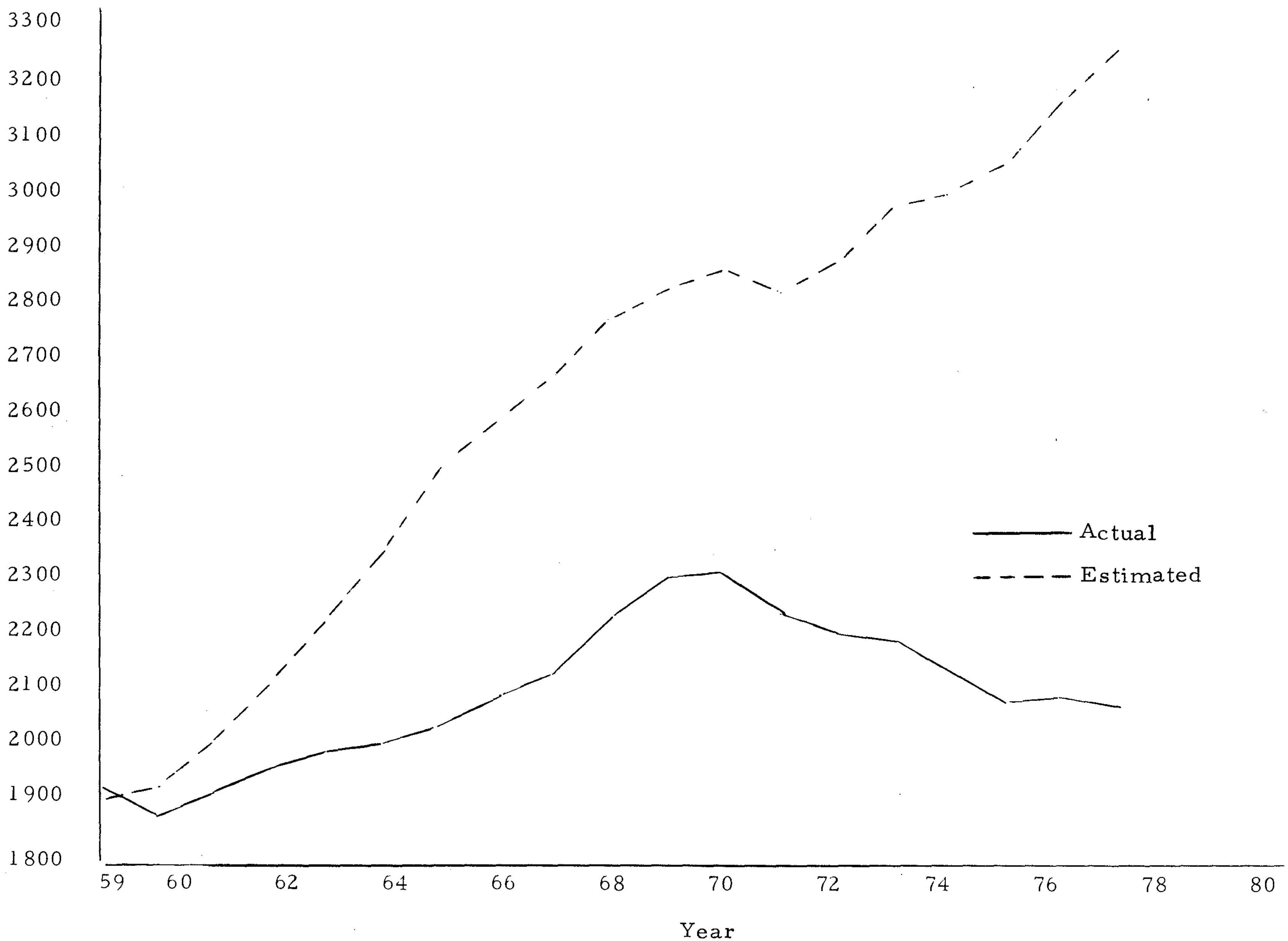


FIGURE 17

KOD - OTHER DAIRY CATTLE

('000 hd)

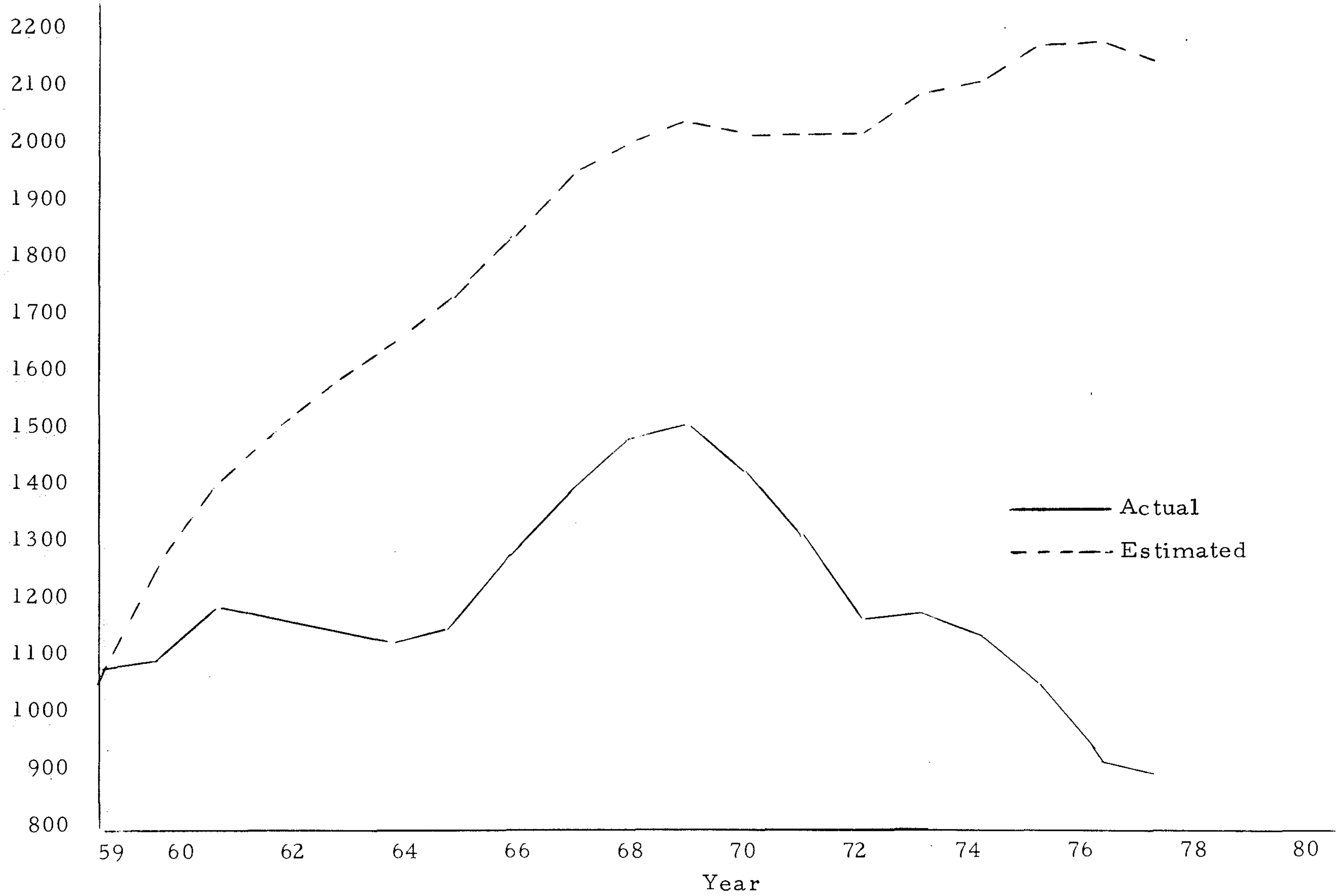


FIGURE 18

KE - BREEDING EWES

('000 hd)

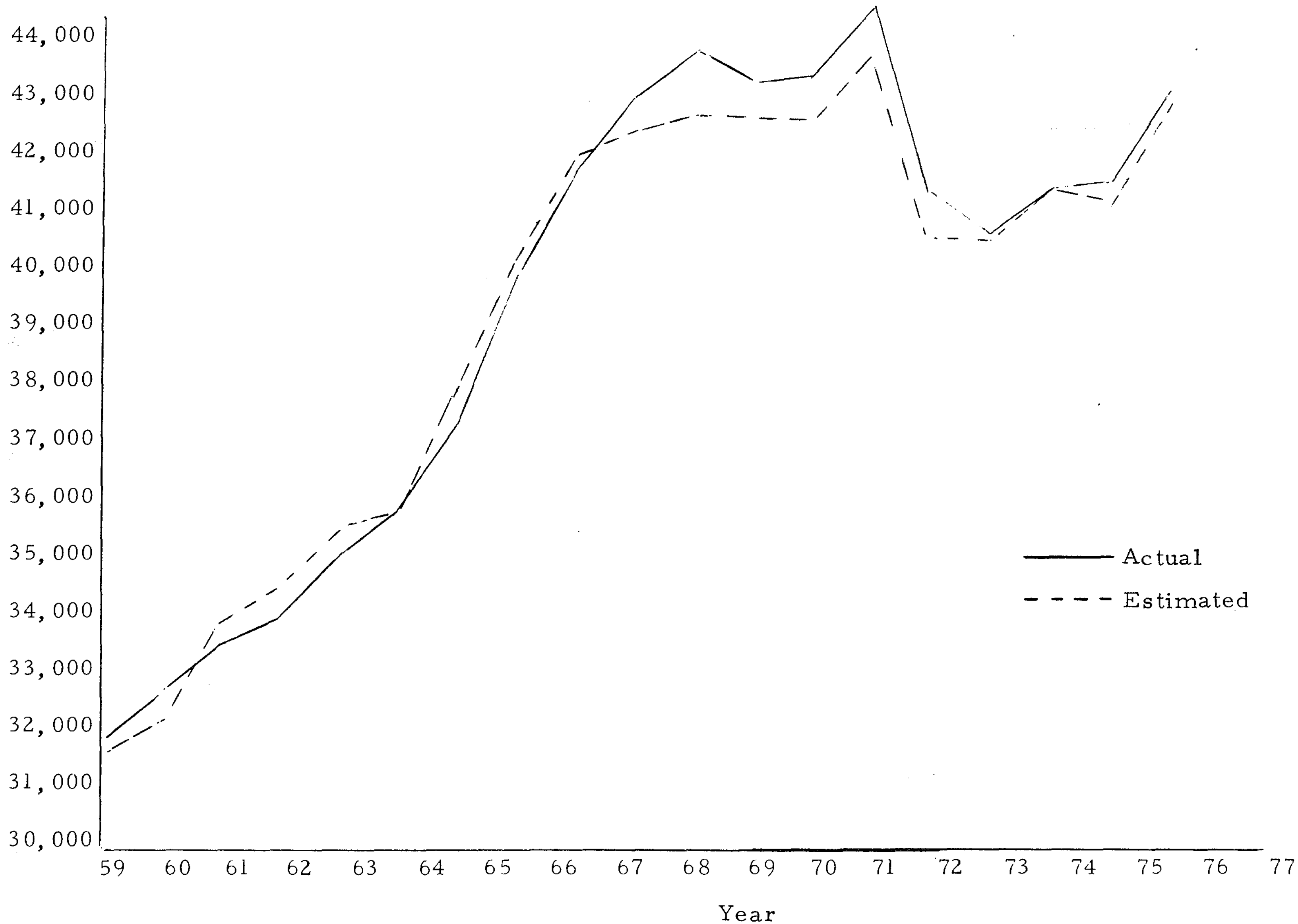


FIGURE 19

KHGT - EWE HOGGETS

('000 hd)

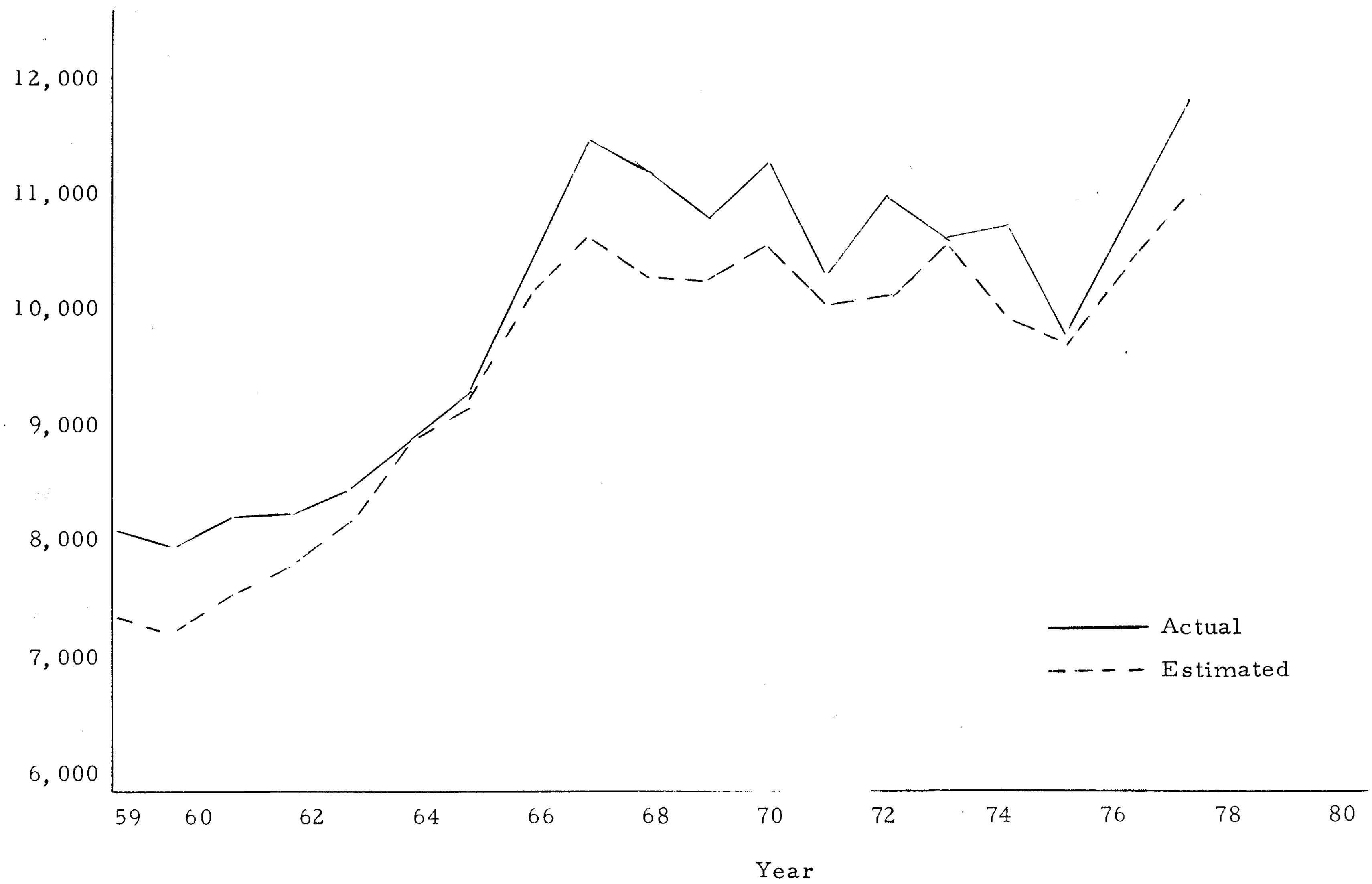


FIGURE 20

KOS - OTHER SHEEP

('000 hd)

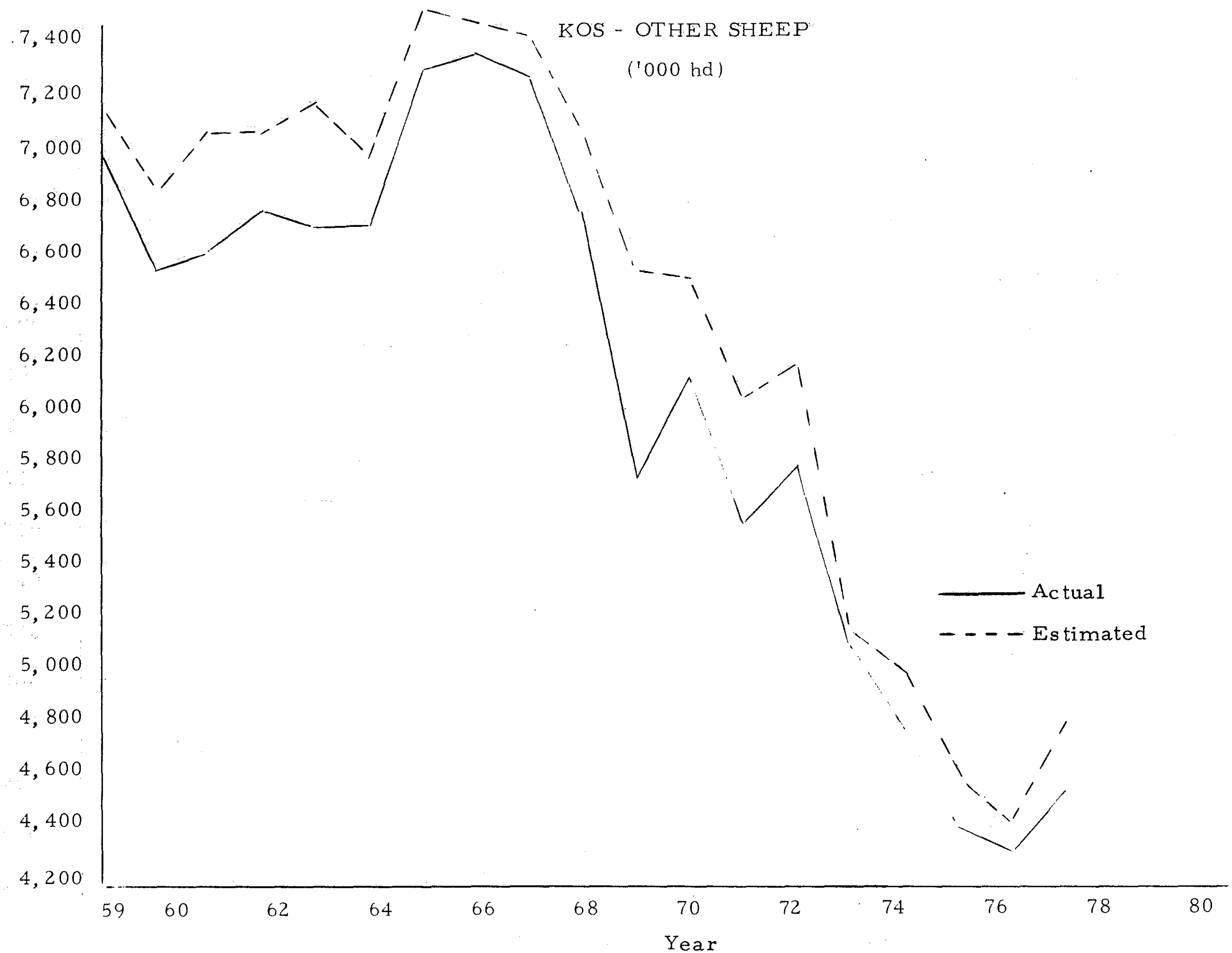


FIGURE 21

QPB - QUANTITY OF PRIME BEEF PRODUCED

('000 t, bone-in)

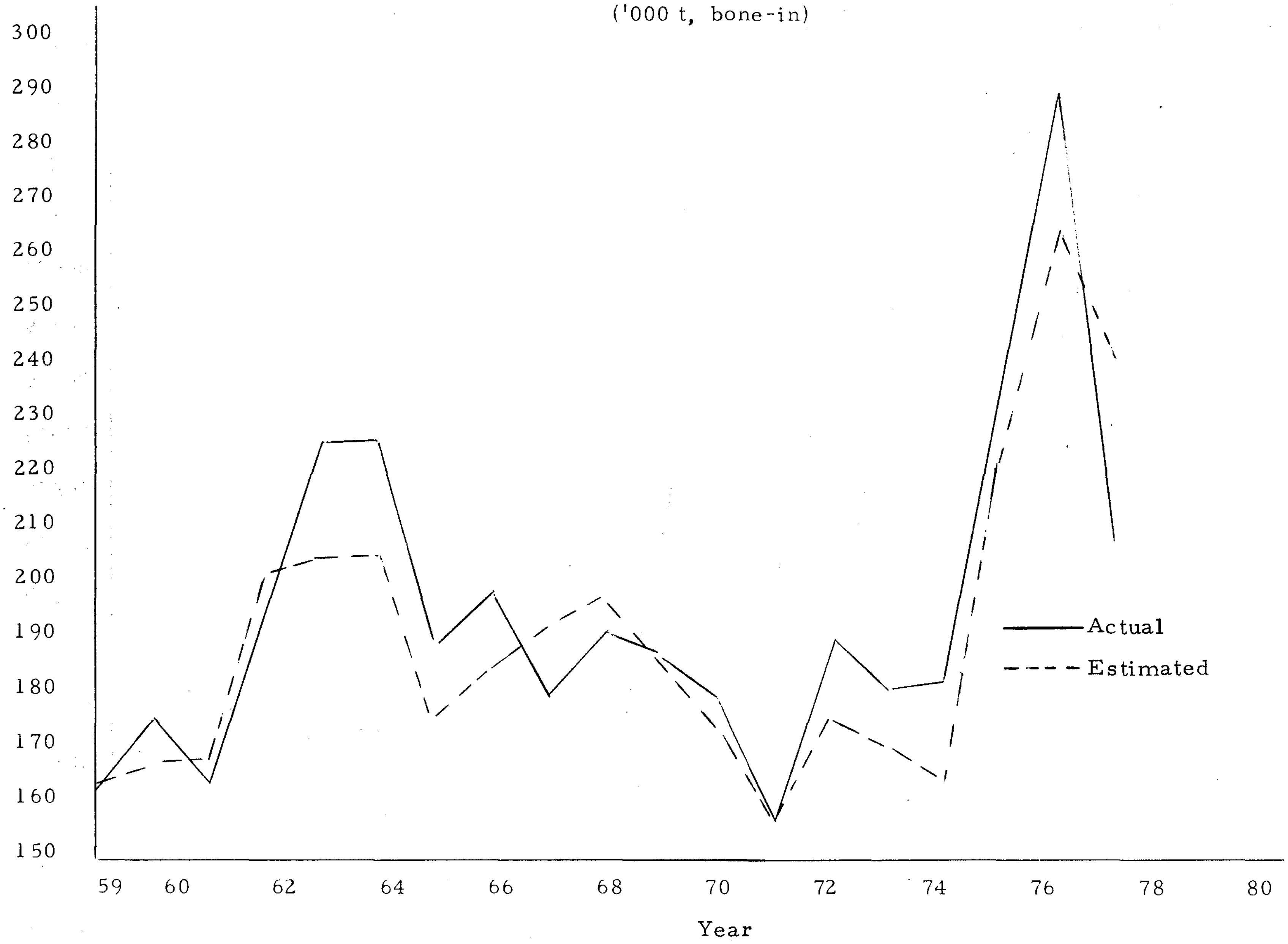


FIGURE 22

QMB - QUANTITY OF MANUFACTURING BEEF PRODUCED

('000 t, bone-in)

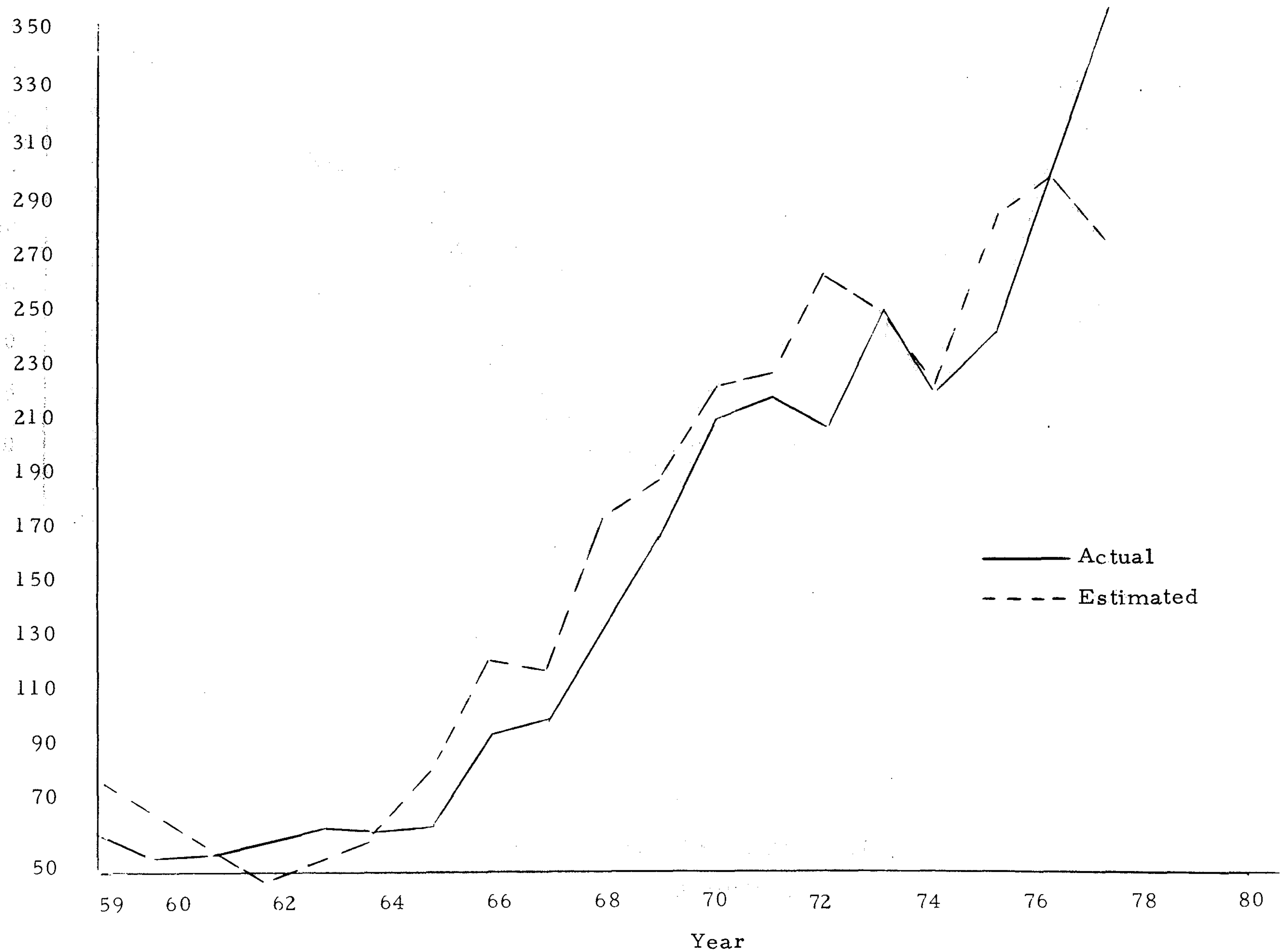


FIGURE 23

QW - QUANTITY OF WOOL PRODUCED

('000 t, greasy)

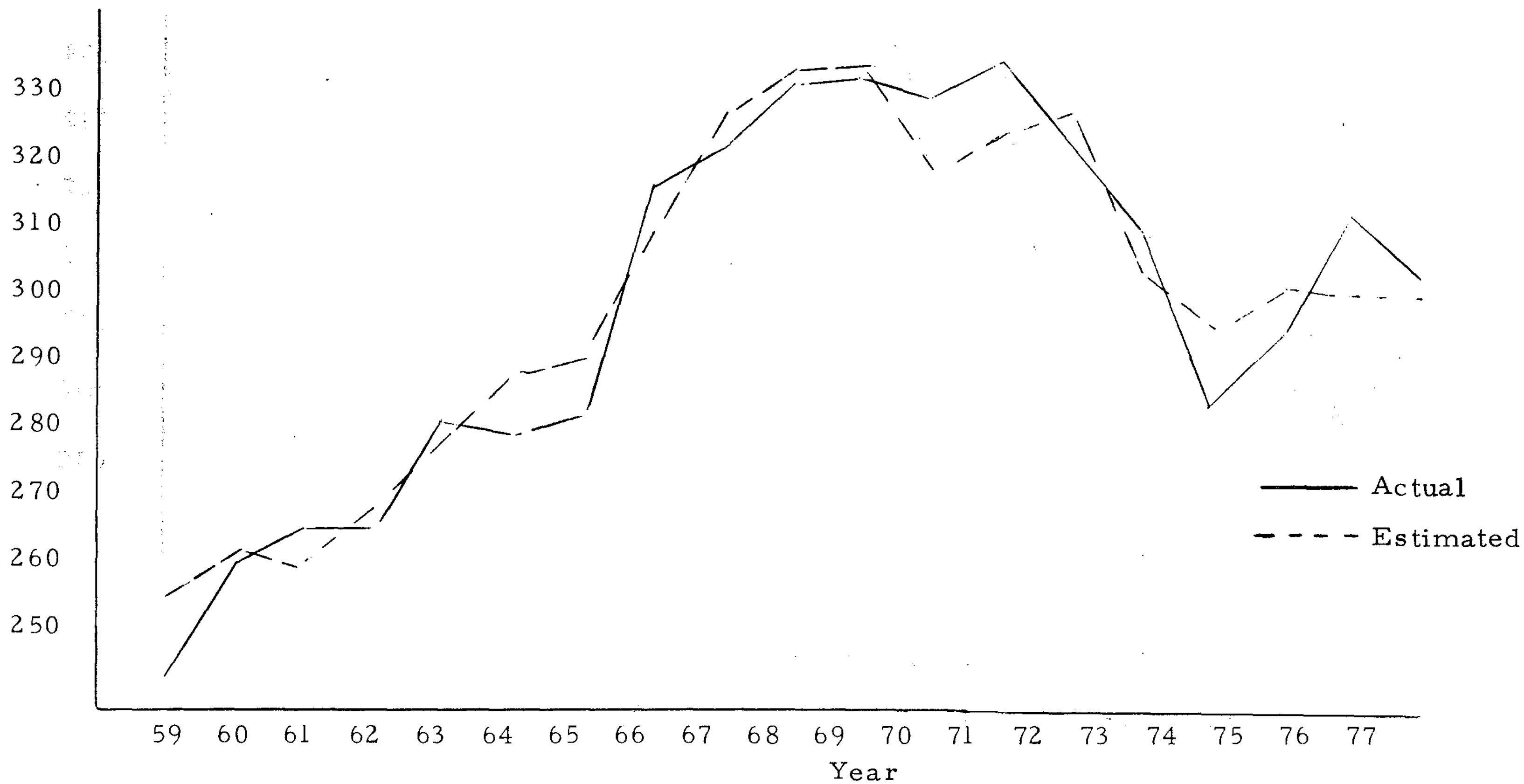


FIGURE 24

QL - QUANTITY OF LAMB PRODUCED

('000 t, bone-in)

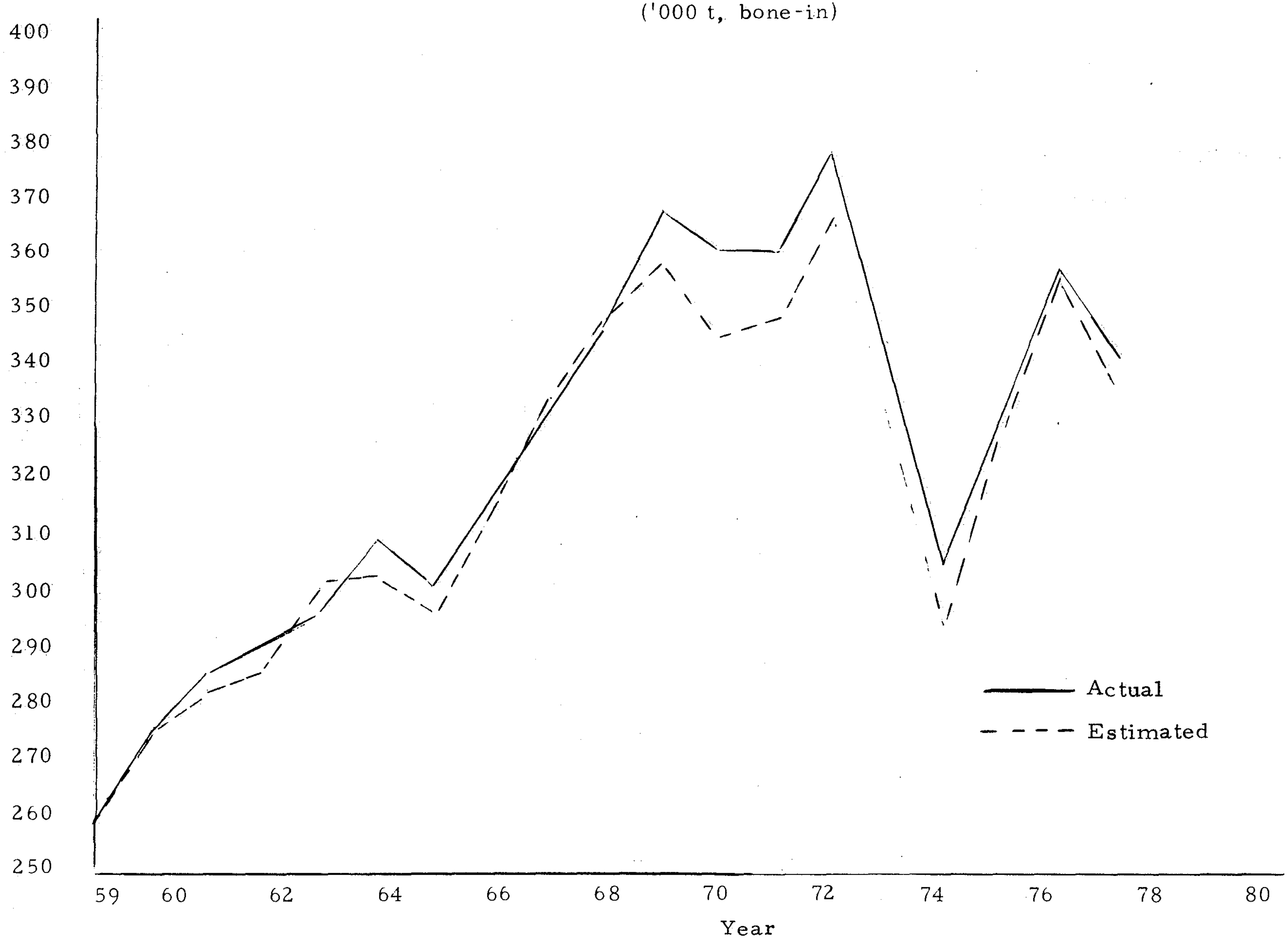


FIGURE 25

QM - QUANTITY OF MUTTON PRODUCED

('000 t, bone-in)

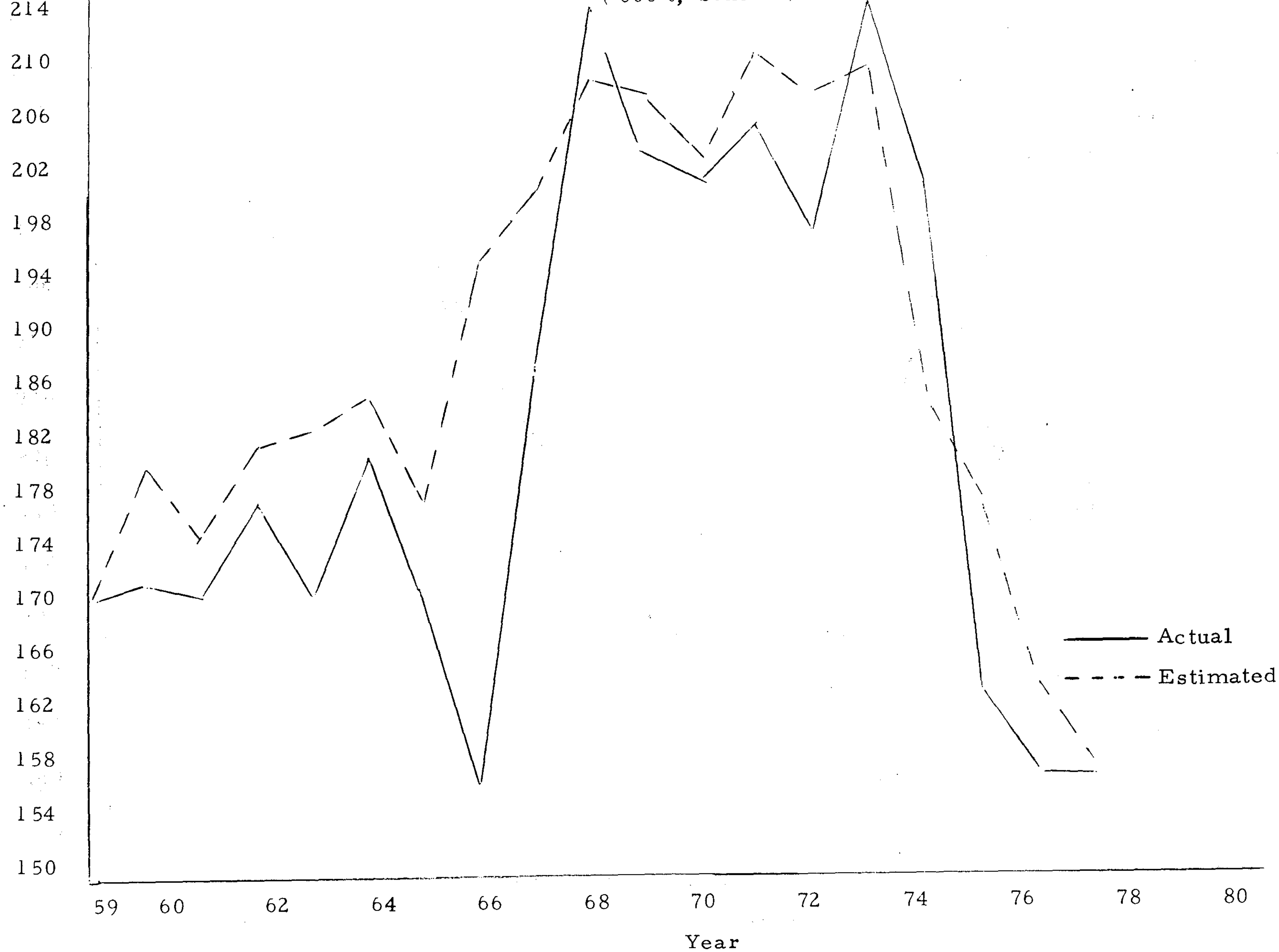


FIGURE 26

QMLK - QUANTITY OF MILKFAT PRODUCED

('000 t)

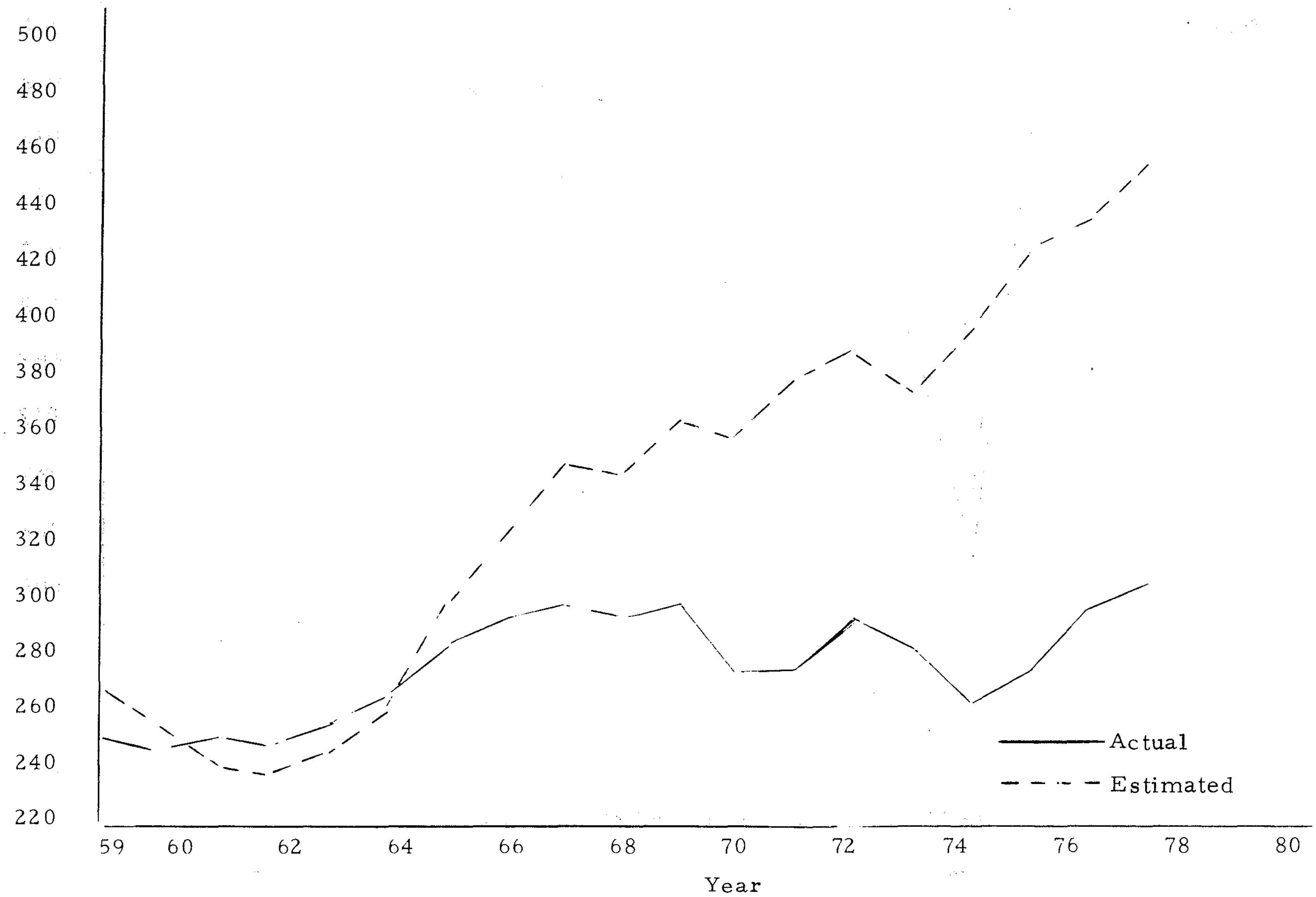


FIGURE 27

PRBPC - RETAIL PRICE OF PRIME BEEF

(c/kg)

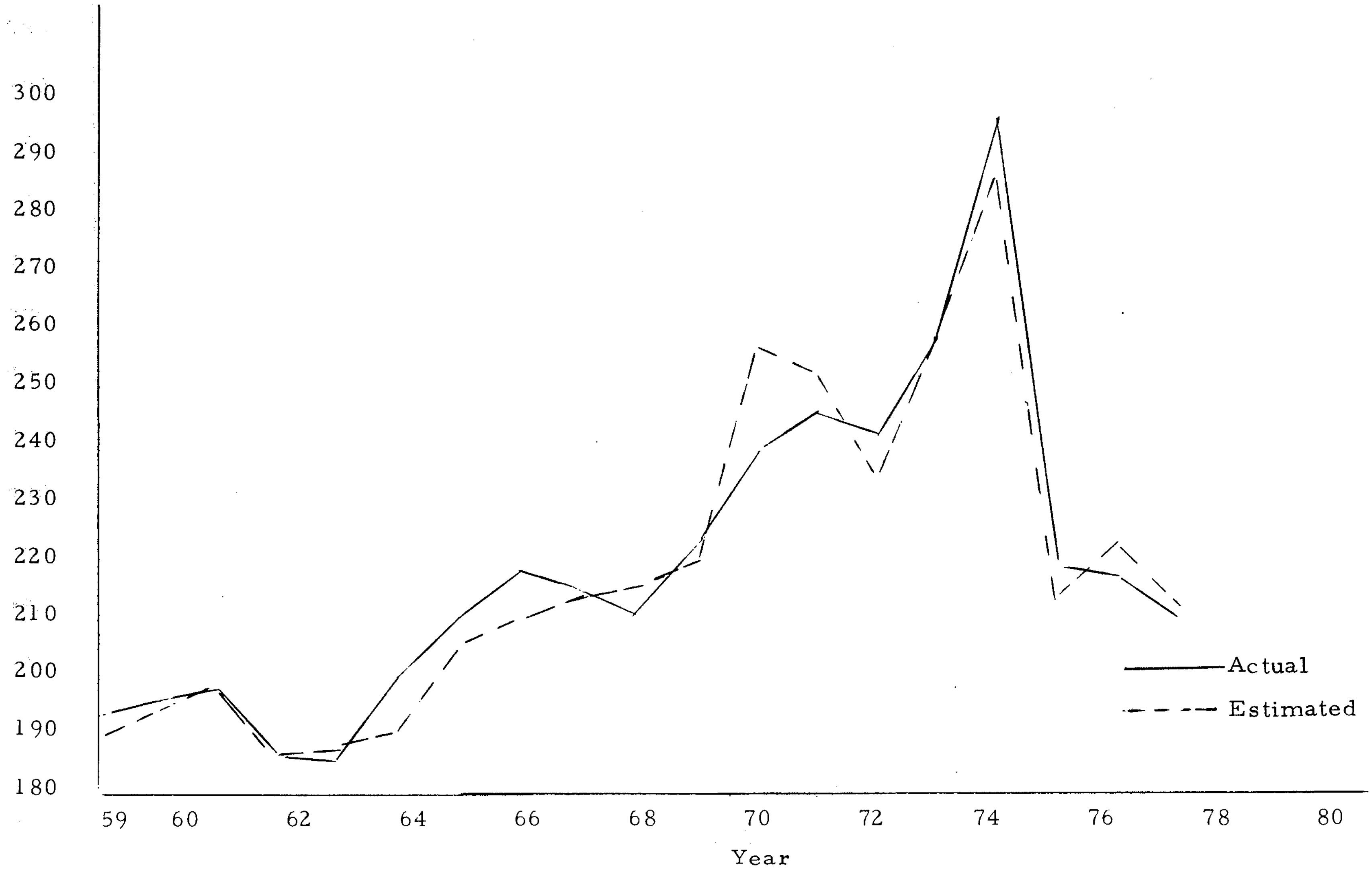


FIGURE 28

PRMC - RETAIL PRICE OF MUTTON

(c/kg)

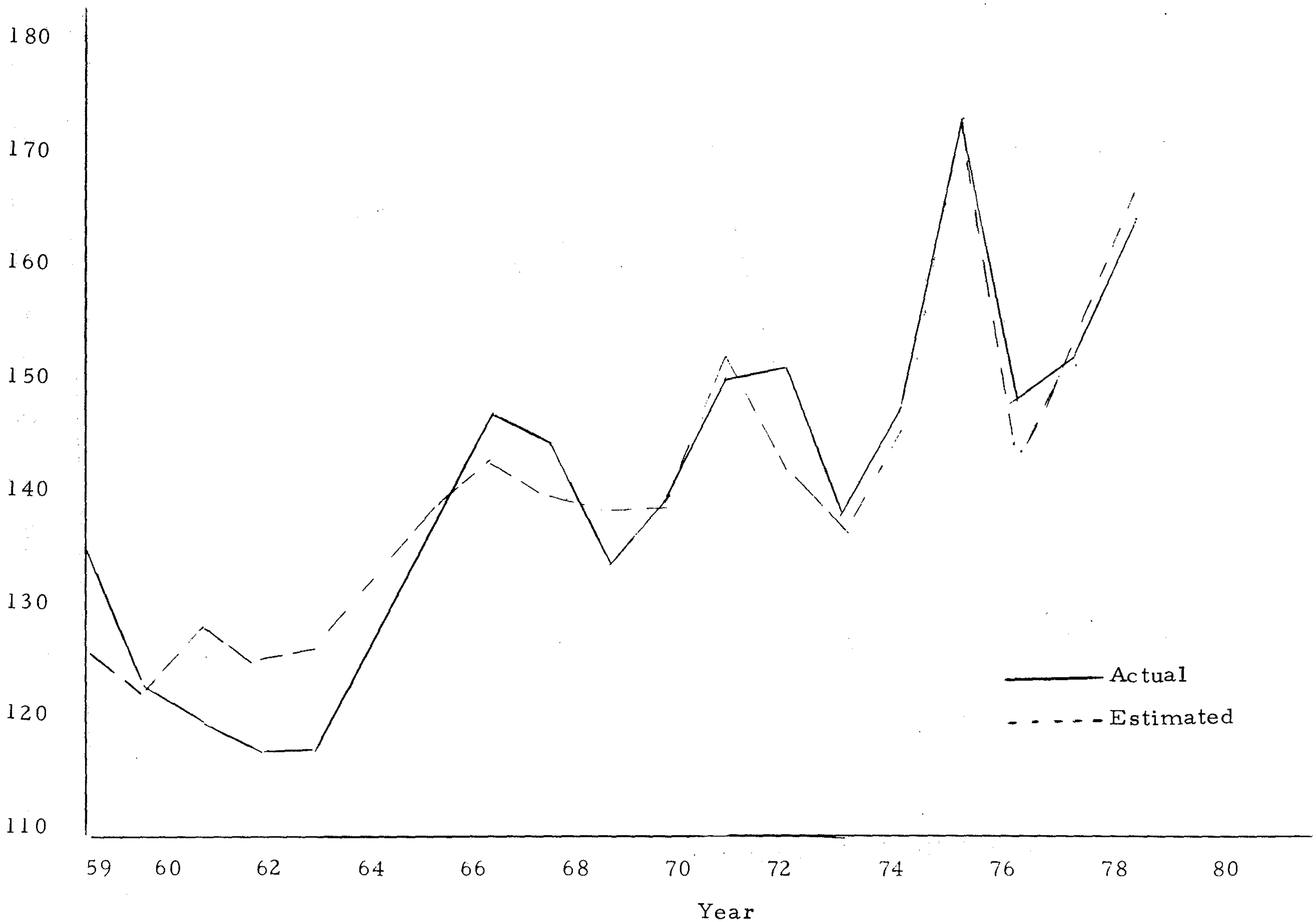


FIGURE 29

CBV - PER CAPITA CONSUMPTION OF BEEF AND VEAL

(kg)

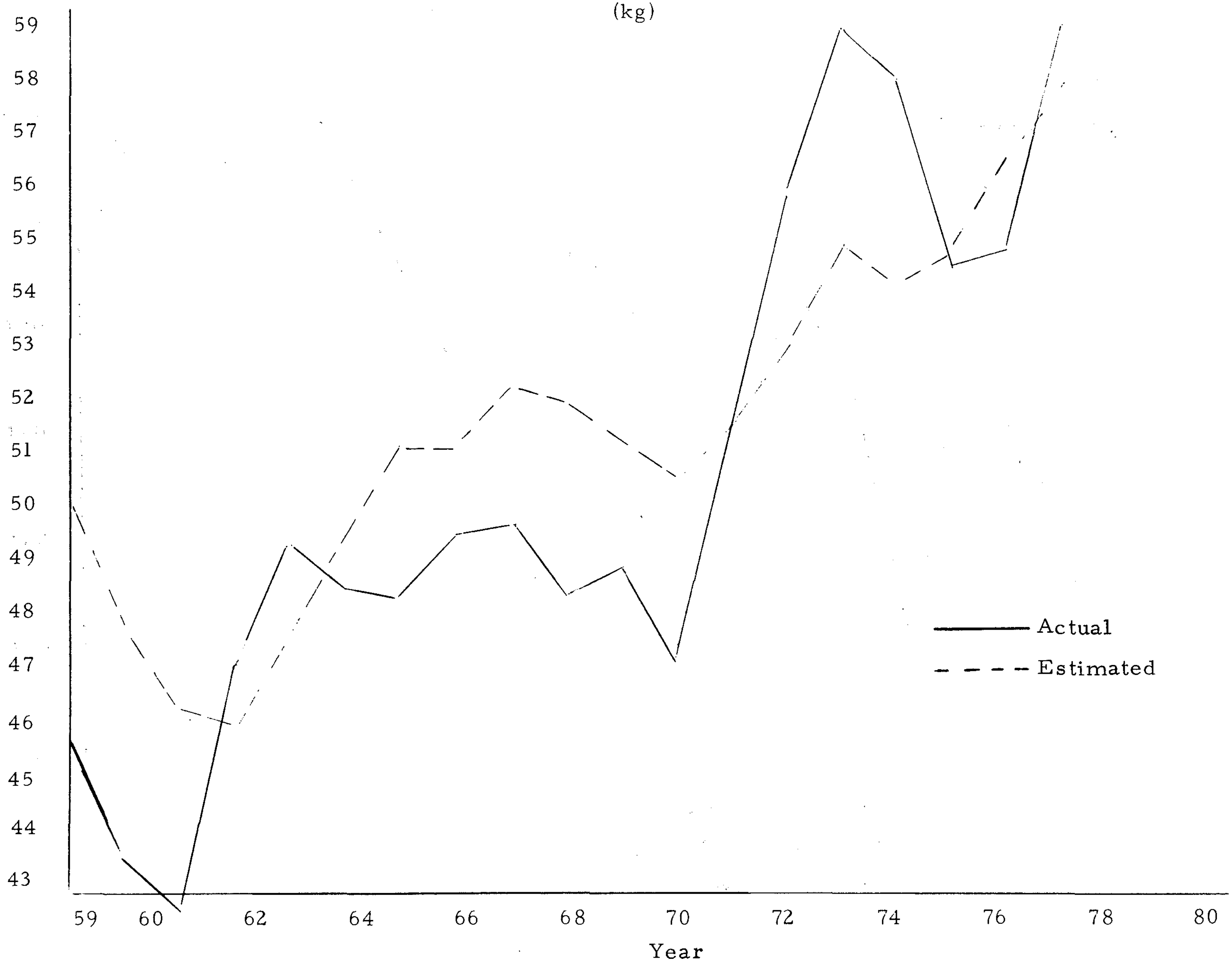


FIGURE 30

CM - PER CAPITA CONSUMPTION OF MUTTON

(kg)

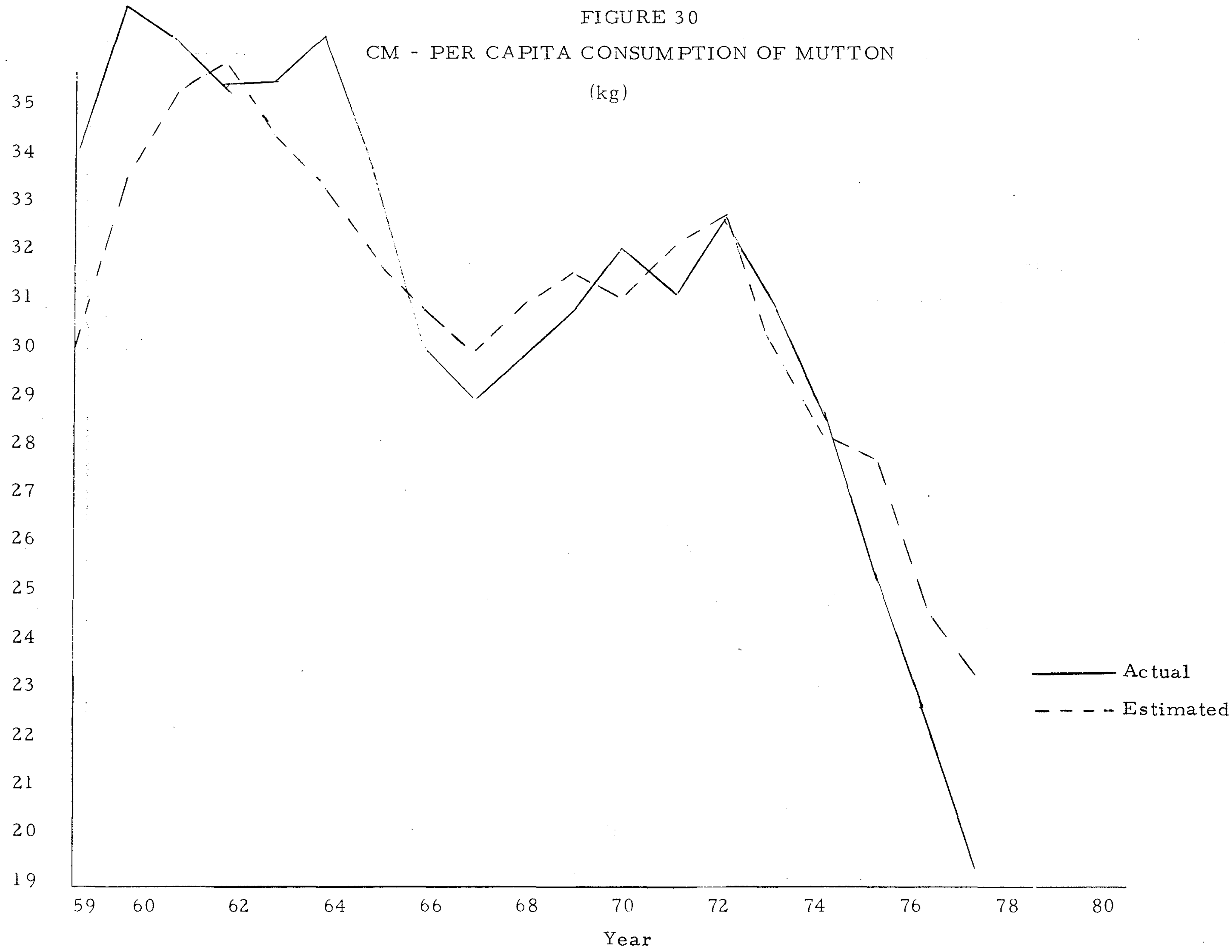


FIGURE 31

CL - PER CAPITA CONSUMPTION OF LAMB

(kg)

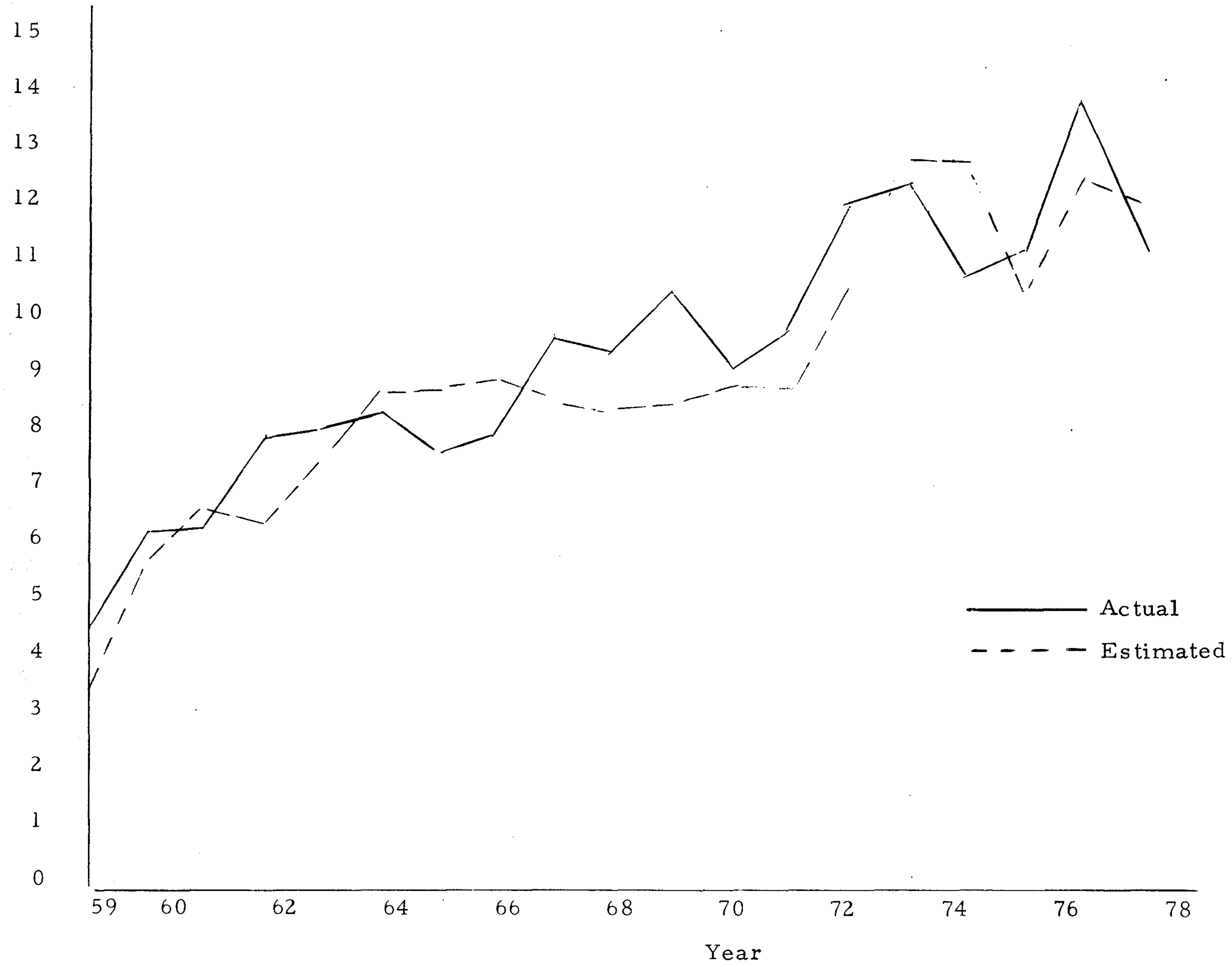


FIGURE 32

CP - PER CAPITA CONSUMPTION OF PORK

(kg)

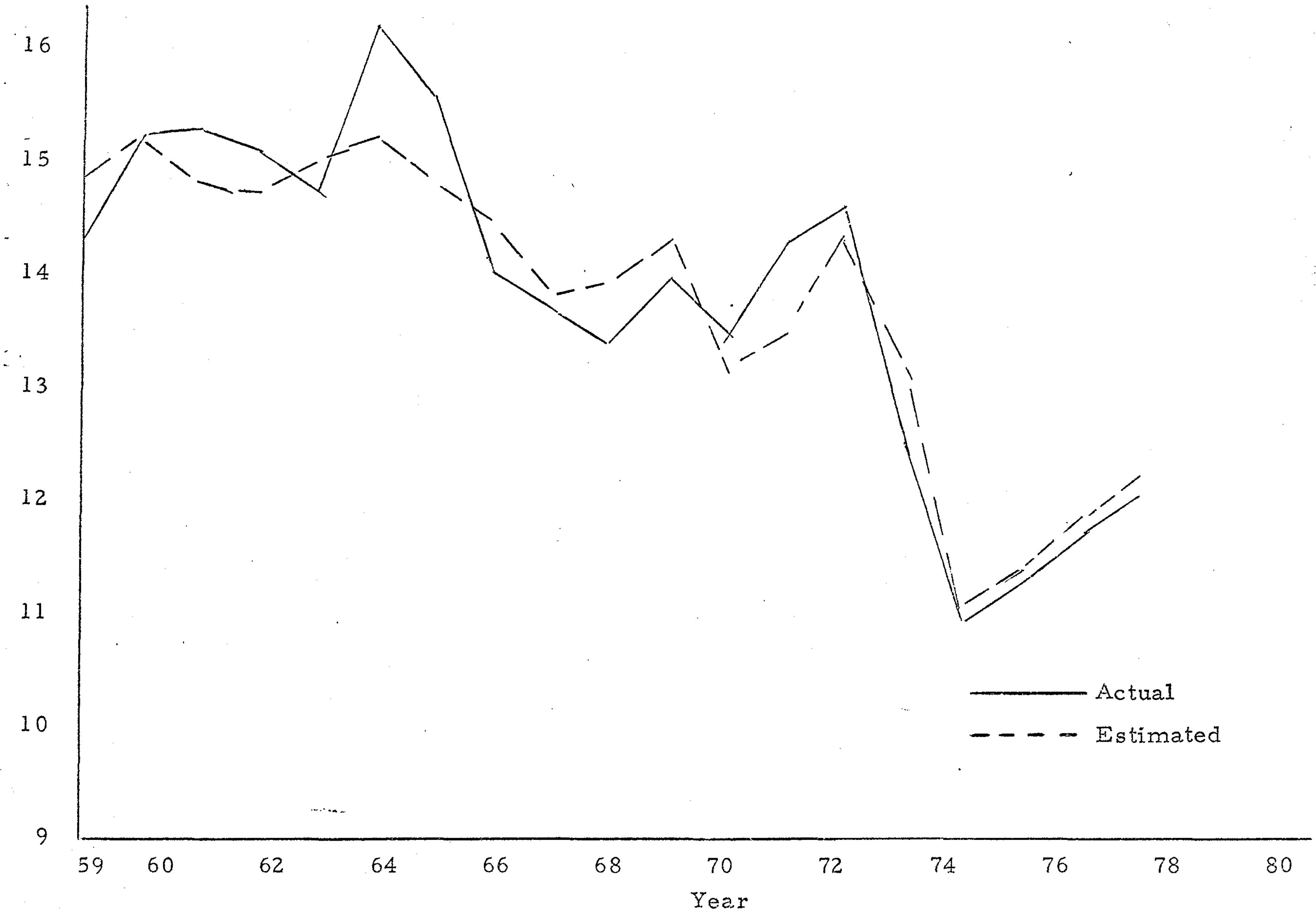


FIGURE 33

TCBV - TOTAL CONSUMPTION OF BEEF AND VEAL

('000 t, bone-in)

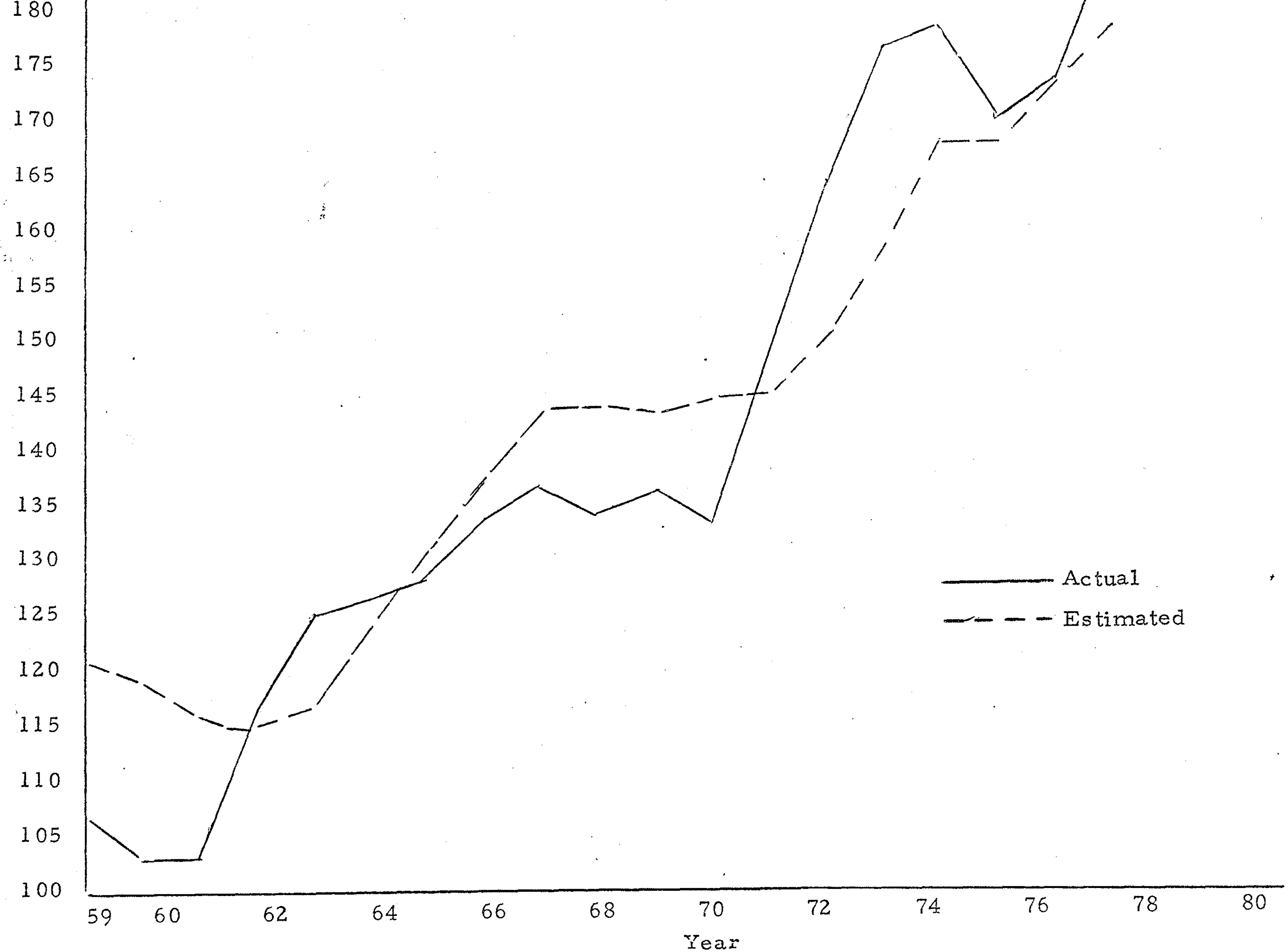


FIGURE 34

TCM - TOTAL CONSUMPTION OF MUTTON

('000 t, bone-in)

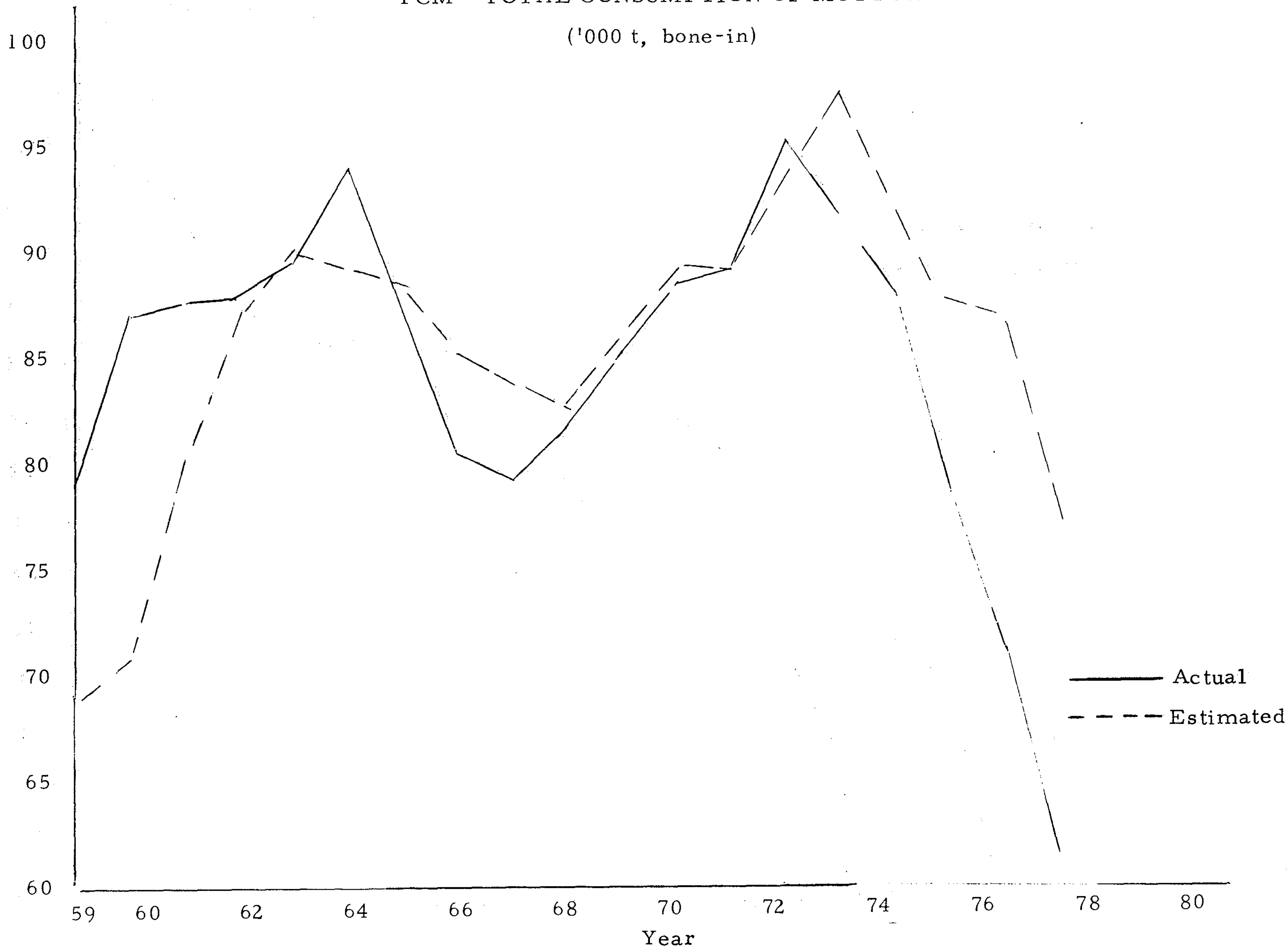


FIGURE 35

TCL - TOTAL CONSUMPTION OF LAMB

('000 t, bone-in)

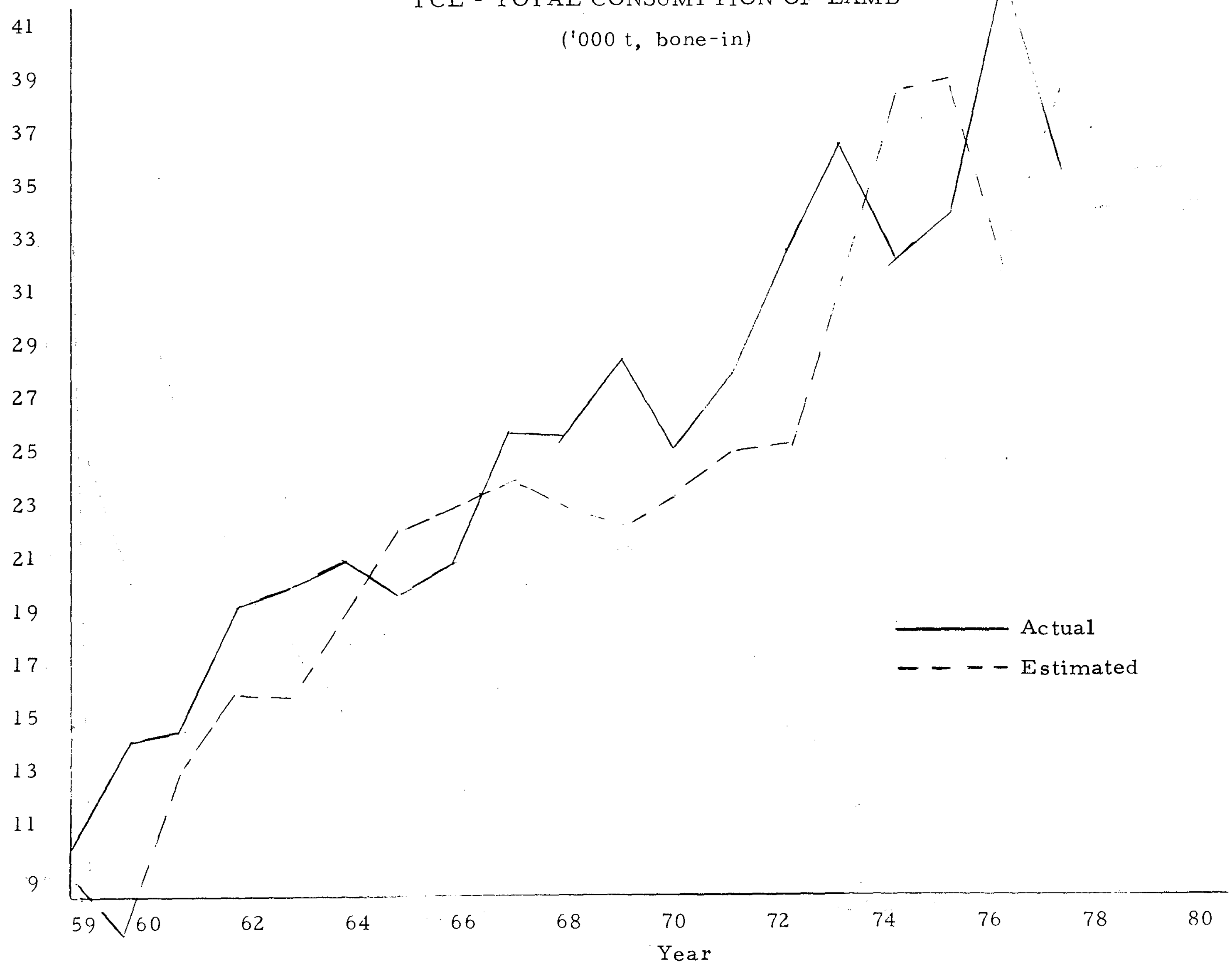


FIGURE 36

TCP - TOTAL CONSUMPTION OF PORK

('000 t, bone-in)

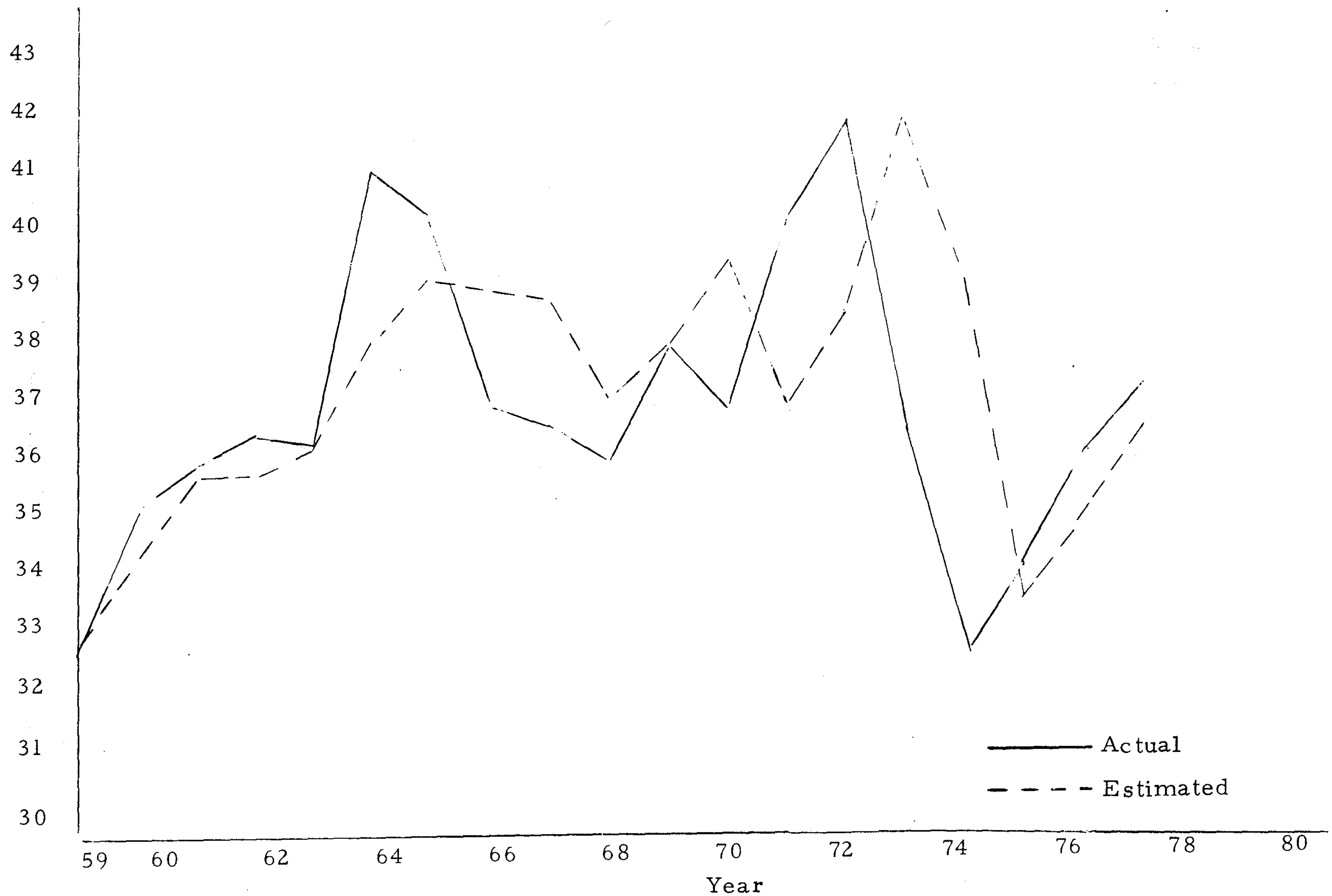


FIGURE 37

XBV - EXPORTS OF BEEF AND VEAL

('000 t, product weight)

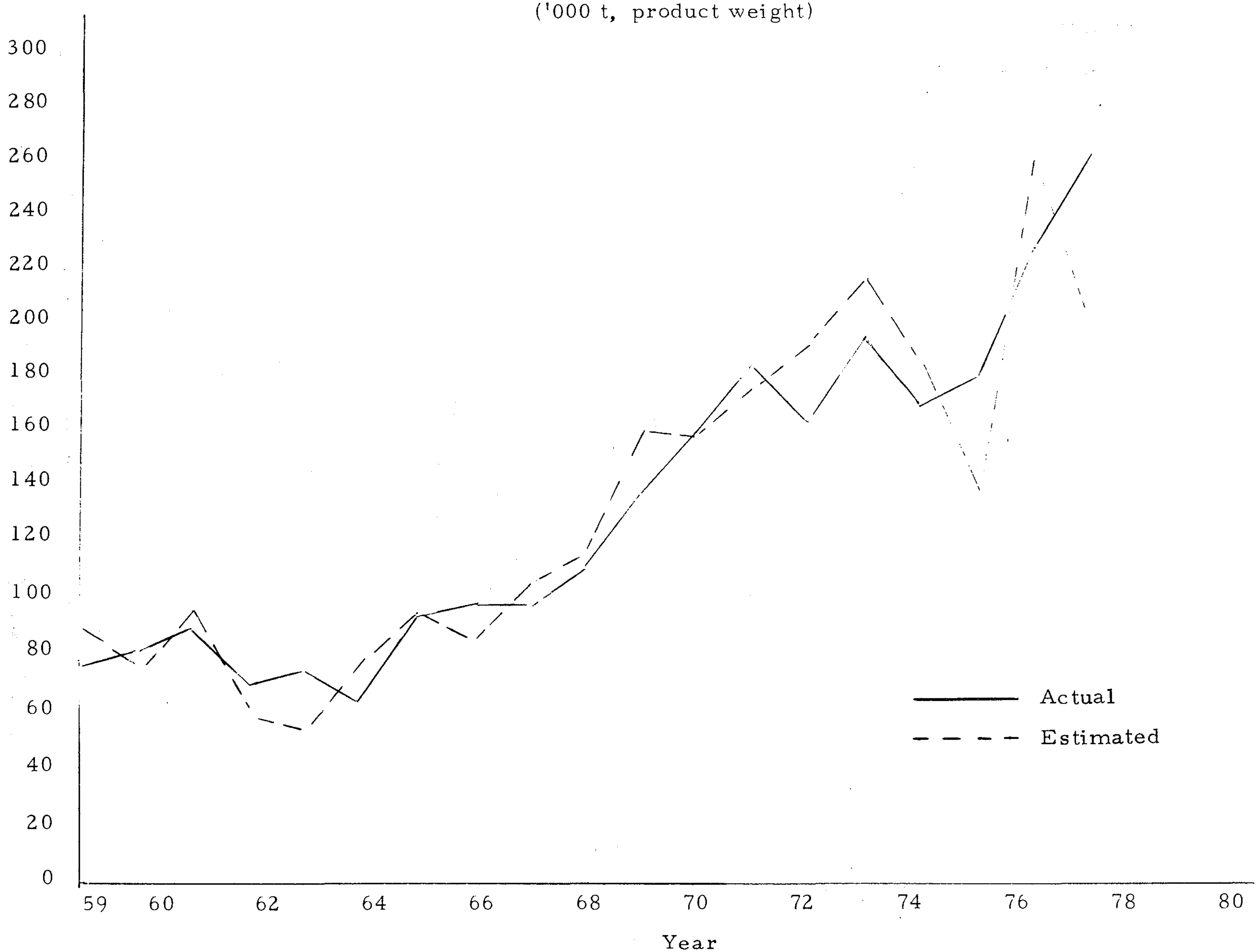


FIGURE 38

XM - EXPORTS OF MUTTON
('000 t, product weight)

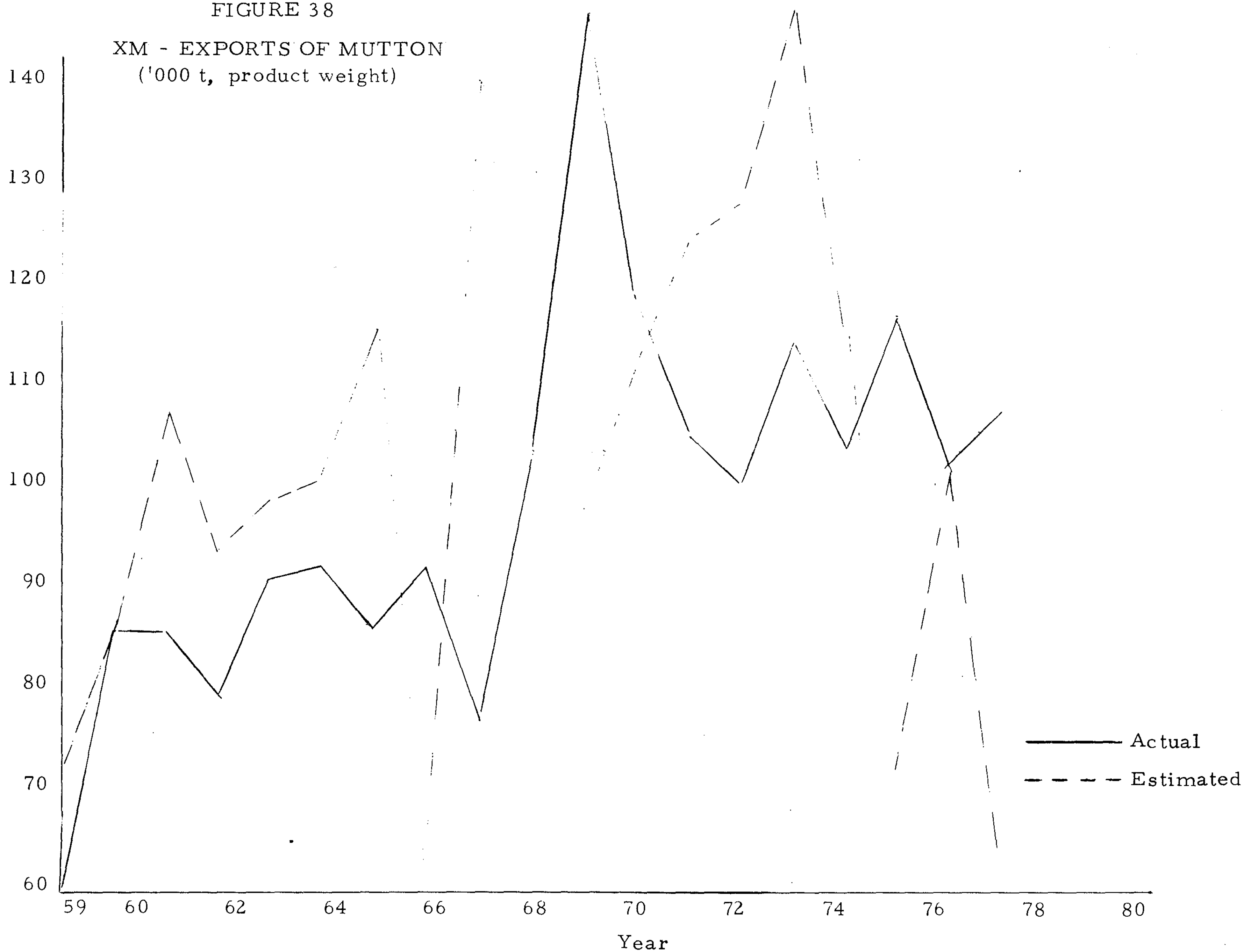
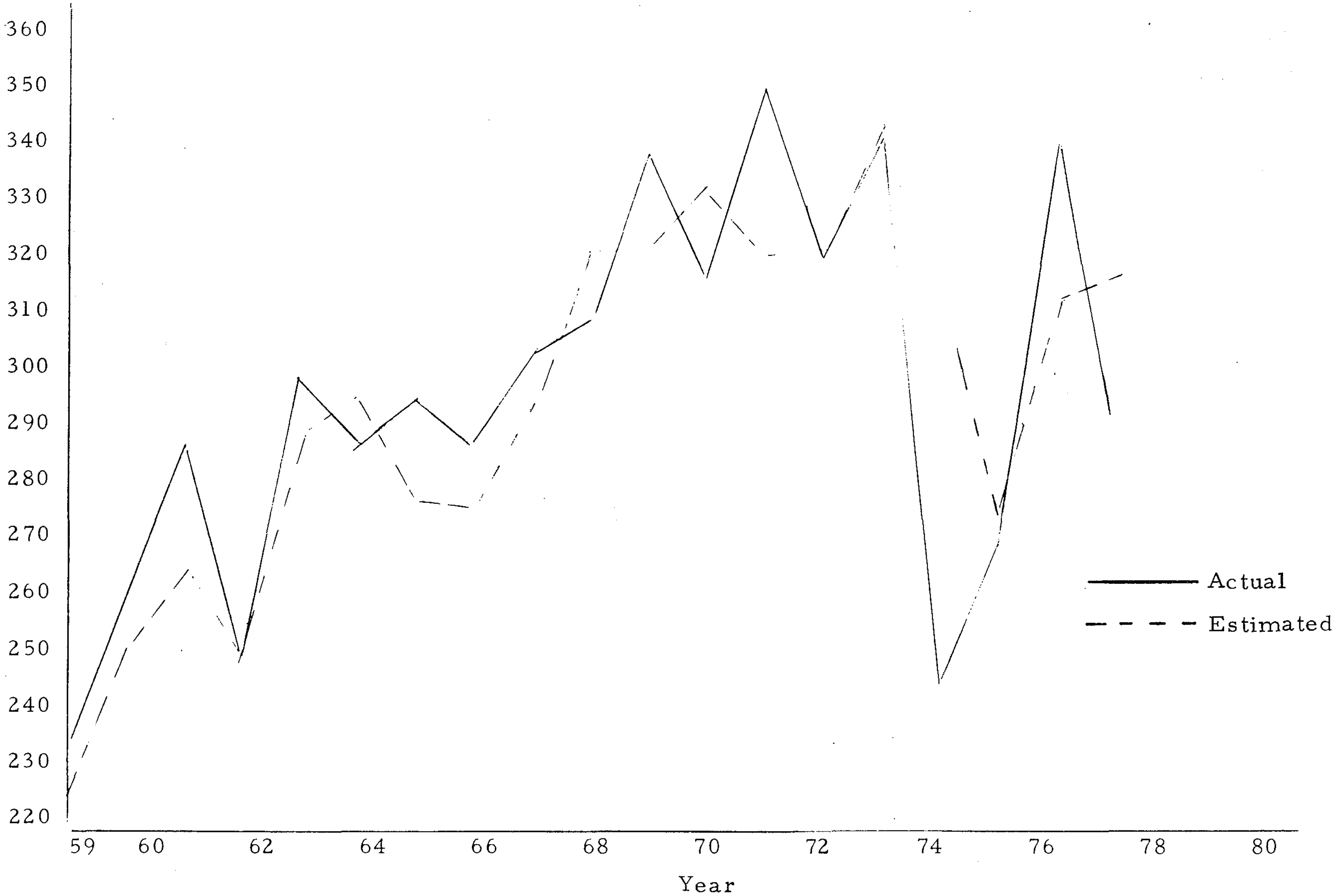


FIGURE 39

XL - EXPORTS OF LAMB

('000 t, product weight)



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