A STUDY

OF

THE AGGREGATE SUPPLY FUNCTION

OF

NEW ZEALAND WHEAT

by

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Thesis presented in part fulfilment of the requirements for the degree of Master of Agricultural Science and Honours in the University of New Zealand.

June, 1955.

INTRODUCTION

The acreage of wheat in New Zealand fluctuates quite markedly from year to year. The acreage grown depends upon economic conditions at the time of planting and certain technical factors. In this thesis an attempt has been made to identify the specific influence of certain of these economic and technical variables.

Reducing the discussion to its simplest terms, the aim of this thesis has been to answer such questions as:

"What is the effect on wheat acreage of 1d rise in the price of wheat?" or

"If the fat lamb schedule next year is 1/3d per lb., what will the effect on wheat acreage be?" or

"Given such and such conditions, what is the best estimate of the acreage which will be sown in wheat?"

and "What conditions are necessary in order that New Zealand should produce 100,000/200,000/300,000 acres of wheat?"

Answers to these questions are useful on two counts. Passively, administrators will wish to forecast domestic production when making arrangements to import wheat; and acreage has a big influence on production. Actively, administrators, or the Government, may wish to influence production and answers to the above questions will tell them the conditions under which this may be done.

The factors determining the price of wheat have been studied, as it was felt that the supply function for wheat could not properly be understood without some mention of these factors.

In attempting to estimate the influence of specific economic and technical factors on the acreage of wheat, there are two alternative methods which may be used. A sample of farmers can be asked how they reacted to different factors and which ones they considered to be the most important; or past records of important economic variables may be related to wheat acreage by statistical means.

The sampling method has a number of disadvantages. Firstly, it is only open to the investigator to discover what the farmer thinks is important in determining his production plans. Secondly, there are distinct "fashions" in farming opinion, so that a factor, say the shortage of labour, which looms large one year may be almost forgotten a year later. Thirdly, it is extremely difficult to aggregate the results of a survey as there is no common denominator to which replies of "not important", "very important" and "occasionally considered" can be reduced. The advantage of the survey approach is that it brings the investigator into close contact with producers, thus giving him a "feel" for farmer's behaviour and often revealing attitudes which would never have been deduced from purely theoretical considerations.(1)

The disadvantages of the statistical or econometric approach are that lack of contact with producers may lead the

(1) For a very interesting survey of wheat farmers see: D.B. Williams, Ross Parish and A.G. Bollen, "Attitudes and Expectations of Wheatgrowers in New South Wales". Review of Marketing and Agricultural Economics, Vol. 21, (1953).

investigator to neglect one or more important variables, that satisfactory data may not be available for certain of the factors which should be used, and that changes in the structure of the economy may invalidate the estimates.

The main advantage of the econometric method is that numerical estimates of the influence of the different factors are obtained, and these estimates reflect the way farmers have behaved in the past, and not the way they think they have behaved.

These two alternative approaches are, of course, complimentary. The time available for this thesis, however, meant that only one of the alternatives could be presented in any detail.

It was felt that the econometric approach would give a more useful answer to the problem being studied, or, in simpler terms, the answers to the questions outlined above would be simpler, more precise, and less subject to personal bias, if the econometric method were used.

That this conclusion was reached is not surprising as the writer was essentially interested in the econometric approach and the methodological problems involved in its practical use, and chose his subject accordingly. Had he been interested in problems of sampling or survey method he would have chosen another topic.

Another question which received consideration was whether to study certain "marginal areas" or total wheat acreage. It is, of course, the behaviour of the marginal areas that determines the changes in acreage from year to year and, in this sense, a study of them might provide an adequate answer to the questions asked. The marginal areas approach was rejected, however, as it was felt

that the designation of particular areas as marginal would be arbitrary, that the data for the "marginal areas" would be no more satisfactory than for total acreage, that after the 1951 harvest of 90,000 acres it was doubtful if the whole of the Dominion's wheat land should not be considered to be marginal, and that, in any case, it was the behaviour of total acreage which was of prime interest.

Chapter 1 shows that the price and quantity of wheat are not determined simultaneously, but successively. This means that the supply and demand functions may be considered separately.

The demand function has altered too often to be treated in any but a descriptive way. Thus, Chapter II is a survey of the factors which have determined the price of wheat in the period 1919-1953. This chapter does not claim to be a detailed essay in the economic history of the period, but it does present an account of the marketing arrangements over this period. The author had to make himself familiar with this material in order that he should be able to "feel at home" with the data used for the supply function. The information in this chapter is not essential to an econometric thesis, except as an argument against using econometric estimates to obtain a "supply function". It seemed possible, however, that a later student of the Wheat Industry might be saved considerable labour by the inclusion of this chapter.

The rest of the thesis is concerned with the estimation of the Supply Function for New Zealand Wheat. Chapter III deals in a general way with problems of specification, of multicolli-

nearity, and of auto-correlation of the error term.

Chapter IV discusses the specification of the supply function and the variables to be explored.

Chapter V presents the results of empirical testing of the data together with the results of a number of different hypotheses as to the supply function. All of the hypotheses are, of course, consistent with the empirical data.

ACKNOWLEDGMENTS

I wish to thank Dr. H. B. Low for his continuous advice and assistence in the preparation of this thesis, and Professor A. L. Rae, Mr. A. Glenday and Mr. G. P. Braae for advice on statistical problems.

CONTENTS

CHAPTER I

THE AUTONOMOUS NATURE OF THE SUPPLY AND DEMAND FUNCTIONS

In this chapter certain salient features of growing and marketing wheat in New Zealand are discussed.

1.1 An Annual Crop.

Wheat is an annual crop, with a comparatively long period of production. Wheat is sown between April and July and is harvested in January-February. Preparations for sowing start as early as March so that the production period is, effectively, March-April to January-February. The decision to produce, which must be taken about March, will depend upon economic and technical factors. Once the acreage has been decided upon, the yield will respond almost exclusively to technical factors; that is to say, economic factors in or prior to March may affect the quantity of wheat produced by farmers the following January-February. Subsequent to March economic factors will have little effect on the quantity produced. There is an exception to the latter statement in that a very low price might lead farmers to refrain from harvesting their wheat.

When the production decision is made, there are two alternatives: either wheat price for the subsequent harvest is known or it is not. If wheat price for the subsequent harvest is known at planting it follows that it must be determined without

knowledge of the quantity produced. In this case wheat price will be independent of the quantity produced. Wheat acreage, however, will probably be affected by the price fixed. The price fixed for the next harvest may well have been influenced by the production or acreage of the last harvest. Thus this alternative might be represented diagrammatically

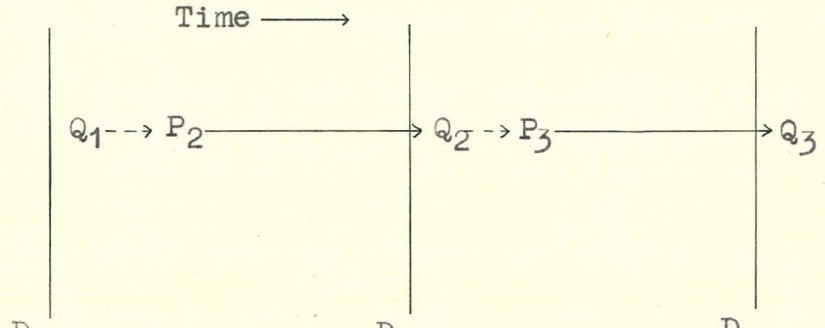

Fig. 1

Where the Q's represent the quantity of wheat produced, either in bushels or acres, the P's represent the price fixed and the subscripts indicate that the P's and Q's refer to the same harvest. It will be noticed that the arrows indicate a one way causal relationship. In the diagram the full arrow indicates a definite, firm relationship, while the dotted arrow indicates a more tenuous relationship. Thus, in Fig. 1 wheat price for period two, P_2 , may be affected by the quantity produced the previous harvest, Q_1. This tenuous relation is indicated by a dotted arrow, while the firm relation of the effect of P_2 on the quantity produced in the second period, Q_2, is indicated by a full arrow.

The other alternative is that the price to be paid for next harvest is not known at planting. In this case the price for the previous harvest will probably influence the acreage sown, because producers tend to take present price as the best estimate

of future price, and the quantity produced at harvest will probably influence the price for that harvest. In this case the system might be represented:-

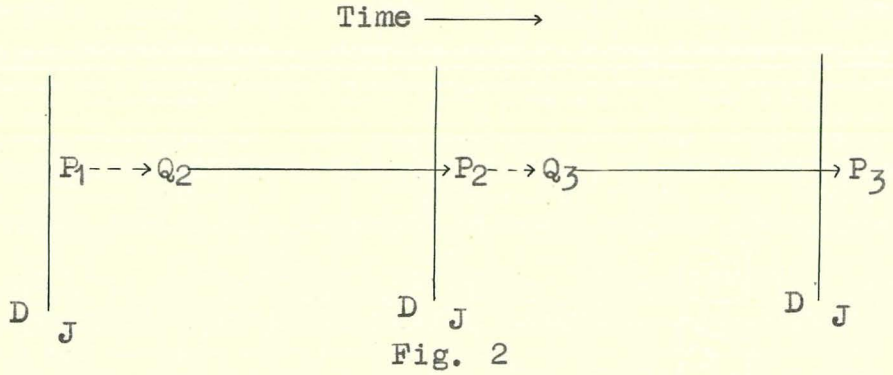

Fig. 2

Again, this is a set of one-way causal relations. The essential difference between Figs. 1 and 2 is that in Fig. 1 P_2 affects Q_2, while in Fig. 2 Q_2 affects P_2.

The important point about these systems is that in neither case are price and quantity determined simultaneously. Either price affects acreage, or acreage (together with yield) affects price, but the situation where the same price and quantity affect each other contemporaneously does not occur. This means that it is possible to distinguish between the factors affecting price and the factors affecting quantity.

1.2 The Factors Determining Wheat Acreage.

Just which are the important factors determining the acreage of wheat, and just how important each factor is, are the main subjects studied in this thesis. For the moment it suffices to establish the fact that the acreage of wheat sown for threshing depends upon economic and technical considerations in the March prior to harvesting; that is, the acreage of wheat may be considered to be the dependent variable in the supply function for New Zealand wheat.

If price at harvest ever fell so low that it did not pay some farmers to harvest their crops, then price and quantity would be determined simultaneously, as the low price would tend to reduce the supply, while the reduced supply would prevent price falling further. In this case a system of simultaneous equations would have to be used. There is no evidence that this situation has occurred during the period studied.

In the next chapter the marketing of wheat for the period 1920-1953 is described. The number of times these marketing arrangements have been changed means that the demand function for New Zealand wheat is not susceptible to estimation by econometric methods.

CHAPTER II

AN HISTORICAL SURVEY OF THE WHEAT INDUSTRY 1919-1953

In this chapter an attempt is made to describe the various forms the marketing of wheat has taken over the period considered. The discussion shows that the period is not suitable for examination by econometric methods as the "structure" has changed too frequently. The chapter gives some explanation for the price in individual years being what it was, and will supply a general background to the discussion of the Supply Function.

2.1 The General Structure of the New Zealand Wheat Industry.

Wheat in New Zealand is predominantly produced in the South Island in areas of comparatively low rainfall. It is produced on mixed farms which often rely on fat lamb or some other product to produce the major revenue. Between the Wars there were approximately seven thousand wheat farmers so that the individual farmer could not influence the market price for wheat. There are approximately fifty mills in the Dominion which purchase New Zealand wheat for milling into flour. Second grade wheat is sold to poultry producers and for stock feed. When domestic production exceeds demand wheat may be sold for export, while the normal excess of demand over supply is met by importation.

Marketing arrangements have not been uniform over the whole of the period studied, and the more important changes in marketing arrangements are now considered in greater detail.

2.2 Government Control 1919-1922.

Complete Government control of the New Zealand Wheat Industry was first instituted by an Order in Council of the 22nd December, 1917. This order prohibited private dealing in wheat and made arrangements for the Government to purchase all milling wheat harvested in 1918. Good milling wheat and Free inferior wheat were defined, and provision was made for registered wheat brokers to handle the crop on behalf of the Government. All wheat produced (save 100 bushels per producer) had to be offered to a Government Wheat Broker. The broker had to purchase all f.a.q. milling wheat at the controlled price. Any wheat offered to the Government broker but rejected as below f.a.q. standard became known technically as Free Wheat and could be disposed of privately by the grower. Millers were forbidden to use Free Wheat for milling purposes so that most Free Wheat was sold to the poultry industry. Millers were granted Wheat Purchase Warrants by the Wheat Controller in proportion to their output of flour in previous years. Wheat was sold to the miller by any broker on the presentation of a wheat purchase warrant. The price of wheat to millers was sufficiently in advance of the price to growers to cover the broker's costs.

The formal Government organisation consisted of:

(1) The Wheat Controller and his staff, with headquarters in Christchurch.

(2) The Government Brokers, licensed by the Board of Trade and bound to keep faith with the regulations.

(3) The Wheat Trade Advisory Committee, consisting of represen-

tatives of wheat-growers, flour-millers and Government brokers, to confer with the Wheat Controller when required.

Neither the millers nor the growers had a central marketing organisation. These marketing arrangements persisted for the harvests 1918-1922.

The prices for the four harvests 1919 to 1922 were 6/6d, 7/3d, 7/6d and 5/6d per bushel March Tuscan, f.o.b. South Island ports, respectively.(1) The first three prices were "incentive prices" which aimed to make New Zealand self supporting in wheat. It seems likely, however, that much of their potential effectiveness was sacrificed owing to the prices being announced subsequent to planting, so that growers, instead of being sure of a high return, were gambling that the Government would be as generous this year as last.

By March, 1921, the prices for fat lamb and wool reflected the post-war slump and wheat appeared to be a relatively attractive crop. Wheat acreage expanded to 353,000 acres (as against an average of 213,000 acres for the previous five seasons). It seemed likely that the Government would have to dump surplus New Zealand wheat overseas on a very depressed market. The increased acreage was apparent by July, 1921, and the harvest price for 1922 was announced at once as 5/6d per bushel to keep spring sowings as small as possible. 10.5 million bushels were produced but by strict grading The Government was able to avoid purchasing more than 7.9 million bushels at the guaranteed price. The price to

(1) These prices are quoted from the Parliamentary Wheat Committee 1929, p.249 f.f. It is explained on p. 54 below that the prices given by the Wheat Committee were used for the computations in this study.

millers was fixed ninepence in advance of the price to growers to provide a fund to offset losses on wheat dumped overseas. The loss was not as large as anticipated so that the Government made a net profit. This profit was used in subsequent years to subsidise the price of bread.

In 1918, 1919 and 1920 the Government imported Australian wheat to make good the local deficiency. A profit was made on these transactions. The profit was used to subsidise the price of flour.

2.3 The Harvests 1923-1927.

On the understanding that there would be no increase in the price of bread the Government relinquished control of New Zealand grown wheat for the 1923 harvest. The ban on private importing was maintained for the 1923 and 1924 harvests and this permitted the Government to dispose of its carry over from the 1922 harvest. There was no carry over from the 1923 harvest but when the removal of the ban on private importing was discussed it was contended that if the duty on imported wheat and flour was re-imposed it would be impossible to keep the price of flour down to £15:10:0 f.o.b. South Island ports, while if imports were allowed duty free millers using imported wheat would make higher profits than those millers who had already purchased the higher priced New Zealand wheat. The Government imported sufficient wheat to meet millers' requirements.

It was known in 1922 that the Government intended to relinquish control of the Wheat Industry. On the initiative of Mr. W.G. McDonald, the millers formed an organisation, Distributors

Ltd., to handle the marketing of flour.(2) This company was monopolistic in tendency. The supply of flour to the market was limited by restricting the output of individual mills. In November, 1922, the company handled the flour produced by all mills in New Zealand except two large mills in Auckland (Bycrofts Ltd. and the Northern Roller Milling Co.) and five small mills.(3) This led to the organisation being prosecuted under the Commercial Trust Act. The Government's case was lost when an appeal by Distributors Ltd. to the Privy Council was allowed.

A farmers' Wheat Committee was formed in 1923 under the chairmanship of Mr. G.W. Leadley of Ashburton, a former member of the Wheat Advisory Committee. This organisation was in no way designed to act as a monopolistic organisation but rather to express growers' views, and to attempt to represent their interests.

At the beginning of 1923 there was a carry over from the 1922 harvest and an anticipated surplus from the 1923 harvest. The growers' organisation was in no way strong enough to consider holding a portion of the crop off the market, so that in the absence of

(2) From 1901 to 1914 the majority of the flour marketed in New Zealand was handled by the New Zealand Flour Millers' Co-operative Association Ltd., and from 1914 to 1917 by the New Zealand Flour and Produce Co. Ltd. These Associations acted both as monopsonists and monopolists (Copland "Wheat Production in New Zealand" p. 244), wheat being purchased by the Association and parcelled out to the millers who would mill it and sell their flour through the Association. In 1917, with the commencement of Government control, the New Zealand Flour and Produce Co. Ltd. had no further useful function and went into voluntary liquidation. Thus, Distributors Ltd. was not the first millers' organisation.

(3) Evans, "A History of the Wheat Industry in New Zealand", Thesis, Canterbury University College, 1938, p. 94.

Government intervention there seemed to be little reason why the price should not be forced down to export parity. The Government however, did exert its influence to encourage the millers to come to an agreement with the farmers' Wheat Committee. A satisfactory arrangement was reached for the 1923 and 1924 harvests, the price being 5/3d f.o.b. March Tuscan. The payment to growers was slightly below the cost to millers, due to the costs of administration, and the formation of an equalisation fund which did not have to be used and was eventually distributed to growers.

In December, 1924, a Gazette notice revoked the embargo on the importation of wheat and flour as from the 1st March, 1925. The duty on wheat was 1/2½d per bushel and on flour was £3:0:0 per ton.

A sudden fall in the world price of wheat led to a deadlock between millers and farmers, the latter claiming a higher price than the millers would pay. The Government was consulted as a result of a conference held in Wellington on the 23rd April, 1925. The conference was attended by representatives of the wheatgrowers, the executive of the National Farmers' Union, the millers, poultry men and grain merchants, and the following resolution was sent forward to the Government: "That in order to overcome the present deadlock in the wheat situation and secure for the New Zealand wheatgrower a fair price for his produce and to ensure a continuance of wheat growing on a scale sufficient for the Dominion's growing requirements, this conference requests that the Government should either reimpose the embargo on flour or levy a dumping duty on further importations".

Cabinet, after discussion with the Minister of Agriculture, decided that millers were to offer 6/8d for Tuscan, an advance of 5d on the ruling prices, the millers to be rewarded by an increase in the price of flour.

In May, 1925, the millers and growers met and agreed to a price of 6/5d[4] for the 1926 harvest, the growers to plant sufficient for New Zealand's requirements. This agreement was ratified by the Government. Bad weather and the fact that growers were not individually under an obligation to increase their acreages prevented growers from planting more than half the necessary acreage.

At the end of 1925 it appeared that the 1926 harvest might be dominated by a low world price. The Industry requested the Government to take control of the 1926 harvest. Accordingly, the Government gazetted notices in December, 1925, and January, 1926, prohibiting respectively private dealings in wheat and private importation. The other preparations necessary for the control of the Industry were also made. A shortage of wheat in New Zealand, together with a comparative failure of the Australian harvest, reconfirmed the Industry's faith in the market mechanism, and the Government was persuaded to revoke its Gazette notices and to permit the free market to operate behind a tariff. A price of 6/10d f.o.b. March Tuscan was established by the market.

The 1927 harvest was a good one and a price of 5/8½d was established. This led to allegations of dumping and a demand from growers for an increase in the duty of flour from £3 to £4

(4) Wheat Industry Committee Report, but see Evans "A History of the Wheat Industry in New Zealand" where the price is given as 5/6d.

a ton. The Government placed the growers' request before the 1927 Tariff Commission. The Commission suggested the Sliding Scale and in May the Government announced that the sliding scale of duties would be included in the Customs Amendment Act 1927.

2.4 The Sliding Scale 1928-1932.

In October, 1927, Parliament passed the Sliding Scale of Duties. The sliding scale provided for a duty of 1/3d per bushel when the price at the port of export was 5/6d per bushel. The duty increased by a halfpenny for every halfpenny the price at the port of export was below 5/6d and decreased by a halfpenny for every halfpenny the price at the port of export exceeded 5/6d until when the price at the port of export reached 6/9d the duty ceased to operate. A similar duty was imposed on flour, the rate being £3:10:0 a ton when the price at the port of export was £13:10:0, the duty disappearing when the price at the port of export was £17:0:0 a ton.

The argument used to support this duty was that New Zealand was not self-supporting on wheat but needed to be for defence, or that farmers' costs were inflated by the protection afforded to secondary industry and thus protection was needed to compensate farmers for these increased costs. The sliding scale meant that at a time of low world prices the farmer got the protection he needed, while when the world price rose the duty did not press so heavily upon the consumer as would a fixed tariff.

Under the sliding scale a monopoly seller of wheat could make a nice calculation as to the maximum price that could be charged for New Zealand wheat without losing the market to

imported wheat or flour. Further, such a monopoly seller would not seriously be embarrassed by production in excess of domestic requirements as the surplus could be dumped oversea without endangering the price charged for wheat sold locally. Thus it is not surprising then that the growers should form a monopolistic marketing organisation.

In December, 1927, following the passing of the sliding scale, a meeting of wheatgrowers in Ashburton appointed a Wheat Committee, under the chairmanship of Mr. W.W. Mulholland, to look after their interests. Specifically, the committee was instructed "to assist in marketing this season's wheat (i.e. 1927-28) and to do all possible to obtain the value of the wheat for the growers; and to this end, to endeavour to co-operate with stock and station agents, etc. ..... to devise a permanent scheme for marketing wheat in future seasons; to submit such a scheme to the growers through the medium of the Farmers' Union and Agricultural and Pastoral Associations and to invite them to appoint representatives to attend a conference to decide whether or not to accept it".

The 1927-28 harvest was too far advanced for the Wheat Committee to do more than advise farmers of the general wheat position and to indicate the prices which farmers might expect to be able to obtain. The price for the 1928 harvest was 5/8½d and there was a carry over of 1½ million bushels. Conferences were held with Stock and Station Agents and the grain merchants in various centres, and a scheme was drawn up for the marketing of the 1929 harvest.

The scheme was approved by growers and the Wheat Committee was authorised to go ahead with the formation of "The New Zealand Wheatgrowers' Co-operative Association Ltd." with a subscribed capital of £50,000. This company was generally referred to as "The Pool".

Growers were canvassed to take shares in the company and to sign a contract by which they, the growers, contracted to sell all their milling wheat through the Pool for the next five years. These contracting growers had to take at least four £1 shares in the company and were known as "Pool"-growers as distinct from the "Free" growers who had not contracted for the sale of their wheat. The Pool managed to get control of 40 per cent of the crop.

The carry over of 1½ million bushels from the 1928 harvest had to be shouldered by the Pool before it could "stabilise" or control the market.

It has often been remarked by economic theorists that the most advantageous position for an entrepreneur is to be a free agent in an otherwise organised market. This proved to be the case for wheat growers. The Pool, in order that the market price might be maintained, was forced to hold its supplies off the market until the free growers had disposed of their crops. Thus, the free growers were able to sell their crops as soon as they were harvested at the high price guaranteed by the Pool, whereas the Pool had to wait before it could sell and had to carry any surplus there might be from season to season. It has been estimated that the Pool managed to raise the price of wheat

about 9d above what it would have been on the absence of the organisation; and this with control of only 40 per cent of the market, so that the Pool benefited all growers, the free growers slightly more than the Pool growers.

To maintain the market the Pool exported 200,000 bushels of the two million bushels surplus it carried over to the 1930 harvest.

The prices for the 1929, 1930 and 1931 harvests were 5/11½d, 5/11½d and 5/8½ respectively. In 1929 a Select Committee of the House of Representatives unanimously recommended that the sliding scale be maintained. Seven of the ten members of the committee came from wheat growing constituencies so that the committee may have tended to consider the interests of growers rather more than of consumer.(5)

As early as January, 1931, Mr. W.W. Mulholland, the Chairman of the Board of Directors of the New Zealand Wheatgrowers' Co-operative Association Ltd., expressed the view that the overall price for the 1932 harvest might be 4/-d per bushel. This view was enlarged upon by him in the February issue of "The Wheatgrower":-

"A misapprehension seems to have arisen in some quarters with regard to my remarks in last number on the prospects for 1932 wheat. When I mentioned 4/-d per bushel as the best that could be looked for, in my opinion, I was not thinking of a reduction of the duty bringing it about, and was not suggesting that such a reduction would be acceptable to wheatgrowers. In my opinion there is a strong probability that a large acreage will be planted this coming season, an acreage large enough to give us a considerable surplus in 1932 if the season produces average yields. This surplus would probably be far too large for our Association to deal with unless our numbers were increased to nearly 100 per cent of growers without putting too heavy a burden

(5) Wheat Industry Committee Report, 1929.

on ourselves with insufficient benefit. It would be too costly unless shared by all. The alternative would be that export parity should rule, and last week the price to Australian farmers was 1/7d per bushel, sacks in. On that parity our wheat is worth less than 1/-d per bushel on trucks, sacks extra, for export, or so low that it would pay better to burn the crop than harvest it. I think that probably by 1932 the world market will have improved; but any improvement that could reasonably be expected would still mean ruin to the wheatgrower if we have an unmanageable surplus; and in any case this catastrophe, with the surplus we, in my opinion, must calculate on, can only be avoided by such organisation as will enable the burden to be spread over the whole of the wheat. Members can readily understand that the Directors have been doing their utmost to find a way of dealing with such a situation".

Mulholland's fears appeared to be confirmed when a survey of growers indicated that from 290,000 to 300,000 acres had been planned. The average yield for the past five years was 33.68 bushels per acre.(6) Thus it appeared that some 10,000,000 bushels might be produced. Even under the sliding scale wheat and flour were imported equivalent to 750,000 bushels per year. How much flour would have been imported if New Zealand wheat could have been regarded as a perfect substitute for Canadian or Australian flour is uncertain, as at this time millers were still importing flour for blending. In 1929 the Government Statistician estimated 6,500,000 bushels were needed for milling. Thus the threatened surplus would be about 4.25 million bushels and might be much greater if the crop was of good quality. If the Pool were to try to maintain the price of wheat it would have to dispose of this surplus at a time when world wheat prices were severely depressed. It seemed likely that it would not be profitable for the Pool to try to maintain the domestic price by holding wheat off the market as it had done in the previous three

(6) This is a simple arithmetic average of the Government Statistician's average yield for the past five years.

years. In the absence of support from the Pool it seemed likely that export parity would rule for the whole crop. At one time this threatened to yield 1/-d per bushel, sack extra, at country sidings. It is unlikely that such a price would have paid the cost of harvesting. In the Parliamentary Wheat Committee Report 1929, cutting, stooking, stacking, threshing and carting a crop is estimated as costing 1/2d per bushel. Costs, of course, would have fallen somewhat due to the depression but it will be seen that 1/-d per bushel would leave little over once harvesting costs had been paid.

The prospective surplus led the Directors of the Wheat-growers' Co-operative Association to open negotiations with the millers for the sale of the next season's crop. Under the agreement the millers contracted to buy milling wheat at a set price included in the agreement. The organisation set up to operate the agreement was known as the Wheat Marketing Agency Company Ltd.. There were eight Directors of this company, four from the millers and four from the growers, so that in the event of a disagreement no action could be taken until both sides of the Industry were agreeable. The four growers' representatives were elected by an Electoral College with 105 members, 70 from the "pool" growers and 35 from the "free" growers.

This new organisation of the market differed radically from the simple Pool. The power of the Pool to fix the price of wheat was derived from an agreement amongst a certain proportion of the growers not to accept less than the specified price. The power of the Wheat Marketing Agency to fix the price was derived

from an agreement amongst the millers not to purchase wheat below a certain price. In more formal terms the price fixing by the Pool was monopolistic while the price fixing of the Wheat Marketing Agency was due to monopsonistic powers. The reason that the millers' monopsonistic powers were not used to force price down to the export parity, when conditions were favourable to such a manoeuvre, is probably political. The millers will have been content with a price which gave them a "fair" profit, rather than jeopardise their protection against imported flour. Once the millers had signed the agreement the grower had three main ways of disposing of his wheat - he could sell at the fixed price to a miller, or sell for fowl wheat, or sell for export. The latter two alternatives would yield a far lower return, so that effectively the grower had no alternative but to sell at the fixed price. The contribution of the Pool to the agreement was an undertaking not to try to force prices up above those specified in the agreement. In view of the harvest prospects, this undertaking was not very valuable.

In February, 1932, the protection of wheat was reduced to a sliding scale based upon 8d duty when the price at the port of export was 5/-d. The sliding scale of flour duties was based on a duty of £1:12:0 a ton when the price at the port of export was £13:0:0.

The calculations on which the price of wheat for 1932 were fixed are reported in "The Wheatgrower" in some detail. They are an excellent example of the calculations which theory suggest take place.(7)

(7) The Wheatgrower, Vol. III, No.3, p.18.

"The following is an analysis showing how the prices of the 1932 crop have been arrived at:-

Australian Flour Landed North Island.

	£ s d	£ s d
Price plus duty f.o.b. Australia ..	13: 7: 0	
Freight and Insurance ..	1:10: 6	14:17: 6
Less Exchange on freight at 13% ..	3:11	
No duty charged on importers' commission 2½% on £8, making the flour imported cheaper to this extent ..	4: 0	7:11
		14: 9: 7

New Zealand Flour Landed North Island

F.O.B. South Island ..	13:12: 0	
Less 2½% ..	6:10	13: 5: 2
Freight to North Island ..		1: 1: 0
		14: 6: 2

New Zealand flour cheaper per ton by 3s.5d.

Value of Wheat when Flour is £13:12:0 f.o.b.

2,000 lb. Flour ..	13:12: 0	
800 lb. Bran and Pollard (£4/10/- per ton)	1:16: 0	
Gain selling sacks in ..	4: 7	
	15:12: 7	
Less 5% ..	15: 8	14:16:11
Less cost of manufacture (including cost of sacks)		3: 9: 0
		11: 7:11

Eleven pounds seven shillings and eleven pence pays for 48 bushels of wheat and is equivalent to an average of 4/9d per bushel f.o.b. In order to enable the spread of varieties to be given the prices were fixed at 4/8½d f.o.b. for Tuscan in March." (8)

(8) The price reported to me by the Wheat Committee for the price of Tuscan f.o.b. in March, 1932, is 4/7½d. It seems likely that this discrepancy reflects a provision in the Wheat Marketing Agency Agreement for part of the price paid by the millers to be withheld to form an equalisation fund for any wheat that had to be dumped oversea.

2.5 Government Control 1933-1953.

At the end of 1932 it was estimated that the 1933 harvest would cover 294,000 acres with an average yield of 37-38 bushels per acre, giving a total yield of 10,878,000 bushels, which with normal importation would mean a surplus of 3,000,000 bushels. The Wheatgrowers' Co-operative Association accordingly negotiated with the millers for the renewal of the Wheat Marketing Agency agreement. As late as the January issue of the Wheatgrower, which was probably written early in December, it appeared that these negotiations would be successful:-

> "The Wheat Marketing Board (Wheat Marketing Agency Co. Ltd.) attacked the problem of the marketing of the coming crop very energetically during the past month, and the scheme has been completed. As it has not yet been formally accepted by some of the parties, I (W.W. Mulholland) am unable to give any information about it. I believe that this acceptance will be forthcoming."(9)

Negotiations, however, broke down and a joint approach to the Government by the millers and growers, together with an official estimate by the Department of Industries and Commerce that in the absence of organised marketing growers would not receive 2/-d on trucks at country stations, resulted in the Board of Trade (Wheat) Regulations 1933, which were gazetted on January 6th.. These regulations provided for the setting up of a Wheat Purchase Board, consisting of four representatives of the milling industry and four wheatgrowers, under the chairmanship of an independent chairman appointed by the Government. This board was given control of the marketing of all f.a.q. New Zealand milling wheat.

The Wheat Purchases Board fixed the price of wheat to

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(9) "The Wheatgrower" Vol. IV, No. 3, p. 2.

millers for the 1933 harvest on the basis of 4/7½d per bushel March Tuscan. This was the same as the previous year. How the price for 1932 was calculated has been shown on page 19. Since that time, however, the depression had resulted in a reduction of freight rates so that the spread between imported and domestic flour had been reduced and large quantities of Canadian flour were being imported by the North Island. Early in 1933, when the North Island millers included the prestige value of Canadian flour, there was little price incentive to use New Zealand wheat. To meet this invasion of the home market the Wheat Purchases Board arranged to lower the price of New Zealand flour in the North Island by 15/-d a ton. Twenty-three per cent of this subsidy was borne by the millers, the balance by the growers. With the formation of the Wheat Purchases Board to control the Wheat Market, the Pool became redundant. A special Act of Parliament was passed in 1933 by which United Wheatgrowers (N.Z.) Ltd. was set up. The shares in The New Zealand Wheatgrowers Co-operative Association Ltd., which had been held by individual farmers, were transferred to the Directors of United Wheatgrowers, to be held by them in trust for the wheatgrowers of the Dominion. The Directors of United Wheatgrowers were elected by an Electoral College, the members of which were elected by a postal ballot in their respective districts. All wheatgrowers with more than five acres in wheat were entitled to vote. In theory, this represented a stronger organisation than the Pool, for the Directors could claim to represent all wheatgrowers in the Dominion. This strength, however, was only superficial as the

members of United Wheatgrowers were in no way bound to the organisation, while the members of the Pool had been, by their contracts.

Wheat marketing has not been released from Government control since the formation of United Wheatgrowers so that there has been no opportunity to test its strength as a marketing organisation. United Wheatgrowers has been active in presenting cost data to the Government in repeated attempts to get the price of wheat raised.

The threatened surplus materialised and there were two million bushels f.a.q. wheat which could not be disposed of to millers. To facilitate storage, the Wheat Purchases Board paid steeply rising monthly increments for wheat sold later in the year. This encouraged the millers to fill their stores at once and those farmers with storage space had an incentive to use it and hold their crops off the market until later in the season.

Some provision had to be made for dumping a portion of the surplus oversea. To this end, an equalisation fund was built up by reducing the price to farmers as compared with the previous year. The intial payout to farmers was 3/4d f.o.b., but later payments brought this up to 3/10d.

A million bushels were exported and the other million bushels of the surplus was sold to the 1934 wheat pool account at the export parity of 3/-d per bushel.

The initial payment to growers for the 1934 harvest was 3/6d per bushel as it was not at all clear whether the Board would again be faced with an export surplus. The Board did not export and the final payout was 4/5d.

For the 1935 harvest the price to millers remained at 4/7½d. The initial payout to growers was 4/-d and the final payout was 4/7¼d. Threepence of the final payout was provided by a profit on wheat purchased from the 1935 pool at export parity and sold to millers at the domestic price.

The General Election of 1935 resulted in a Labour Government. In 1936 the Government replaced the Wheat Purchases Board with the Wheat Committee. The Wheat Committee differed from its predecessor in that its control covered not only wheat, but flour and bread as well. The Wheat Committee operated a vertical control of the Wheat-Flour-Bread Industry as well as the horizontal control of Wheat marketing which had been exercised by the Wheat Purchases Board. The Wheat Committee was under the direct control of a Minister of the Crown. Hon. D.G. Sullivan, Minister of Industries and Commerce, was the first chairman of the Wheat Committee, the members of which held their positions at his pleasure.

Both the Wheat Purchases Board and the Wheat Committee rationed supplies of New Zealand wheat to mills to avoid flooding the flour market. In the milling industry, when working an eight to twelve hour day the individual mill is still operating on falling average cost curve so that so long as marginal revenue exceeds marginal cost there is a continual tendency to expand production, which makes the Industry liable to price wars.

Rationing led some mills to import flour to "blend" with their New Zealand flour, partly to give it better baking qualities, but also, apparently, to make their lines go further. The "free"

mills, i.e. those not bound by an agreement with Distributors Ltd., were able to import wheat and mill it, thus leading to congestion of the local market. With the stabilization of the wheat and flour market which resulted from the Wheat Purchases Board and the Wheat Committee, the risk of price fluctuating involved in importing wheat and milling it was negligible so that the free mills could operate quite profitably on small margins.

With the introduction of the Wheat Committee an embargo was placed upon the importation of flour. Only wheat might be imported, as this gave extra employment in the mills and the useful byproducts of bran and pollard. The embargo on flour imports, of course, reduced yet further the dependence of the New Zealand market on the world market. The only check remaining upon the price fixed by the Wheat Committee was the possibility of exporting flour or wheat, and of importing wheat. The direct responsibility of the Wheat Committee to a Minister meant that the price of wheat became the subject of Cabinet discussion and decision.

By taking control of the marketing of flour the Wheat Committee usurped the function of Distributors Ltd., which went into voluntary liquidation. The New Zealand Flour Millers' Society was formed in 1937 and took over the "political" functions of Distributors Ltd. The Flour Millers' Society indicates the views of the trade to the Government and any allied organisations which may require the views of the millers.

In 1936 the selling price to millers was increased by 1½d

to 4/9d. The embargo on flour permitted the withdrawal of the North Island Flour subsidy, resulting in a further saving of 2½d per bushel. The final price to growers was 4/9¼d. The farthing premium of growers' price over millers' price is presumably the result of a profit on wheat carried over.

In 1937 the embargo which had been placed upon the importation of flour was extended to the importation of wheat, thus still further cutting the domestic market off from the effect of world prices and effectively preventing "over-supply" of the domestic market and resulting price wars. Wheatgrowers appealed to the Minister for an increase in price, and 6d per bushel was granted as a result of an investigation into costs by a Government Wheat Cost Investigation Committee. Thus the price for the 1937 harvest was 5/3d. In December, 1936, the Minister announced that the price for the 1938 harvest would also be 5/3d.

The Wheatgrowers, however, petitioned the Minister to make the price for the 1938 harvest 5/9d per bushel. The Minister toured the wheat growing areas and directed the Department of Industries and Commerce to make a full investigation into the costs of wheatgrowing. As a result of this investigation the Wheatgrowers' petition was granted and 5/9d per bushel was the basic price for the 1938 harvest.

This price, 5/9d, was paid for the harvests of 1939, 1940, 1941, 1942, despite a number of appeals from Wheatgrowers for a higher price.

By December, 1941, the Government's policy of Price Stabilization had been announced and, as a patriotic gesture, the

Wheatgrowers decided not to ask for a higher price for the 1943 harvest. The Government's price Stabilization policy, however, did not prevent a 5 per cent wage increase being authorised early in 1942. This wage increase led growers to revoke their earlier resolution, and an appeal was made for a higher price for the 1943 harvest. On April 20th the Minister announced that the price for the following harvest would be 5/11d and a further appeal by the wheatgrowers was heard by the Price Tribunal. The Price Tribunal recommended the price be 6/1½d per bushel plus a halfpenny per bushel contribution to a storm insurance fund. The Government accepted the recommendation so that the effective price for 1943 was 6/2dper bushel. The Minister's increase of 2d in April may have been sufficiently early to encourage growers to expand their acreages. The increase granted by the Price Tribunal was not known until July when it could only have affected the latest spring sowings.

For the 1944 harvest the wheat price remained unchanged at 6/2d per bushel. For the 1945 harvest the price was increased to 6/6d per bushel in response to an appeal by United Wheatgrowers for compensation for increased costs.

In November, 1944, the growers asked for 7/-d per bushel for the 1946 harvest, claiming that if this price was paid 300,000 acres would be planted. At the same time the Australian crop was reported to be much smaller than usual so that it was doubtful if the Government would be able to cover a domestic shortage by the importation of Australian wheat. The Government was still committed to its policy of "Stabilization", and

increased prices were only permitted to compensate the producer for increased costs. The Government wanted to increase wheat production but its stabilization policy prevented a simple increase in the price of wheat. Instead it was argued that increased output justified an increased price, and a "sliding scale" of prices was arranged, the price paid increasing as the acreage planted increased. The "price" was the price to be paid for the whole crop, and the acreage the total acreage planted in New Zealand. This meant, of course, that the price to be received by the individual producer was independent of any change in his own acreage, the price being determined by aggregate wheat acreage. This in turn meant that the "sliding scale" of prices lost its incentive effect to the individual grower, and hence to the entire industry. If 200,000 acres or less were planted the price would be 6/6d per bushel and for every 10,000 acres planted above 200,000 the price increase 1d per bushel over the whole crop, until when 270,000 acres were planted the ceiling of 7/1d per bushel would be reached. This plan was announced before planting. Later the ceiling was lowered until 7/1d would be paid if 235,000 acres were planted. In any event 164,000 acres were planted and 7/1d was paid. Thus, in a year when the growers assured the Government that a price of 7/-d per bushel would produce 300,000 bushels, in point of fact a higher price produced only half the acreage. From 1939 to 1945 the price of wheat increased from 5/9d to 6/6d per bushel which can be compared with an increase in the export price index of from 354 to 508.[10] The export price index is, of course, determined almost

(10) N.Z.- All Groups Export Prices Index Numbers, Calendar Years, 1952 = 1000.

exclusively by farmers' returns on export products. A study of the farming Press makes it quite clear that over this period the price of wheat was unattractive to growers. The Government made repeated efforts to increase acreage by "Grow More Wheat" campaigns. This "planning by exhortation" aimed now at 250,000 acres, now 300,000 acres and occasionally even at 350,000 acres. Wheat acreage was never sufficient to meet national requirements and imports of Australian wheat were made annually.

Early in 1947 the Minister of Industries and Commerce, Hon. D.G. Sullivan, announced that a contract had been signed between the Australian and New Zealand Governments for the sale of 18 million bushels of wheat to New Zealand. The first 4.5 million bushels had already been delivered at a price of 9/6d f.o.b. Australian ports. The remainder of the contract was to be purchased at 5/9d f.o.b., at least 3.5 million bushels to be taken annually by New Zealand and at most 4.5 million bushels to be supplied by Australia. This contract turned out to be extremely favourable to the New Zealand Government as world prices rose steadily from 1947. It is possible that the equanimity with which the shrinking acreage of wheat has been viewed by the Government over the past ten years is due to the explosion by war time experience of the "defence" argument for protecting the Wheat Industry, and the advantage derived from the Australian contract. The other important factor is that growers have been less active in pressing for a higher price since the second war than they were in the inter-war period. Since the second war the acreage of wheat has been reduced because other products were much more

profitable and it seems that growers have been quite happy to abandon wheat. In the inter-war period when prices were not so attractive, growers looked to wheat to provide a significant portion of their income and, even if other products were less attractive, they were, nevertheless, concerned at the "low" price for wheat.

The price for the 1947 harvest was raised to 7/4d per bushel subsequent to planting as a result of the presentation of cost figures to Government representatives by United Wheatgrowers.

During 1947 the subsidy on fertilizer was removed, the Arbitration Court gave a wage increase and the price of wheat was accordingly increased to 8/-d per bushel.

Further increases in cost led to the 1949 harvest being sold at 8/6d and the 1950 harvest at 8/9d.

In March, 1950, the Minister of Industries and Commerce announced that the price for the 1951 harvest would be based on 9/9d f.o.r. March Tuscan, an effective increase in price over the previous season's f.o.b. price of 1/5d. The f.o.r. price benefited those growers who had the longest rail cartage to their local port. As the vast majority of wheat has to be carted to a port, either for milling or shipping to the North Island, cartage is a real cost, and a price which does not make allowance for it tends to distort the economy. This was described as an "incentive payment" and was not even nominally connected with costs but was designed to induce farmers to grow more wheat.

The price for the 1952 and 1953 harvests was 10/-d f.o.r. and 11/-d f.o.r. respectively.

CHAPTER III

PROBLEMS OF ESTIMATION USING A SINGLE EQUATION

An equation is "identified" and is in "reduced form"[1] if there is no other relation in which one of the independent variables is a function of the dependent variable.

The equation studied in this thesis has wheat acreage as the dependent variable. The independent variables are the factors which affect the production decision that results in the dependent variable (wheat acreage). Obviously, wheat acreage, which is a result of the production decision, cannot be used to "explain" any of the factors which led to the decision.[2] This simple argument justifies the estimation of structural coefficient by the use of a single equation.

This chapter is concerned with the problems which arise in the estimation of structural coefficients from time series data.

3.1 Errors of Specification.

The whole rationale of economics and econometric procedures is dependent on the assumption that economic events are

(1) T.J. Koopmans "Identification Problems in Economic Model Construction", Chap. II of "Studies in Econometric Method" Ed. W.C. Hood & T.J. Koopmans. G. Tintner "Econometrics" p.155 f.f.

(2) T.J. Koopmans "Statistical Estimation of Simultaneous Economic Relations", Journal of the American Statistical Association, Vol. 40, 1945, p.459 f.f.

related in a certain definite manner, that economic events are not "random". It is assumed that economic phenomena are connected by an underlying "true" relationship with certain coefficients which have remained unchanged over the whole of the period studied. An error of specification occurs when the relationship estimated does not correspond to the underlying "true" relationship.

3.1.a. The Form of the Relation.

Given a number of independent variables, the relation which connects them to the dependent variable can assume an almost infinite variety of forms. Thus the relation may be a simple linear relation, or it may be a quadratic or higher order in one or more of the variables, or it may be a simple multiplicative relation, or only a few of the variables may have a multiplicative relation, and so on.

If the relation estimated takes one form and the "true", underlying relation takes another, then the estimates of the parameters will be biased, due to an error of specification.

It is an unfortunate characteristic of econometric procedures that if coefficients are estimated for a relation which has a different form from the "true" relation apparently valid results will nevertheless be obtained. There is no automatic danger signal that appears when a relation of the "wrong" form is used. Attempts to put a machine together the wrong way are often foiled because a nut's thread will not fit a bolt. There is no analogy in econometrics.

As Wold has observed(3) the only satisfactory test for the

(3) Wold "Causality and Econometrics", Econometrica, Vol. 22, April, 1954, p. 170.

accuracy of our assumed form for the relation is given by its predictive success. Some indication of the usefulness of our estimates is given by the coefficient of multiple determination,[3a] R^2. A large R^2 may normally be taken to indicate that the relation we are trying to estimate corresponds closely to the true relation. At the same time a large R^2 can be given by any series which, though it is not causally connected to the dependent variable, happens to fall in the appropriate way.

There are an almost infinite number of forms that a relation may take. There has been very little discussion amongst theoretical economists as to the form which relations are likely to take. Questions such as "Is the reaction of an entrepreneur to two stimuli likely to be additive or multiplicative"; "Are there certain very sensitive variables which should also be represented by a squared term?"; "Are changes in variables more important than their absolute levels?" are seldom seriously discussed. These questions are of obvious importance, but as yet not very much has been done either on the empirical evidence or the theoretical basis. For the investigator who has not had close contact with a large number of producers, there is no a priori reason for preferring one form to another. Each different form represents a different hypothesis as to the nature of the "true" structural relation.

In this study the original figures and first differences have been examined. While in a long series both methods should lead to identical estimates of the coefficients, in a short series there may be large differences. The first estimate corresponds

(3a) Ezekiel, "Methods of Correlation Analysis", p. 211.

to the assumption that it is the absolute level of relative prices which is important, while the latter assumes that it is the changes in price which have been important. As there is no way of telling a priori which hypothesis is right the two alternatives were both examined. It is, of course, probable that the farmer takes both the level and the changes in level of variables into account. Least-squares, however, demands that there be one dependent variable, so that either the absolute acreage or the change in acreage has to be made the dependent variable.

In short, there is no satisfactory safeguard against using the wrong form for the relation. The investigator can only be aware of the possibility of this error and be careful that the form of the relation estimated by him is at least plausible.

3.1.b. The Variables Included.

If the relation studied includes a variable that should be excluded or excludes a variable that should be included, then there is an Error of Specification. Again, the problem arises that there is no entirely satisfactory test for this occurrence. The tests of significance, in which the biometician is able to place great faith, are of much less use in econometrics due to a tendency for all economic variables to be affected by the major economic phenomena. Thus population, factory production and National Income all tend to increase at a logarithmic rate, while prices, wages and terms of trade are affected by the trade cycle, and prices, National Income and wages are affected by secular inflation. This means that theory must be used as the main criterion for the inclusion or exclusion of a variable.

This latter statement, possibly, needs to be amplified. Considering the connection of wheat price and acreage, the investigator feels quite confident in assuming that there is a connection. If a farm product such as butterfat was being dealt with, where each season's decision to produce can cause only a slow change in output, at least in the upward direction, it might be expected, as Johnson showed in his thesis,(4) that price of butterfat had little short term relationship with output. In the case of an annual crop such as wheat, however, price can be expected to have a more direct effect since the choice of acreage to be planted is exceedingly wide. It follows that in this case the investigator is not interested so much in establishing the existence of the relation as in estimating its coefficient. That statistical tests are unable to detect any certain relation between price and acreage may lead to the theory being reconsidered. If, even after reconsideration, the theory appears valid, the investigator will conclude not that the postulated connection is incorrect but that its effect has been prevented from showing up statistically due to the "interference" of another variable, or due to the form of the relation being wrong. It is, of course, impossible for the econometrician to obtain another "sample" of data in which the other variable did not "interfere" and from which the relation could be estimated.

There are other variables, however, which do need to be "justified" by statistical tests. Thus the postulated relation of oat price and wheat acreage may be considered to be merely

(4) R.W.M. Johnson "The Nature of Aggregate Supply of New Zealand Agriculture", Thesis, Massey Agricultural College, 1953.

tentative, subject to confirmation or refutation by tests of the empirical data. Once justified, the investigation becomes interested in the estimation of the coefficient connections the independent to the dependent variable.

It goes almost without saying that investigators should always be careful to note and to examine thoroughly cases where "the facts" do not conform to the "present state of theory". The repeated occurrence and noting of the Giffin Paradox led to the theory of demand distinguishing between the substitution and the income effects of a change in price.

Thus the inclusion or exclusion of variables does not depend solely upon statistical tests, but rather upon a well-judged combination of these with theory.

The procedure followed in this study is to compute the zero-order correlation coefficients amongst the variables which appear to supply a plausible explanation of changes in wheat acreage. The resulting correlation matrix indicates the empirical relationships existing between the variables.

A high degree of multicollinearity leads to the immediate suppression of some variables, and the remaining variables are investigated. Two criteria of significance are used, the lenient criterion which merely requires that the standard error of a partial regression coefficient should not be greater than the regression coefficient (approximately the 63 per cent level of significance)(5) and the strict criterion which requires that partial regression coefficients be twice their standard error (approximately 95 per cent level of significance).

(5) This more lenient criterion is suggested by Wold; Wold and Jureen "Demand Analysis", p. 246

Each of these criteria has its advantages. Where the strict criterion is used the problem of multicollinearity should not be serious as multicollinearity leads to partial regression coefficients with large standard errors.(6) On the other hand, the 95 per cent level of significance tends to exclude variables which theory suggests are of major importance.

The lenient criterion, on the other hand, leads to the inclusion of most of the variables which are not blatantly multicollinear and which are suggested by theory. In a sense it will provide a better estimate of the structural coefficients than the strict criterion as an estimate is obtained of coefficients for which no estimate could be obtained if the 95 per cent level of significance were used. Multicollinearity will, of course, be more serious when the lenient criterion is used.

3.1.c. Index of a Variable.

The third type of Error of Specification occurs when instead of using the "true" series to represent a variable, another "parallel" series is used. Thus if the "true" explanatory series is the Price of Wheat in March and the Price of Wheat in April is used, then there is an error of specification. Such an Error of Specification might also be described as an Error of Observation. If the farmer's decision is based on March prices but April prices are used, the usefulness of any coefficients derived will depend on the correlation between March and April prices.

(6) Haavelmo "Remarks on Frisch's Confluence Analysis and its use in Econometrics". Statistical Inference in Dynamic Economic Models, Ed. Koopmans, p.258 f.f.

In avoiding this type of error the first, and most obvious error would be made if a production decision in March was "explained" by an alteration in price in the subsequent June. The second step is to use the series which, empirically, appears the most useful. When there are two alternative series, which are equally acceptable on theoretical grounds, the series which best "explains" the dependent variable should be used. Strictly, the judgment of the success of alternative series in explaining the dependent variable should be made on the basis of the partial correlation coefficients and R^2. This process would, however, involve a very severe computational burden without leading to a very much improved estimate. Consequently, judgments as to the efficacy of alternate series in explaining the dependent variable have been based on zero-order correlation coefficients. Correlations were derived for the dependent and several of the more important independent variables with the alternative series. The series with the highest correlation with the dependent and lowest correlation with the other independents was chosen.

Two alternative series which might be used to represent a variable are likely to be highly correlated. They will be the result of similar economic forces. This high correlation means that, even if the "wrong" series is used, the resulting error is not likely to be serious. Further, this correlation will be due to the structure of the economy so that it is likely to be maintained and the loss in efficiency of prediction may be negligible.

3.2 Multicollinearity.

Multicollinearity occurs when two independent variables are highly correlated. This leads to the estimates of the structural coefficients being unreliable. It can be seen that if two independent variables were perfectly correlated then the value of one of their partial regression coefficients could be anywhere between + ∞ and - ∞ , provided that an appropriate adjustment was made to the other coefficient. As the independent series become more highly correlated so the reliability of their partial regression coefficients is reduced. This reduced reliability of the partial regression coefficients is reflected in their increased standard errors.(7)

3.2.a. The Zero-Order Correlation Matrix.

In this study a correlation between independent variables, the absolute magnitude of which is in excess of ·8, has been taken as prima facie evidence of multicollinearity. This criterion has not been derived directly from theoretical considerations, but from general experience which suggests there can be very few cases in which a correlation in excess of ·8 between independent variables does not give unsatisfactory estimates.

That intercorrelation of one independent with any other independent should be less than ·8 is taken as a necessary condition for the absence of multicollinearity. Further examination may lead to other multicollinear relationships being established with consequent suppression of a variable.

(7) Haavelmo "Remarks on Frisch's Confluence Analysis and its use in Econometrics". Statistical Inference in Dynamic Economic Models - Ed. Koopmans, p.258 f.f.

Where two plausible explanatory series are multicollinear by this criterion, one or other of the variables has been suppressed. Which variable to suppress has been a matter for theoretical discussion. Where the two series are of equal theoretical merit, alternative equations have been derived, using first one of the multicollinear variables and then the other. It might be argued that in any case of multicollinearity alternative equations should be presented, using first one of the offending variables and then the other. Such an argument is unsound as it neglects the paramount importance of theory in econometrics. Unless a relation can be explained on theoretical grounds estimation of parameters is purely descriptive and merely indicates the empirical relationships which have held between variables in the period studied. Such a "descriptive" relationship may by chance have certain statistically desirable properties such as a large R^2 and a "d" of about 2, but these do not make it a better estimate of the structural parameters than a theoretically justified equation even though the latter has none of these "desirable properties".

It often happens that two series which are multicollinear in ordinary figures lose this multicollinearity when transformed into first differences. Thus while only one of the two variables may be used when estimating the coefficients from the original figures, both variables may be included when the first difference transformation is used. The reduced incidence of multicollinearity when data is transformed into first differences might suggest that coefficients should only be derived in this

form. It can be proved, algebraically, that for a large sample the coefficients obtained in first differences and original figures will tend to be the same. For a short series, however, the estimates may be widely divergent - as can be seen by comparing the zero-order correlation matrix for original figures and first differences.

An estimate made using original figures indicates how the absolute magnitudes of the variables have been related. While an estimate using first differences indicates how the changes in absolute magnitude of the variables have been associated. Estimates of regression coefficients, made from first difference data, may have certain desirable qualities such as small standard deviations and random residuals. In this respect these coefficients may be preferable to estimates obtained from the original data. When "first difference coefficients" are substituted into the equation using original data, they will not result, except by chance, in an estimation with minimum variance.

If the relationship postulated exists between the original magnitudes rather than amongst the changes in magnitude, it would appear preferable to use the original data, for it is to be anticipated that the stochastic element would be smallest in an estimation which does not commit an error of specification.

Thus the variables which are not prima facie multicollinear and which appear theoretically plausible are obtained by considering the zero-order correlation matrix.(8)

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(8) A similar method is used by Houthakker "Some Calculations on Electricity Consumption in Great Britain - H.S. Houthakker, Journal of the Royal Statistical Society, Vol. CXIV, 1951, p. 366.

3.2.b. Levels of Significance.

It has been noted above that multicollinearity leads to increased standard errors of the partial regression coefficients. The significance of a partial regression coefficient in an equation is judged by the ratio of its size to the size of its standard error. If this ratio is 2 for 30 d.f. the partial regression coefficient is significant at about the 95 per cent level of significance. If it is 1 the level of significance is about 63 per cent. The 63 per cent level of significance permits a greater amount of multicollinearity than the 95 per cent level and it permits the inclusion of variables which would be excluded at the 95 per cent level.

In estimating coefficients the aim is to obtain the best estimate, subject always to the condition that when even the best estimate is unreliable there is no point in computing it. At the 63 per cent level estimates of more coefficients can be obtained than at the 95 per cent level. These estimates, however, will be less reliable in terms of multicollinearity than the smaller number of coefficients obtained at the 95 per cent level. The 63 per cent level estimates, however, may be more reliable than the 95 per cent estimates in the sense that the effect of additional variables has been taken into account.(9) This argument may be illustrated by considering a simple hypothetical illustration. Consider the case where there are two independent variables, both of which Theory leads us to expect to be important but one of which is definitely more

(9) The use of the lenient criterion is suggested by Wold; Wold & Jureen "Demand Analysis", p. 246.

important than the other. Suppose these independent variables have a zero-order correlation of 0.4. Suppose that they can both be included at the 63 per cent level but only one of them can be included at the 95 per cent level. Then the alternatives are either an estimate of the two coefficients, such estimate being subject to some degree of multicollinearity, or an estimate of the important variable which is not, formally, subject to multicollinearity. The coefficient obtained, however, at the 95 per cent level will not measure simply the effect of the series to which it belongs but will have attributed to it some of the effect which strictly belongs to the excluded variable. Quite simply, which level of significance is used depends upon which sort of unreliability is thought to be most dangerous.

3.2.c. Confluence Analysis.

Confluence Analysis gives some indication of the existence or absence of multicollinearity. Frisch's bunch-map technique is the result of postulating a series of underlying or "true" relations amongst the variables being examined. By successive minimization in all possible directions, the variation in the standardized regression coefficients which would have resulted from the choice of each of the other variables as the dependent is illustrated. Frisch's technique was developed before the necessity for multiple equation models had been realised.(10)

It is felt that the introduction of the multiple equation

(10) Ragnor Frisch "Statistical Confluence Analysis by Means of Complete Regression Systems", Oslo, 1934. T. Haavelmo "The Statistical Implications of a System of Simultaneous Equations", Econometrica, Vol. II, Jan. 1943, p. 1-12.

approach has greatly reduced the usefulness of bunch-maps. The existence of Frisch's underlying or "true" relationships must be due either to the structure of the economy or to the chance sample of observations which was obtained. Where the underlying relations represent the structure of the economy, a multiple equation model should be used to derive their coefficients. Where the apparent existence of underlying relations is due to chance, there is no reason to minimize in any direction but that of the dependent variable, and the size of coefficients obtained by illegitimate minimization is of little interest.

Prior to Haavelmo's "The Statistical Implications of a System of Simultaneous Equations", bunch-maps were of use in warning investigators of the possible existence of more than one relation amongst the variables.

Bunch-maps are presented in this study for the equations with a small number of variables to show how the present variables react to this treatment.

3.3. Autocorrelation of the Error Term.

It often happens that when the structural coefficients of a relation have been estimated by least squares, the residuals are found to be non-random.(11) This invalidates the tests of significance which are based on the assumption of a normal, random distribution of the error term. The coefficients estimated remain the "best" estimates in the sense that they give the residual with the smallest variance. But this variance cannot be

(11) The randomness of the error term is tested by using the Durbin and Watson "d"-test. Durbin and Watson "Testing for Serial Correlation in Least-Squares Regression". Biometrika, Vol. 37 (1950), p.409 f.f.

confidently used to test for the significance of the coefficients obtained.

The autocorrelation of the residual may be reduced by making specific allowance for it. This technique has been used and is presented together with some discussion in Section 5.5.[12]

In theoretical terms autocorrelation of the residual suggests that the complex of factors which have not been taken into account specifically but nevertheless affect the equation, tend to move rather slowly.

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(12) See Klein "A Textbook of Econometrics", p. 85, and "Statistical Inference in Dynamic Economic Models", Ed. Koopmans, p. 337

CHAPTER IV

SPECIFICATION OF THE SUPPLY FUNCTION FOR NEW ZEALAND WHEAT

In this chapter the form of the relation is considered together with the variables to be included and the series to be used.

4.1. The Problem of Specification.

The general problem of specification has already been dealt with. The specific problem of the form of the relation to be estimated now has to be dealt with. There are an almost infinite variety of forms which could be specified and some of the more important forms are set out below and then discussed.

Let Wa be Wheat Acreage,

Pw be Wheat Price,

Pa be the Price of an Alternative Product,

Cw be Cost of Wheat Production,

Ca be the Cost of Producing the Alternative Product,

Cg be the General Cost of Agricultural Production,

R be Rainfall or a technical factor,

t be Time or Trend.

Then some of the more plausible forms the relation might take are:

(A) $Wa = a + bPw + cPa + dCw + eCa + fR.$

(B) $Wa = a + b\frac{Pw}{Pa} + c\frac{Cw}{Ca} + dR.$

(C) $Wa = a + b\frac{Pw}{Cw} + c\frac{Pa}{Ca} + dR.$

(D) $Wa = a + b\frac{Pw}{Cg} + c\frac{Pa}{Cg} + dR$

(E) $Wa = a + bPw + cPa + dR.$

(F) $Wa = a + b \log Pw + c \log Pa + d \log R.$

(G) $Wa = a + bPw + cPa + dR + et.$

where a, b, c, d, e are regression coefficients estimating structural parameters.

The above seven forms suffice to illustrate the problems which have to be considered in the specification of the Supply Function. The subscript indicating the period to which the variables relate has been omitted as the independent variables all refer to a production decision taken in March, while the dependent variable results from this production decision. A stochastic term should, of course, be included in each equation.

(F) is merely (E) transformed into logarithms while (G) is (E) with Time added. In a similar way, it would be possible to transform the first four equations. Further, it would be possible to transform the equations into logarithms and add time, thus giving a further set of plausible equations.

Equation (A) is probably, in principle, the most satisfactory, as it allows specifically for the theoretically important variables. Thus the entrepreneur is supposed to base his production plans on the return anticipated from each line of production, together with their relative costs of production and certain technical factors, and all of these are allowed for. It might be argued that equation (B) or (C) were the more plausible as these suggest that relative prices and costs or price relative

to cost are the most important factors borne in mind by the entrepreneur. If (B) or (C) were the "true" relation, the influence of the various factors would be picked up by (A), while if (A) were the true relationship, it is not certain that (B) or (C) would lead to an unbiased estimate of the relative effects of the different factors. Thus (C) will not be able to distinguish between a large value for $\frac{Pw}{Cw}$ which is produced by a high Price and a large value produced by low cost, while the money illusion may lead to quite different behaviour in the two cases. Thus (A) is a more general case than (B) or (C).

The above discussion is, however, somewhat academic, as in this investigation it was impossible to obtain cost series for individual products which were in any way satisfactory. This fact meant that changes in relative cost of production had to be ignored, and these are quite possibly among the major factors contributing to the residuals. The absence of satisfactory cost series also prevented the use of a "net income" form of the relation.

If d and e in (A) are equal to zero, then (A) is the same as (E).

If C in (B) is equal to zero, (B) might still lead to useful estimates. This is especially so as relative prices are less likely to be affected by the money illusion than are price/cost ratios. Where the price of more than one alternative product is included in (B) these prices would occur as fractions, all of which would have wheat price as numerator or denominator, as it is the "alternative product price/wheat price" ratio which

is thought to be important. The wheat price/wheat price ratio would, of course, be a constant so that the number of coefficients to be estimated in this form is one less than in (E), with the same number of alternative prices. In this study relative prices were experimented with, but it was preferred to use the alternative form (E). In most cases it was found that more than one price series could not be included in the relation due to multicollinearity. This meant, of course, that price relatives would also have been non-significant.

Form (D) involves deflation of relative prices by a variable Cost of Farm Production. The object of including this variable would be to convert absolute prices, in some sense, into "real" prices; that is, to allow for the general changes in the value of money. For, obviously, changes in the general cost of farm production would not indicate anything about the relative advantage of producing alternative products. The argument for this general deflation of a set of variables, either by the inclusion of Time (G) or a general Cost of Farm Production (D), rests on the fact that if two variables are moving through time, each subject to its own independent trend, then the two series will tend to be correlated to the extent that their trends are similar. Hence, the regression of one on the other will tend to be significant even though there is no causal relation. The inclusion of a deflating variable will give partial correlation and regression coefficients which do not attribute the major portion of the trend to the variable being deflated. Thus the object of including Time or Cost of Farm

Production is to modify the coefficients obtained from those variables having a common trend with the dependent.

The trend common to almost all economic variables over this period involves the slump after the first war, the depression of the thirties and the inflation since 1939. It is possible to postulate an ideal variable "the value of money" which would make exactly the right allowance for this trend. The partial correlation and regression coefficient with "the value of money" held constant, would be for trend free variables and would enjoy greater confidence than estimates from which trend had not been eliminated.

Changes in the value of money are reflected in prices and costs. It follows that price and cost series will approximate to the ideal variable "value of money". Each price and cost series, however, will have its own peculiar quirks which distinguish it from the ideal variable. These individual quirks will tend to be least in the less volatile series which are not strongly subject to seasonal influences.

The above argument suggests that Cost of Farm Production might be a satisfactory deflator for wheat price; but it also suggests that the price of fat lamb, which reflects a world parity price, would be an equally useful deflator. In other words, so long as two of the independent variables in a relation have the same general trend as the dependent, there is little danger of one of them having inflated partial correlation coefficients due to trend. Thus, deflation by general cost of Farm Production or Time appears normally to be an unnecessary

precaution.

This leaves relations (E) and (F) to be considered. The two relations reflect alternative hypotheses - in (E) the assumption is made that the influence of the various factors is additive, while in (F) the assumption is made that the relation is multiplicative. The second assumption has the advantage that it results in elasticities and cross-elasticities being constant. While this is a useful property there is no a priori reason to believe that the structural coefficients do, in fact, have this peculiar property. Scatter-grams were drawn between the variables in ordinary and logarithmic paper. There were no cases where visual examination suggested that the logarithmic transformation was preferable, and in the event the simple hypothesis expressed by (E) was adopted.

4.2. The Plausible Variables and Series.

One of the first questions the econometric investigator must ask when studying a relation is - what are the variables which could enter into this relation? This question is now considered for the Supply Function of New Zealand Wheat.

4.2.a. The Supply of Wheat.

The Supply of Wheat depends upon the acreage of wheat planted and the yield per acre. The former is a reasonable indicator of the farmer's intentions, the latter is an apparently random variable depending upon a large number of natural phenomena. In a technical study of wheat production the investigator would be justified in attempts to establish the factors which determine the yield of wheat.(1) In an economic study such as this it is

(1) See Tauheed "The Influence of Weather on the Yield of Wheat in New Zealand with Special Reference to the Meyer Ratio", Thesis 1948, Canterbury Agricultural College.

simpler to ignore the fluctuations in yield, which may be taken to be independent of economic considerations and to concentrate on the acreage of wheat. To say that fluctuations in yield are entirely independent of economic considerations is too sweeping as the amount of cultivation, the weight of fertilizer, the weight of seed and the quality of land all influence yield, and may themselves be affected by economic factors. Nevertheless, it would not be profitable to try to estimate the alteration in yield which is due to economic effects.

It follows that the dependent variable in this relation should be some measure of farmers' production plans rather than of their actual achievements.

There are three possible series which might be used to represent wheat farmers' intentions: Forecast Wheat Acreage(2), Total Acreage in Wheat(3), Total Acreage of Wheat for Threshing(3)

(2) The Government Statistician describes this estimate in a private communication:

"Forecast Wheat Acreage. This annual forecast, based on sowing and projected sowings, was commenced in World War I. The method used was to circularize in the spring all growers of a certain minimum acreage of grain crops recorded in the previous year's annual collection of farm statistics, to ascertain their plantings or projected plantings of wheat in the current season. The total acreage so obtained was adjusted upwards to allow for the incomplete coverage. In recent years the enquiries have been addressed to systematically-drawn random samples.

Generally, all wheat sowings are made, as at time of planting, for purposes of grain harvest - threshing. Normally, 98 per cent of the planted area is harvested for threshing, but the proportion not so harvested could rise in a poor season. No separate forecast is made of the area for threshing but, when the estimate of the total grain yield is made in February on the basis of crop reports from Field Officers of the Department of Agriculture, a deduction is made from the estimated total area sown to allow for areas which will not be harvested. This allowance is based on the experience of the five previous seasons."

(3) Reported in the A. & P. Statistics.

The first two estimates are estimates of intentions, while the latter is an estimate of achievements. If the Forecast Wheat Acreage were as accurate as the other two series, it would seem to be the best series to use as, nominally at any rate, it represents quite simply farmers' intentions; but as was indicated in the footnote, this series is rather difficult to interpret. Firstly, it does not profess to cover more than a sample of growers; secondly, the actual figures obtained from farmers are "adjusted" by officers of the Department of Agriculture. It is difficult to say just how important this adjustment is, but there is an obvious danger that an actual sampling of farmers' intentions may be converted into a simple guess by an officer of the Department of Agriculture. Thirdly, the sample will be biased in that it cannot make provision for farmers who did not grow wheat last year but have decided to do so this year. These considerations make the first series unsatisfactory.

Virtually all wheat planted is intended for threshing so that the major acreage of unthreshed wheat is due to the season frustrating farmers' intentions. There is some small acreage, however, which is not intended for threshing, and thus will not be affected by the economic factors discussed below. Thus use of Threshed Acreage fails to make any allowance for farmers' frustrated intentions while Total Acreage may include some acreage not subject directly to economic influences. In the event, Threshed Acreage was used as the dependent variable.

4.2.b. <u>The Price of Wheat</u>.

Theory suggests that the price of wheat should be amongst

the most important factors determining the acreage farmers intend to produce, and that its coefficient should be positive.

One of the problems which is common to all price series is - "Which is the relevant month to take?" In this study the month of March was taken as being the month in which the land was first prepared for wheat. As some land is ploughed in March it is obvious that a price occurring later than March should not be used,(4) while a month prior to March would have involved the production decision being made before the farmer was aware of all the relevant facts.

In the case of wheat price the error involved in taking the "wrong" month would not be serious as the series for the different months are almost simple linear functions of one another. The price of wheat, quoted in official discussions as having ruled in a particular year, is the price of Tuscan Wheat in March, f.o.b. main South Island Ports. Other varieties are at a fixed premium or discount according to the quality of their grain, and in later months an increment is added to the price to compensate growers for storing their crop.

It is obvious that the series of prices used should be those prices known when the production decision was made, and it has been argued that March is the month when the production decision is taken. Accordingly, the prices used were, with one exception, known in March. In the majority of years the price known in March has been the price paid for the previous harvest.

(4) This follows Ward "The Wheat Industry in New Zealand 1918-1948", Thesis Victoria University College, p.109A, and I.W. Weston "Areas of Wheat sown Compared with Fat Lamb Prices in New Zealand" in W.R.I. Annual Report, 4,1933-36,p.46.

But in a few years the price to be paid for the harvest has been announced prior to planting. In these years the announced price has been used. The price for the 1948 harvest presents a special problem. In March the price known to growers was 5/9d per bushel. On April the 20th the Minister of Industries and Commerce announced that the price would be increased to 5/11d and in July a further increase to 6/2d was granted. In this case the price of 5/11d was used as it was argued that those growers who could still be affected by a price announced on the 20th April exceed those who could not. The 1946 harvest also presents a problem. Prior to planting, the Government announced that the price would range between 6/6d and 7/1d per bushel at harvest according to the acreage planted. The price used in this study was 7/1d as growers will have been fairly certain that the Government would not, in fact, pay less than the maximum. The basic series of prices was obtained from the Wheat Committee and the modifications according to announcement before March follow the account given in Chapter II (5)

(5) At a late stage in this study it was discovered that the price for some of the earlier years was reported differently by the Wheat Committee and by the Secretary of the Department of Industries and Commerce in his analysis of the history of the Wheat Industry before the Parliamentary Wheat Industry Committee, 1929, p. 249 f.f. It was felt that, as the two series showed the same general features, recomputation of the estimates contained in the next chapter and the appendices would not be justified. Recomputation would not involve any methodological difficulties. In this sense, the use of any unreliable series does not affect the value of the thesis as a test of technique in investigation. The author feels that he may plead in self-exculpation that the wheat industry has been the subject of two other theses, neither of which mentioned the unreliability of the Wheat Committee's series of prices. The series of prices used in this study were supported by a letter from the Wheat Committee and two theses - Ward "The History of the New Zealand Wheat Industry 1918-1948" and Evans "A History of the Wheat Industry in New Zealand."

4.2.c. The Price of Fat Lamb.

The production of fat lamb is an alternative to the production of wheat on most of the wheat farms in the Dominion.(6) An increase in the anticipated return from fat lamb will tend to reduce the acreage in wheat. Thus, on theoretical grounds, the coefficient with which the fat lamb price series occurs in the relation would be expected to have a negative coefficient.

It proved impossible to obtain one series of prices for the whole of the period. The series used, however, is thought to be the best estimate available of the fat lamb schedule, or its equivalent, for the first week in March. Smithfield prices were available for the whole period. It was felt that though the New Zealand fat lamb schedule is dependent predominantly upon overseas demand, the use of Smithfield prices would not make sufficient allowance for the effect of New Zealand's domestic market, the profits of the freezing companies, or the changes in the schedule due to the byproducts obtained from slaughtering. The fat lamb schedule is affected by the demand for wool, for skins and for tallow as well as the demand for meat. In this sense it is a compound variable. This does not matter, however, as the variable is "determined outside the system" and it is not necessary to "explain" with another relation the series observed.

(6) See I.W. Weston "Areas of Wheat Sown Compared with Fat Lamb Prices in New Zealand", in The Wheat Research Institute's 4th Annual Report, 1933-1936, p.46-47; also Ward "A History of the New Zealand Wheat Industry 1918-1948", Thesis Victoria University College, p.105, "The price of wheat in New Zealand relative to the price of fat lambs and small seeds and wool has been of the utmost importance in determining the production of wheat in so far as this is determined by acreage".

4.2.d. The Price of Wool.

Wool and fat lamb are joint products; each ewe provides a fleece and the lambs may be shorn before they are sold.(7) An increase in wool price will tend to reduce the acreage in wheat so that the wool price series coefficient should be negative. The index of wool price refers to the average price for wool sold in Christchurch for the sales November to March immediately prior to planting.

4.2.e and f. The Price of Oats and Barley.

These are two arable crops which are alternative products to wheat over some, at least, of the Wheat area. Ward does not mention these two crops as being important. He had considerable contact with practical wheat farmers and administrators so that his opinion is valuable. It was not felt, however, that two crops which were potential substitutes for wheat could be excluded merely because Ward failed to mention them. In any case, all the economic variables that Ward mentions have been investigated so that these two variables are not being included at the expense of variables which another authority considers to be more important. Over the period studied the acreage in oats is of the same general order of magnitude as the acreage in wheat. The acreage in barley, on the other hand, is only about a tenth the acreage in wheat so that the effect of changes in barley acreage can only be marginal. The acreage in oats has suffered a secular decline since the first war due to the falling off of the demand for horse fodder. It seems likely

(7) Ward - op. cit., p.105

that since 1919 the structural relations determining oat production have not been constant. This means that any estimate of the effect of oat price on wheat production could not be considered to be too reliable despite any desirable statistical characteristics it might possess.

It has been pointed out in the last chapter that an error of specification occurs if a variable is included when it should be excluded, or excluded when it should be included. The operation of oat and barley price upon wheat acreage is via land being taken out of wheat and sown to the rival crop. This suggests a check on the validity of any relation which may be found to exist between barley or oat price and wheat acreage. If, for example, there is no discernible relation between the barley acreage, when barley price is significant, and wheat acreage the validity of the price acreage relation is suspect. It is, of course, possible for the movements of land out of wheat into some other crop to be masked by other movements, but if a systematic relation is postulated and no trace of it can be found, little faith can be placed in the hypothesis.

An increase in the price of these crops will tend to reduce the acreage in wheat so that the price series should occur with negative coefficients in the relation being estimated.

The series used refer to the price in Christchurch in March and were supplied by the Government Statistician.

4.2.g. and h. The Price of Perennial Ryegrass and White Clover Seed.

Small seeds[8] are to some extent complementary to the

(8) Ward - op. cit., p.105.

production of fat lamb in that both products necessitate the growth of pasture. According to the season, grass grown may be used to carry stock, or it may be shut up for the production of seed. Small seeds may also be grown as a definite separate crop, not dependent upon the season's supply of feed.

These two price series have been included separately as their separate acreages are sufficiently large to be responsible for marginal adjustments in the acreage of wheat. The use of an Index of Small Seeds Price was considered but the difficulty of constructing a reliable index or of interpreting any results led to the project being abandoned.

An increase in the price of small seeds will lead to a decrease in the acreage in wheat so that these series should occur with a negative coefficient in the relation being estimated. The correlation between seed price and wheat acreage is not subject to the same side restriction of a negative correlation between contemporary acreages of the dependent and independent, as the acreage in a seed crop is determined by seasonal factors to a considerable extent.

The prices used in this study refer to the price of the seed in March at Christchurch, and have been supplied by the Government Statistician.

4.2.i. The Acreage in Red Clover for seed.

Red Clover Seed differs from the other alternative products for wheat, in that its effect on wheat acreage is not thought to operate through relative prices but rather through a direct physical, or technical competition for the same acreage.

Red Clover is harvested in March-April[9] and it is thought that harvesting so late may discourage, or even prevent, farmers from using the land for wheat production.

It is suggested that when the farmer decides in November or December[10] on the acreage of red clover seed to be taken, his decision will depend upon relevant prices known to him at that time, and upon certain technical considerations such as the supply of feed. As has been indicated above, the prices which determine the acreage of wheat are not known until March, so that they cannot affect the farmers' decision to take or not to take a crop of clover seed. In this sense, the effect of Red Clover Acreage on the acreage of wheat is independent of price.

The hypothesis that land used for the production of red clover seed is not used for wheat production sets fairly close limits upon the size of the coefficient with which the red clover acreage may appear in the estimated relation. Obviously, as the acreage in red clover prevents land being sown in wheat the coefficient should be negative. The magnitude of the coefficient should be reasonably compatible with the hypothesis that one acre of red clover seed prevents one acre of wheat being grown. It is possible that only a portion of the red clover acreage prevents wheat being sown, while it is not impossible that there should be a multiplier effect via extra acres being needed to feed stock excluded from the red clover area. A partial regression coefficient for wheat on red clover acreage outside the limits -3·0 and -0·3 would not inspire very great confidence, while a regression coefficient of - ·001 or -100·0 would obviously be ridiculous.

(9) Journal of Agriculture, August 1948, Vol.77, p.122.
(10) Ibid, p.121.

4.2.j. Rainfall.

Rainfall has been included because it was thought that farmers' plans might have been frustrated by rain. If this was the case, then the inclusion of rainfall would remove bias from the coefficients indicating the effect of various variables on intentions and will give a more accurate forecast of achievements.

Perusal of the farming Press suggests that rainfall any time between March and July may have an adverse effect on sowings. It also appears that there have been years when a drought has impeded operations. In this case it is extremely difficult to know which series of rainfall figures should be taken. The choice is between Months, between Days Wet or Total Rainfall, and between Stations. The rainfall for the months March, April, May was studied, as it was felt that rain in the early part of the season might prevent growers breaking up their land. Rainfall late in the season may prevent planting, but it is not thought that a serious acreage has often been caught in this way. The Stations Ashburton and Lincoln were considered as being about in the centre of the wheat area. Scattergrams were drawn of wheat acreage against days wet and total rainfall for the months March, April, May at these two stations. Days wet at Lincoln in April gave the most satisfactory result.

The criterion for the correct station to use is not dependent upon the station being geographically in the centre of the wheat area, but upon its being located near those areas most likely to be affected by rainfall.

A large number of wet days in a month is quite as likely

to delay ploughing as is a high total rainfall. An overcast sky and slight drizzle in the morning will often prevent a farmer from including ploughing in the day's operations. While even a high rainfall in Canterbury is unlikely actually to make paddocks unworkable for very long.

4.2.k. The Acreage of Wheat Grown the Previous Year.

Last year's wheat acreage has been included because farmers tend to continue the same production pattern, the same rotation, from season to season. If there is an unprofitable crop in the rotation it will be removed but possibly not until one or two seasons after it first became unattractive, but, once removed, it may have to be very attractive before it will be re-instated.

The farmer who stops growing wheat will suffer a loss on his capital invested in wheat growing equipment. The farmer growing wheat for the first time will have to acquire the necessary equipment and may not have any experience of growing wheat.

Thus this year's wheat acreage is likely to resemble last years, so that this variable should have a positive coefficient.

Last year's wheat acreage is one variable which, though it is expected to be significant when the original data is used, is not expected to be significant in first differences. It is reasonable to expect this year's acreage to resemble last year's but it is not reasonable to expect there to be any marked connection between changes in acreage in successive years.

4.2.l. Certainty.

In the discussion of wheat price it was mentioned that

in some years the price to be paid for a harvest was known before planting; that is to say, there were some years in which growers were certain of their return. It has been suggested in theoretical discussions of the farm firm that the risk involved in producing for an unknown return may prevent farmers from extending production right to the point where marginal cost equals marginal revenue. It would seem, then, that an assured return might result in a higher output than a less certain return. Accordingly, amongst the variables which were investigated in the preliminary stages was one designated "Certainty". This was represented by a simple two value variable taking the value 0, if the price was not known before planting, and the value 1 if the price was known.

The results obtained were not entirely satisfactory and, in any case, experience with the variable suggested that there were in reality three distinct types of certainty. First, the case where the price is unknown. Second, the case where the price is known and is attractive - this will lead to a higher acreage than the first case. Third, the case where the price is known and is unattractive - this may lead to a lower acreage than the first case.

It would, of course, be possible to include three variables in the analysis, one for each type of certainty, but to distinguish between the second and third case would demand a judgment from the investigator, which he felt could be little better than a blind guess.

There was a further objection, in that the degrees of certainty were not even as clearly defined as the above account

suggests, for the different types of tariff provided different degrees of protection. Thus, under the sliding scale, the grower could be "fairly certain" of his return.

From 1938 to the present the principle has been accepted that growers should be paid for the next harvest the same price they were paid for the last, plus an allowance for any increased cost which could be demonstrated to the Government. This has meant that, in a sense, the grower has been certain of his return. The extreme difficulty of demonstrating increased costs to Government officials, however, has meant that growers have been uncertain as to the size of the adjustment which would be made.

In short, experience with "Certainty" suggested that its influence could not be distinguished with confidence by any simple statistical treatment.(11)

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(11) Alternatively, it is possible that Uncertainty Theory does not well describe farmers' reaction to uncertainty. For an interesting discussion of this possibility see "A Study of Farmers' Reactions to Price Expectations" by J.A. Boan, Journal of Farm Economics, Vol. 37,1955, p.50.

CHAPTER V

ESTIMATION OF THE SUPPLY FUNCTION FOR NEW ZEALAND WHEAT

The correlations in ordinary figures and first differences between the plausible variables have been computed.(1) The significance of these empirical relationships is now discussed.

5.1. The Simple Correlation Between the Dependent and the Independents.

The signs of all the correlation coefficients between the independent variables and the dependent are in accordance with the theoretical considerations discussed in section 4.2, with the exception of wheat price in original figures where the correlation r_{ab}, instead of being positive, is negative. The correlation r_{a1b1} on the other hand has the "right" sign. At first blush, it would appear that all the plausible variables are confirmed by the empirical data.

The correlation between the change in wheat acreage last year and the change this, r_{a1k1}, is very low (+·041). This confirms the discussion given in section 4.2.1. to the effect that in first differences last year's wheat acreage was unlikely to be a useful explanatory variable. Accordingly, it has been left out of the first difference calculations.

In original figures all the independent variables are

(1) The matrices of correlation coefficients, Appendix B, may be opened to be read in conjunction with this section.

significant at the 1 per cent level. (Even Wheat Price is significant though it has the wrong sign!) It is evident that this data is likely to be severely multicollinear.

In first differences, none of the variables are significant at the 1 per cent level, and only meat price is significant at the 5 per cent level. Wool price and Rainfall border on significance at the 5 per cent level. The correlations of Barley, Ryegrass and White Clover Prices with the dependent variable, $r_{a^1f^1}$, (-·110), $r_{a^1g^1}$, (-·063), $r_{a^1h^1}$, (-·110), respectively, are unsatisfactory.

The failure of a coefficient to maintain significance when converted to first differences casts some doubt on its validity, even in original figures. Even complete failure in first differences, however, especially when only the zero-order correlation is being considered is not sufficient to justify the rejection of a variable in original figures.

5.2. The Acreage Correlations.

In section 4.2.e and f. it was shown that unless the connection between the acreage of wheat and of oats or barley was such as would be produced by the physical substitution of one crop for the other no confidence could be placed in the correlation of the price of the crop and wheat acreage.

In the case of Barley, the correlation coefficients r_{am} (-0·640) and $r_{a^1m^1}$, (-0·049), show that large barley acreages have been associated with small wheat acreages. This confirms the relation found between barley price and wheat acreage r_{af} (-0·530) and $r_{a^1f^1}$ (-0·110).

In the case of oats, the correlation obtained between acreages r_{a1} (+0·216) and $r_{a^1 l^1}$ (+0·308) indicate that large oat acreages have been associated with large wheat acreages. This relationship persists even when the trend associated with the original figures has been eliminated by taking first differences. It does not seem reasonable, therefore, to suggest that a high oat price has led oat production to be substituted for wheat growing. This leads to the "plausible" variable, oat price, being rejected as being inconsistent with the data collected from 1919 to 1952. Oat price is rejected despite its high correlation with wheat acreage r_{ae} (-0·718), and $r_{a^1 e^1}$ (-0·308).

5.3. Multicollinearity.

In this study a correlation between independent variables with a modulus in excess of ·8 has been taken as clear and sufficient proof of multicollinearity.(2) Where two or more variables are multicollinear it is necessary to suppress one or more until the variables remaining in the equation are no longer multicollinear. Which variable should be suppressed depends on theoretical considerations.

The original data and first difference matrices will be considered separately.

5.3.a. Multicollinearity in the Original Data.(3)

Consideration of Appendix Ba indicates that the most seriously multicollinear variables are Wheat Price, Fat Lamb

(2) See Section 4.3. 32?

(3) It is suggested the Appendix C should be consulted, as this summarises the data on multicollinearity contained in original figures correlation matrix.

Price, Wool Price, Oat Price and Ryegrass Price. "Seriously multicollinear" in the sense that they inhibit the inclusion of other variables, Lamb and Wool prices are, of course, the most seriously multicollinear in the sense of degree of intercorrelation. The multicollinearity of Oat Price with other independent variables has been mentioned in Appendix C for completeness. Oat price has, however, already been rejected as an explanatory variable because of the positive correlation between wheat and oat acreages. This leaves two problems to be discussed: should Wheat Price, or Barley and Ryegrass Price be included and should Fat Lamb or Wool Price be included?

Wheat Price is obviously preferable as an explanatory variable for wheat acreage to Barley Price and Ryegrass Price. The fact that the zero-order correlation (and therefore regression) of wheat acreage and (on) wheat price has the "wrong sign" does not detract from the fact that wheat price is considered to be more important than the other two prices. Putting it another way, theoretical considerations indicate that wheat price is, necessarily, important in determining wheat acreage, there is no such necessary connection between wheat acreage and the other prices. Before, however, there can be any confidence in the "true" relation having been established, it is necessary that the partial regression coefficient should assume the "right" sign.

In choosing between Fat Lamb Price and Wool Price, it is possible to use empirical knowledge of the structure of the industry to distinguish the more important variable. This

knowledge indicates that Fat Lamb Price is far more important to the average wheat farmer. An alternation in wool price might modify the impact of a certain lamb price but it could not dominate wheat farmers' production decisions as could lamb price. The thesis that fat lamb price is more important than wool price is supported by the first difference correlation of these two variables with the dependent. The correlation of the dependent with fat lamb price is significant, while the correlation with wool price is not.

The above discussion leaves the variables which have to be examined in original figures as Wheat Acreage (Xa), Wheat Price (Xb), Fat Lamb Price (Xc), White Clover Price (Xh), Red Clover Acreage (Xi), Rainfall (Xj) and Last Year's Wheat Acreage (Xk). It is to be expected that it will be impossible to include all of these surviving variables in the supply function, as these variables probably retain a fair degree of multi-collinearity even though the most blatant cases have been removed.

5.3.b. Multicollinearity in the First Difference Data.

The matrix of correlation coefficients expressing the relations between the variables in first differences indicates that there is only one prima facie case of multicollinearity. The relation between Fat Lamb and Wool Price maintains its high correlation even in first differences, $r_{c^1 d^1}$ (+0·956). General knowledge of the industry suggests in this case, as in the parallel case above, that lamb price is much more important than wool price. This leaves the variables Wheat Acreage (X^1a),

Wheat Price (X^1b), Fat Lamb Price (X^1c), Barley Price (X^1f), Ryegrass Price (X^1g), White Clover Price (X^1_h), Red Clover Acreage (X^1_i) and Rainfall (X^1_j), to be examined in first differences.

The coefficient of multiple determination, R^2, obtained when all these variables are used in the equation is 0·300.(4) This leads to the conclusion that useful estimates cannot be obtained in this study by the use of first difference data. The matrix of correlation coefficients in first differences has been presented and studied, as it is felt to give a more complete picture of the data used than would be given if the discovery of the non-significance of the data had led to its immediate suppression.

5.4. The Possible Relations Using Original Figures.

It has been explained above that two criteria of significance are used. The lenient criterion demands that the regression coefficients should be equal to or larger than their standard errors, for thirty degrees of freedom this approximates to 63 per cent level of probability. The strict criterion demands that the regression coefficients should be twice their standard errors, this approximates to the 95 per cent level of probability. When the strict criterion was used for the whole period 1919-1952, it

(4) An R^2 of 0·300, when seven independent variables are used, is surprisingly low. There can be no doubt that this is, in fact, the value of the coefficient of multiple determination as the system was thoroughly checked. The sums of squares/cross products matrix was checked by the use of a summation variable. In this check the sum of the observations for a particular period is taken as an "observation" for a new "summation" variable. The sums of squares of this variable are equal to the sum of the sums of square of the original variables plus twice the sum of their cross products. The coefficients obtained satisfied all the resulting seven normal equations and gave a predicted sums of squares which led to an R^2 of 0·300.

was observed that the two largest residuals occurred in the first three years. These three years were deleted and a larger multiple correlation coefficient was obtained.

5.4.a. The Lenient Criterion.

The relation obtained using the lenient criterion involved Wheat Acreage (Xa), Wheat Price (Xb), Fat Lamb Price (Xc), Red Clover Acreage (X_i), Rainfall (Xj), and Last Year's Wheat Acreage (X_k). The equation was:-

$$(1)\quad Xa = 155{\cdot}0 + \underset{(0{\cdot}165)}{0{\cdot}269}Xb - \underset{(0{\cdot}032)}{0{\cdot}108}\,Xc - \underset{(0{\cdot}079)}{0{\cdot}145}\,Xi - \underset{(2{\cdot}334)}{3{\cdot}246}\,Xj + \underset{(0{\cdot}167)}{0{\cdot}507}Xk$$

$$R^2 = 0.713$$

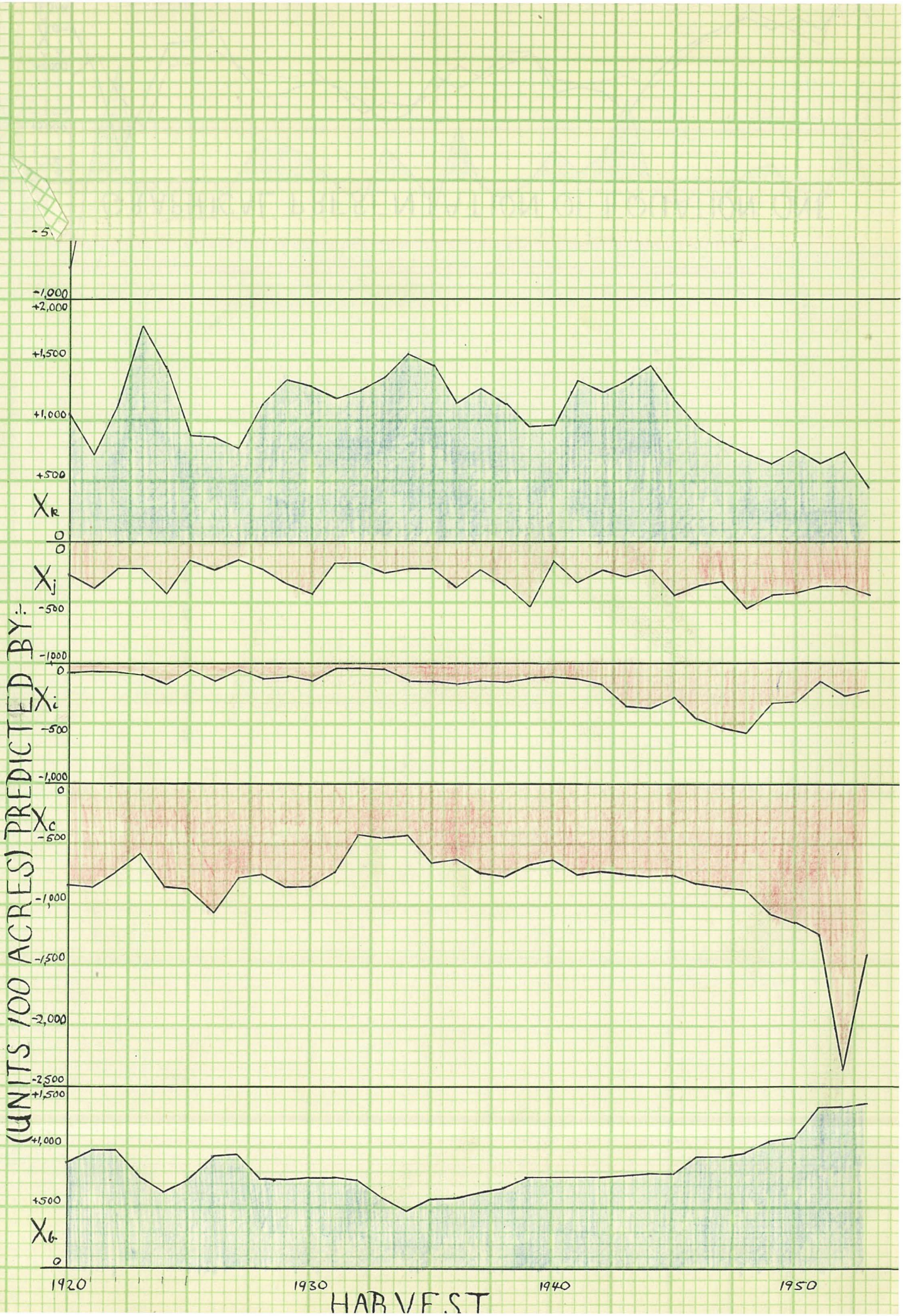
$$\text{"d"} = 1{\cdot}790.$$

In this relation X_c and X_k are significant even according to the strict criterion. X_b is not significant according to the strict criterion. In original figures a positive partial regression coefficient for X_b and significance on the stricter test appeared incompatible. Xi becomes significant at the stricter level if Xb and Xj are suppressed while Xj becomes significant at the higher level if Xb and Xi are suppressed. It appears that Xi and Xj are to some extent multicollinear. The multiple correlation coefficient R^2 is not very satisfactory for prediction. The "d" statistic(5) is quite satisfactory and indicates the residuals are approximately random. This means that the standard errors calculated for the regression coefficients may be considered to be unbiased estimates of the "true" standard errors.

5.4.b. The Strict Criterion.

Using the strict criterion, there were two alternative

(5) Durbin & Watson - "Testing for non-serial correlation in least squares regression", Biometrika Vol.37 (1950) p.409 f.f.


-5.
-1,000
+2,000
+1,500
+1,000
+500
X_k
0
0
X_j
-500
-1000
0
X_i
-500
-1,000
0
X_c
-500
-1,000
-1,500
-2,000
-2,500
+1,500
+1,000
+500
X_b
0
1920
1930
1940
1950
HARVEST
(UNITS 100 ACRES) PREDICTED BY:

relations obtained. Xi and Xj appeared to be too highly correlated to permit them both to appear in a relation and both pass the strict test. As these two variables were of equal theoretical merit, it was decided to derive two relations, the first includes Wheat Acreage (Xa), Fat Lamb Price (Xc), Red Clover Acreage (Xi) and Last Year's Wheat Acreage (X_k) and the second having the same variables except that Red Clover Acreage (Xi) was replaced by Rainfall (Xj). The two relations were:-

$$(2)\quad Xa = 216{\cdot}9 - \underset{(0{\cdot}026)}{0{\cdot}078Xc} - \underset{(0{\cdot}074)}{0{\cdot}192Xi} + \underset{(0{\cdot}135)}{0{\cdot}380X_k};\quad R^2 = 0{\cdot}666;\ \text{"d"} = 1{\cdot}542$$

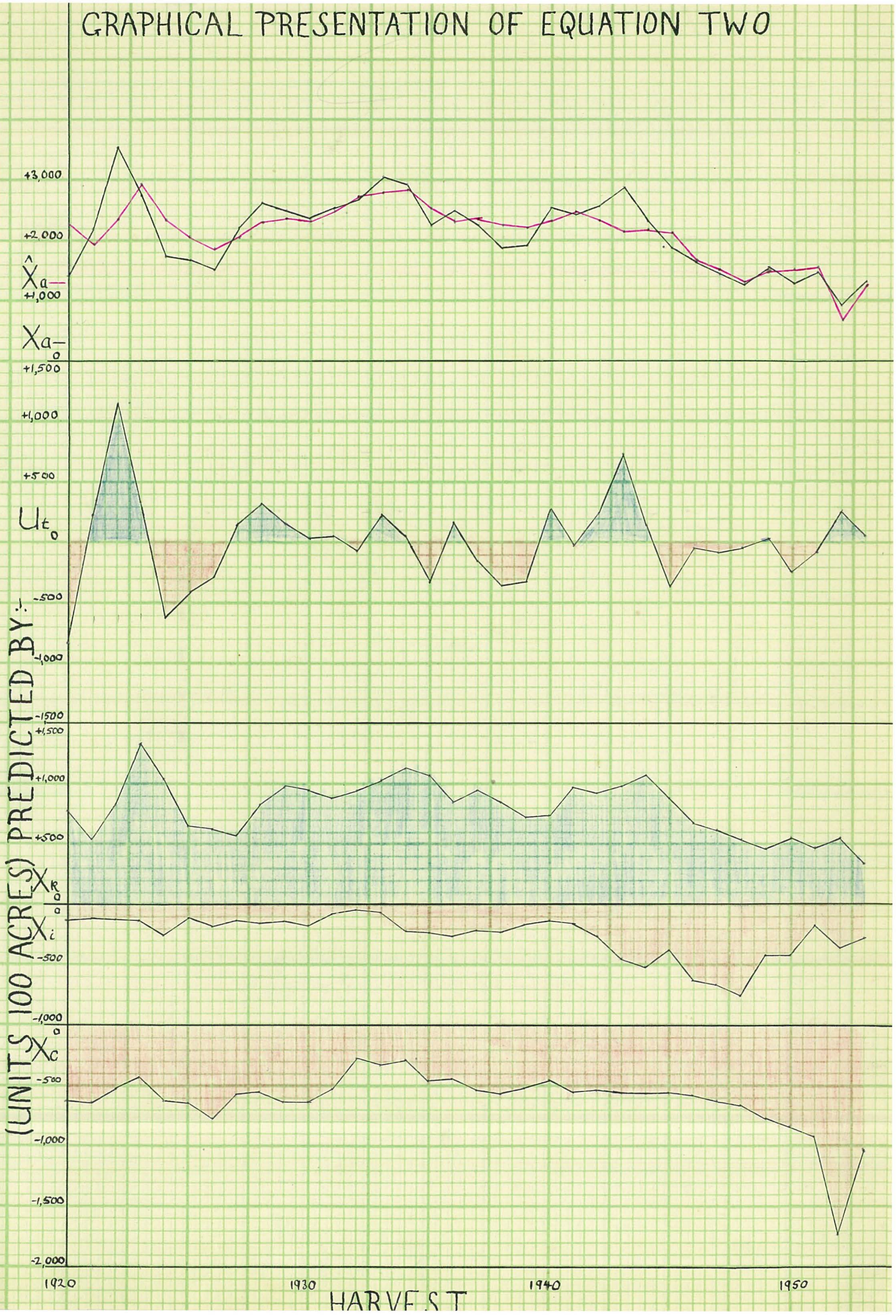
$$(3)\quad Xa = 245{\cdot}2 - \underset{(0{\cdot}026)}{0{\cdot}076Xc} - \underset{(2{\cdot}210)}{5{\cdot}192Xj} + \underset{(0{\cdot}140)}{0{\cdot}352X_k};\quad R^2 = 0{\cdot}655;\ \text{"d"} = 1{\cdot}470$$

Apart from the fact that the variables pass the strict criterion for significance, these two relations are really most unsatisfactory. The multiple correlation coefficients are too low to inspire confidence in prediction based upon these equations, and the residuals are sufficiently auto-correlated to suggest that the standard deviations derived for the regression coefficients seriously underestimate the "true" standard deviations of these coefficients.

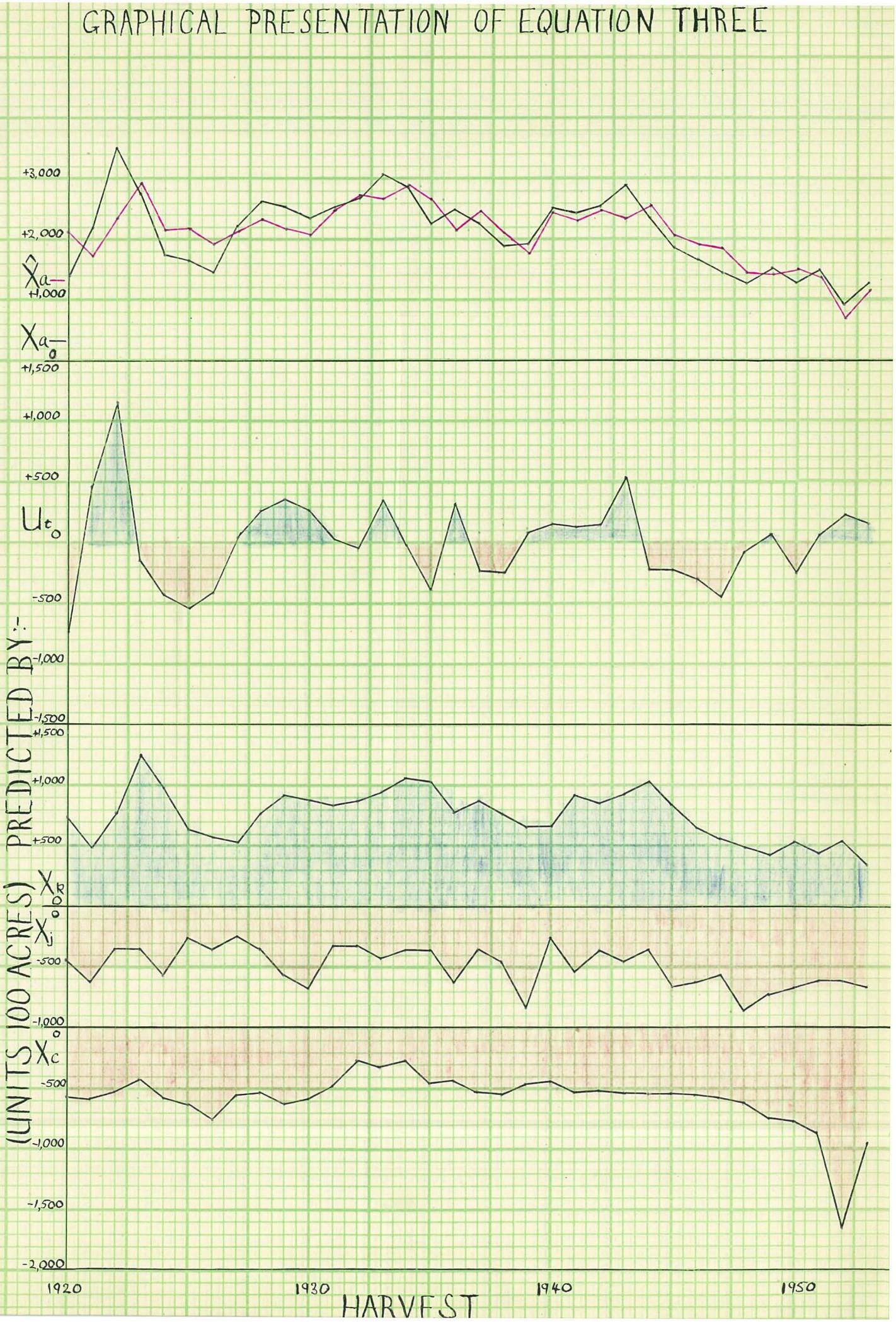
It is interesting to note that replacing of X_i in (2) by Xj in (3) makes little difference to the value of the coefficients occurring with Xc and X_k. All the coefficients in (2) and (3) differ quite markedly from the coefficients obtained by using the lenient criterion.

In relations (2) and (3) only one price occurs, Fat Lamb Price, and it was felt that "trend" might be leading to some of the variables having inflated partial correlation coefficients.

GRAPHICAL PRESENTATION OF EQUATION TWO



GRAPHICAL PRESENTATION OF EQUATION THREE



Accordingly, Time was experimented with. It was found that Time was not significant according to the strict criterion and that it did not greatly reduce the significance of the other variables, or alter their regression coefficients in a marked manner. It was felt that the inclusion of time in these relations was not helpful.

In deriving the "d" statistic for these two series it was noted that in both of them the first three years contained the two largest residuals. This led to the first three years being deleted and the coefficients for these shorter series were computed.

5.4.c. The Shorter Series, Lenient Criterion.

The variables which were significant in the shorter series at the lower level were the same as in (1), except the Wheat Price (Xb) was no longer significant. The relation was:-

$$(4)\quad Xa = +222{\cdot}6 - \underset{(0{\cdot}019)}{0{\cdot}067Xc} - \underset{(0{\cdot}063)}{0{\cdot}123Xi} - \underset{(1{\cdot}799)}{2{\cdot}977Xj} + \underset{(0{\cdot}104)}{0{\cdot}392X_k}$$

$$R^2 = 0{\cdot}810$$

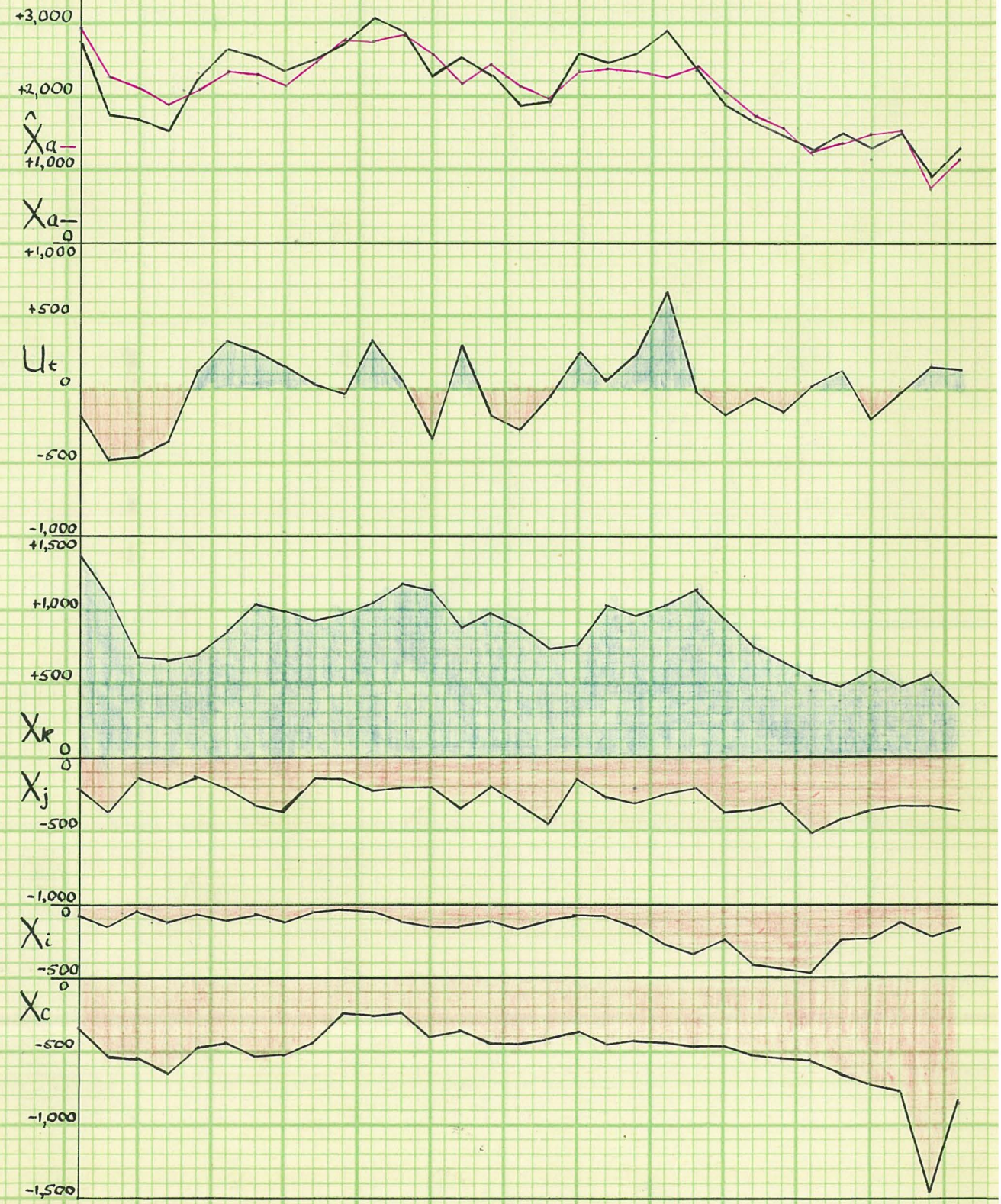
$$\text{"d"} = 1{\cdot}258.$$

In this equation the coefficient of multiple determination is satisfactory, though not very good, for prediction. The residuals, on the other hand, are quite markedly different from random so that the standard errors of the regression coefficients may seriously underestimate the true standard errors.

5.4.d. The Shorter Series, Strict Criterion.

In (4), Xi and Xj are not significant at the higher level of significance, each becomes significant if the other is suppressed. The resulting relations are:-

GRAPHICAL PRESENTATION OF EQUATION FOUR



(UNITS 100 ACRES) PREDICTED BY :-

(5) $Xa = +198{\cdot}5 - \underset{(0{\cdot}019)}{0{\cdot}072Xc} - \underset{(0{\cdot}058)}{0{\cdot}171Xi} + \underset{(0{\cdot}106)}{0{\cdot}418X_k}$; $R^2 = 0{\cdot}791$; "d"=1·270

(6) $Xa = +215{\cdot}4 - \underset{(0{\cdot}020)}{0{\cdot}067Xc} - \underset{(1{\cdot}676)}{4{\cdot}596Xj} + \underset{(0{\cdot}108)}{0{\cdot}416X_k}$; $R^2 = 0{\cdot}783$; "d"=1·247

The residuals from these two equations also fail to pass the test for randomness. The coefficients of multiple determination are smaller than in (4), as would be expected, and they would not inspire great confidence if prediction was based on these equations. The coefficients for Xc and X_k remain remarkably stable in the three equations (4), (5) and (6), while the coefficients of Xi and Xj shift as befits coefficients of series which are, in some degree, multicollinear.

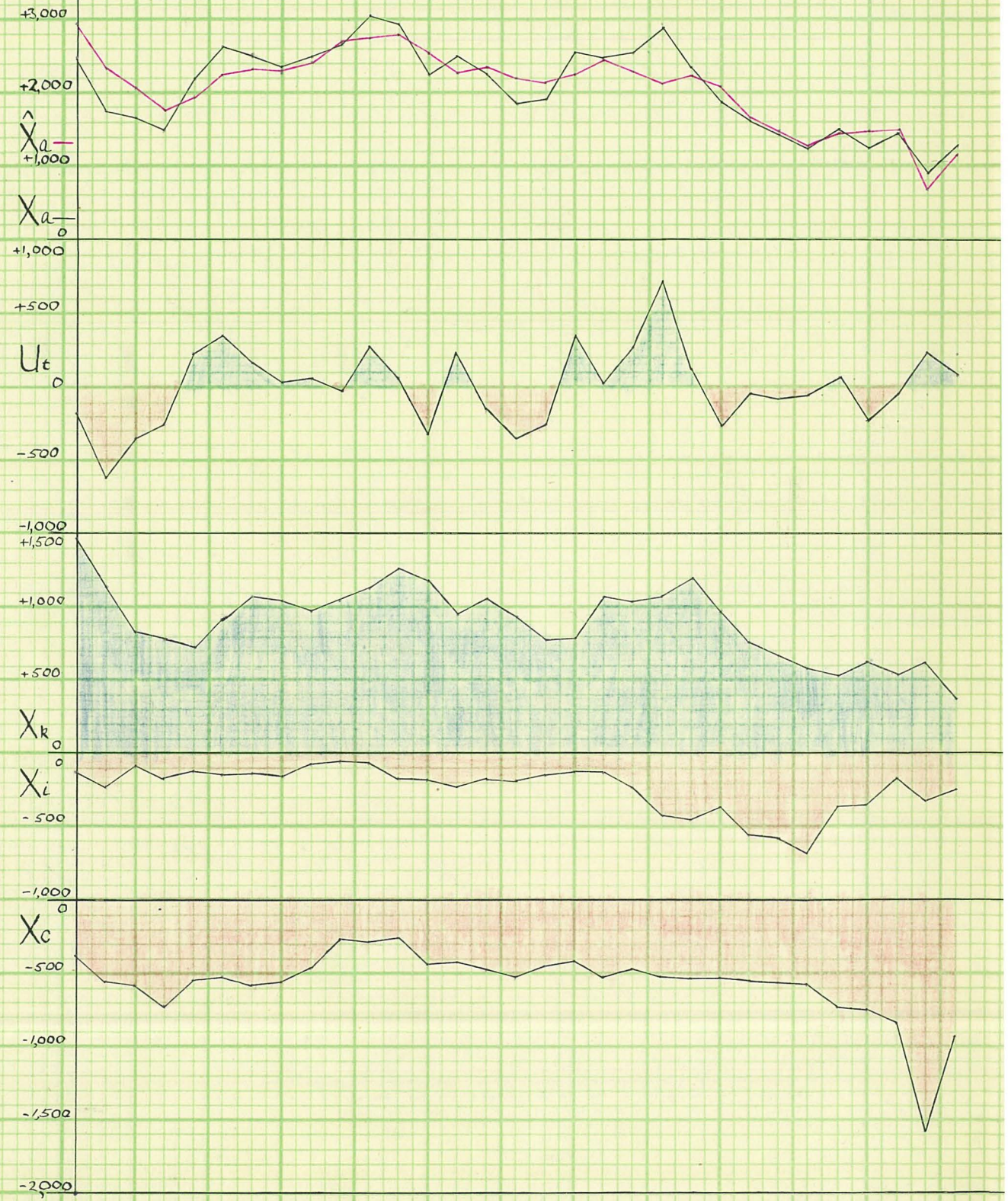
The desirable properties for a prediction equation are that it should have coefficients which are significant at the 95 per cent level at least, that it should have a coefficient of multiple determination in excess of 0·8 and that it should leave random residuals.

These desirable properties can be achieved if in equation (5) the auto-correlation, which is suggested by a "d"-statistic of 1·270 is specifically allowed for.

5.5. Auto-correlation of the Residual.

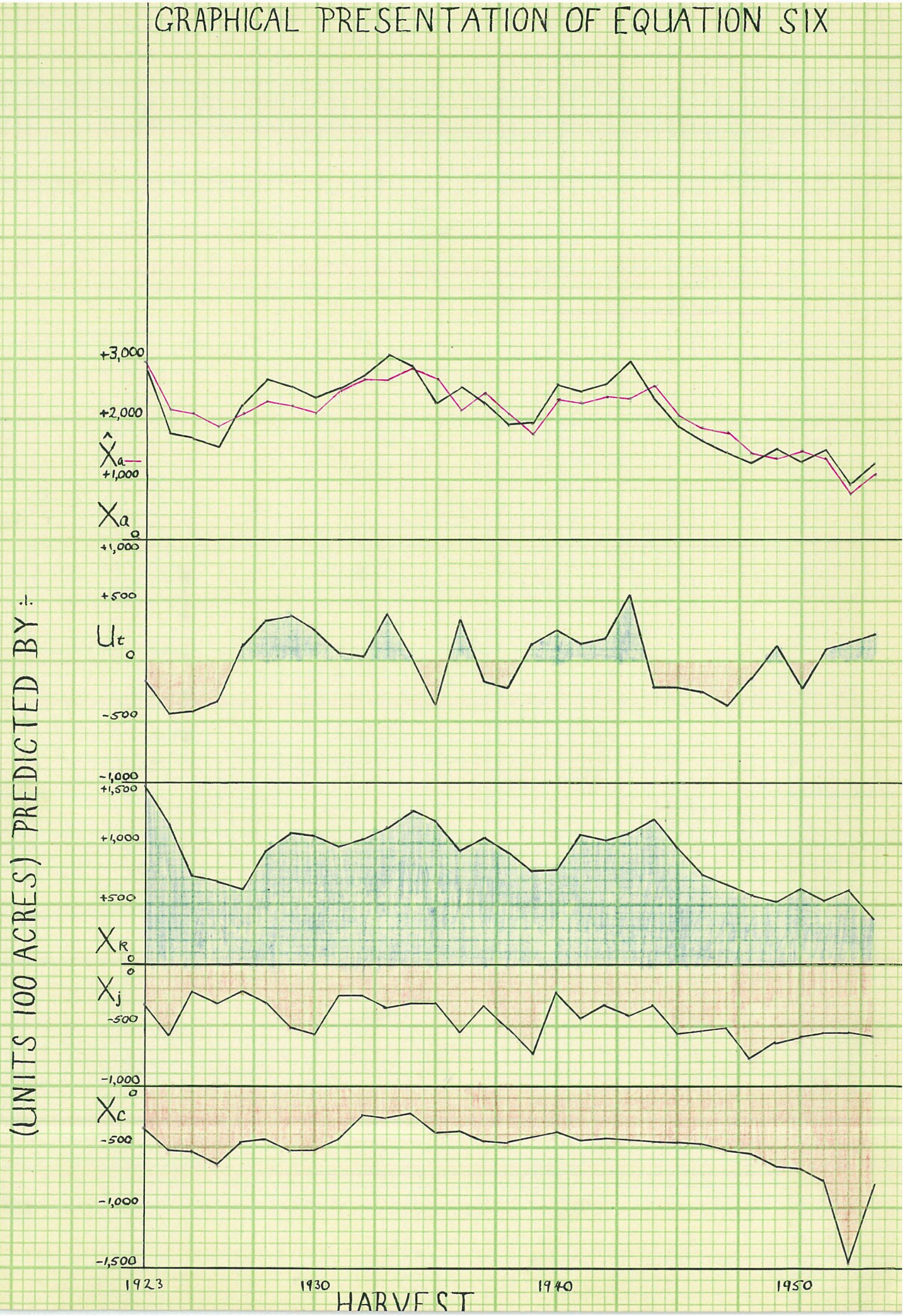
When the specification of the form of the equation was discussed in section 4.1, the tacit assumption was made that all the equations discussed had an error term or residual, which was random, normally distributed with mean zero and constant variance. An alternative assumption could have been made to the effect that successive error terms were correlated, but when this correlation had been allowed for a random residual would be obtained. Thus,

GRAPHICAL PRESENTATION OF EQUATION FIVE



(UNITS 100 ACRES) PREDICTED BY :-

GRAPHICAL PRESENTATION OF EQUATION SIX



equation (5) is expressed as a complete equation:-

(5a) $X_{at} = K + b_{ac}X_{ct} + b_{ai}X_{it} + b_{ak}X_{kt} + U_t$.

(5b) $E(U_t) = 0$; $E(U_t^2) = \sigma_u^2$.

Where U_t is the residual observed in period t. (5b) indicates that the residuals have mean zero and constant variance.

An alternative specification of this equation may be given:-

(7a) $X_{at} = K + b_{ac}X_{ct} + b_{ai}X_{it} + b_{ak}X_{kt} + U_t$.

(7b) $U_t = \rho U_{t-1} + V_t$.

(7c) $E(V_t) = 0$; $E(V_t^2) = \sigma_v^2$.

In this case, the V_t's are assumed to be a random series, normally distributed, with mean zero and constant variance. Substituting (7b) into (7a) gives:-

(7d) $X_{at} = K + b_{ac}X_{ct} + b_{ai}X_{it} + b_{ak}X_{kt} + \rho U_{t-1} + V_t$.

If (7a) for the period t-1 is multiplied by ρ, the auto-regression coefficient, and subtracted from (7d), the result is:-

(7e) $X_{at} - \rho X_{at-1} = K(1 - \rho) + b_{a\not{\rho}}^{c}(X_{\not{\rho}t} - \rho X_{\not{\rho}t-1}) + b_{ai}(X_{it} - \rho X_{it-1})$
$+ b_{ak}(X_{kt} - \rho X_{kt-1}) + V_t$.

Here ρU_{t-1} has been eliminated, leaving the random residual V_t. (7e) may be solved by ordinary least-squares methods to give estimates of the coefficients $b_{a\not{\rho}}^{c}$, b_{ai}, b_{ak} in terms of the observations X_{at}, X_{ct}, X_{it}, X_{kt}, and the auto-regression coefficient ρ. The estimates of the regression coefficients may be substituted into (7e) giving a polynomial in ρ. The root of this polynomial between + 1·0 and - 1·0 which gives minimum variance to the error term V_t is the maximum likelihood estimate of the system (7a) - (7c).

A root to the polynomial in ρ may be obtained by an

iterative process by which an estimated auto-regression coefficient is substituted into equation (7e), and "new variables" $(X_{jt}-\rho X_{jt})$, $(j = c, i, k)$ are formed. These "new variables" may be used to get ordinary least squares estimates of the baj $(j = c, i, k)$ from equation (7e). The baj $(j = c, i, k)$ so obtained are then used in equation (7a) to get a new estimate of the residuals U_t. These estimated residuals, U_t, may then be used in (7b) to get a new least squares estimate of $\hat{\rho}$. This $\hat{\rho}$ is then substituted into (7e) again. This process is repeated until the estimated auto-regression coefficient substituted into (7e) corresponds to the coefficient obtained later from (7b). This iterative process does not, of course, necessarily yield a maximum likelihood solution, as only one of the roots of the polynomial in ρ is obtained.

The system (5a) - (5b) was respecified as (7a) - (7c), and the iterative procedure applied. This yielded a system:-

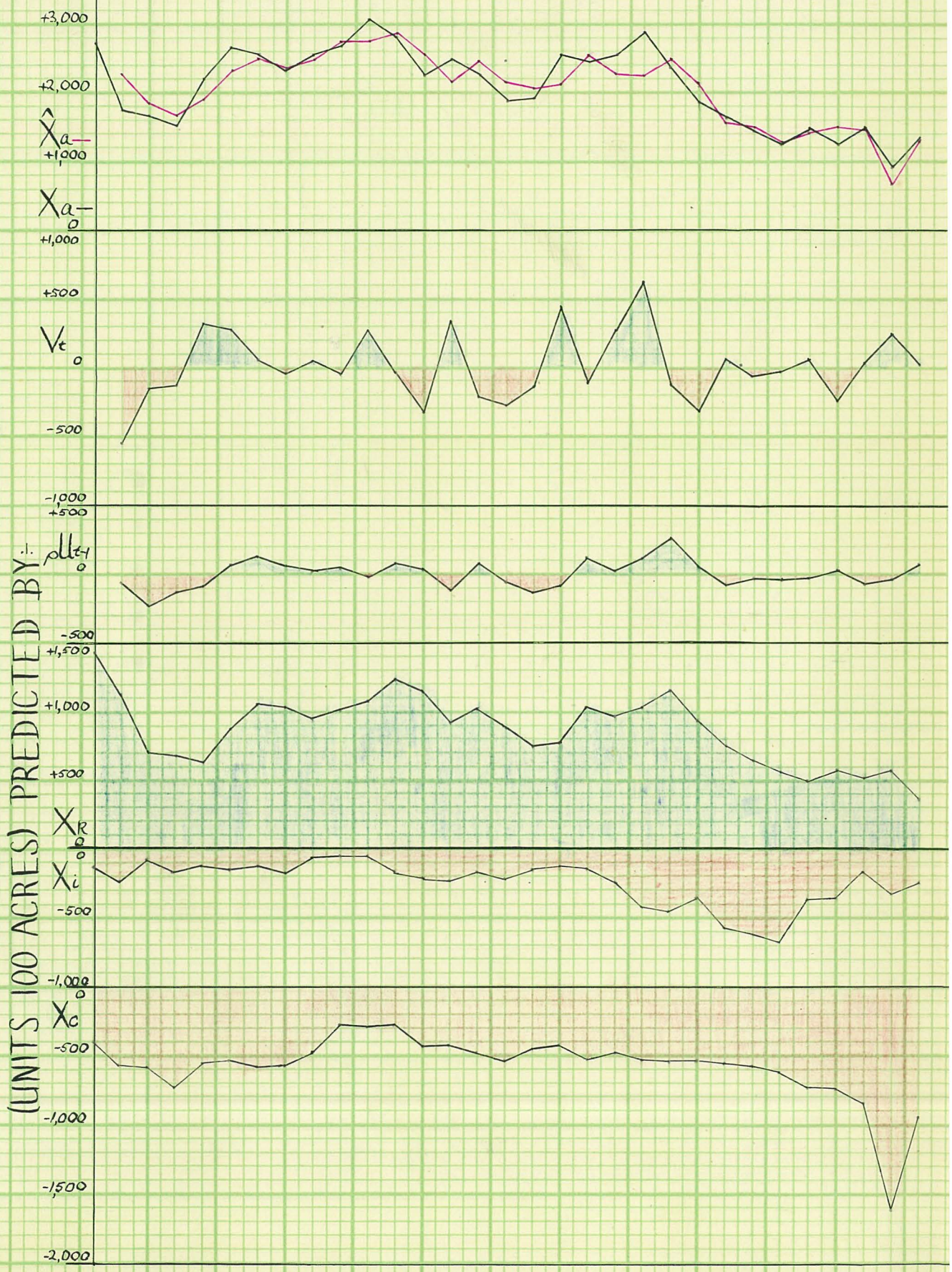
$$(7)\quad \begin{cases} X_{at} = 203{\cdot}5 - 0{\cdot}073X_{ct} - 0{\cdot}176X_{it} + 0{\cdot}403X_{kt} + U_t. \\ \qquad\qquad\quad (0{\cdot}015) \qquad (0{\cdot}055) \qquad (0{\cdot}092) \\ U_t = 0{\cdot}36\, U_{t-1} + V_t \qquad R^2 = 0{\cdot}812; \quad \text{"d"} = 1{\cdot}795. \end{cases}$$

This equation has the three properties demanded of a prediction equation, R^2 is in excess of 0·8, the ultimate residuals are approximately random, and the variables included are all significant at the 95 per cent level of significance. Indeed, in (7) all variables are significant at the 99 per cent level of significance.

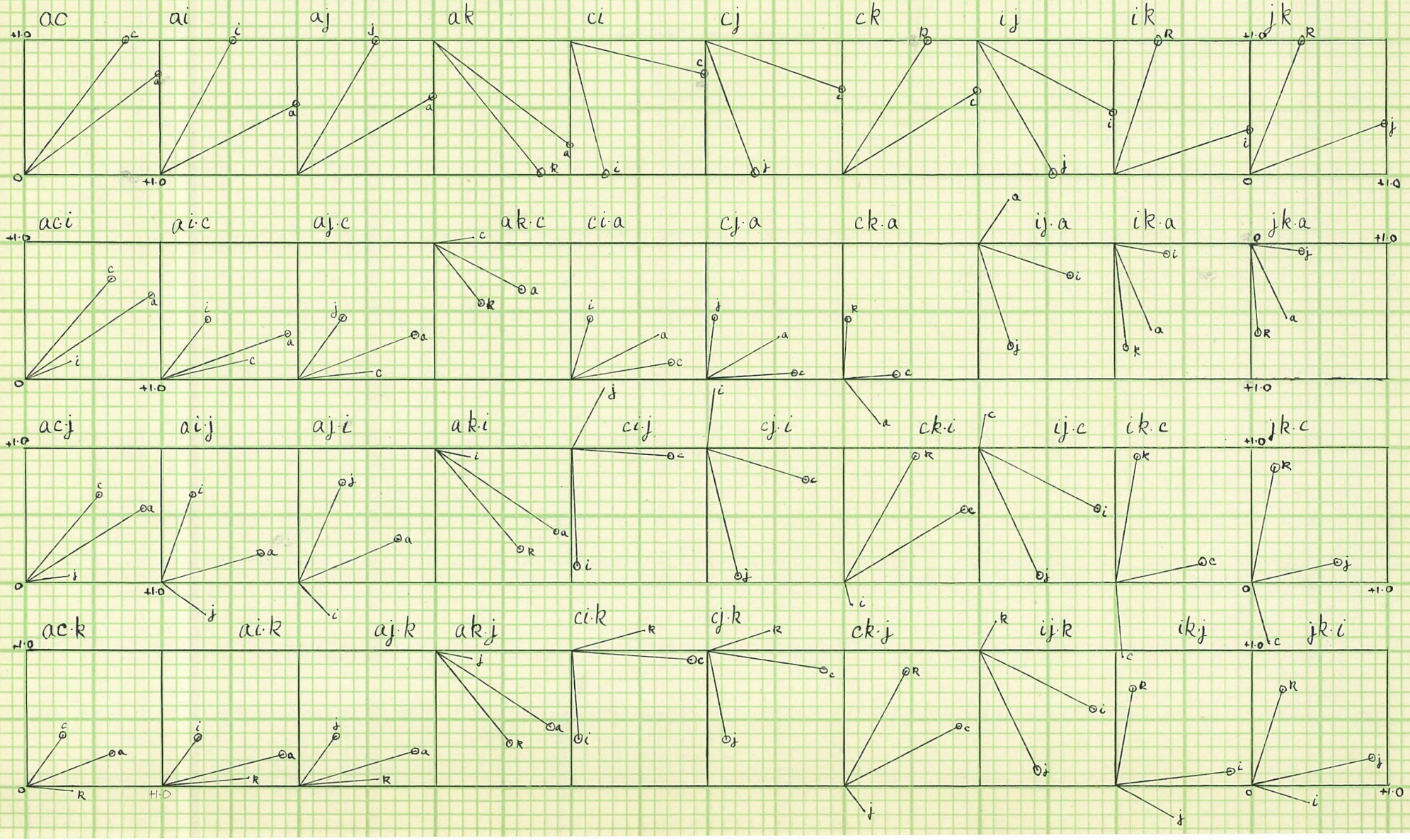
5.6. Confluence Analysis.

It has been explained earlier that the author does not consider the confluence analysis approach to be very useful.

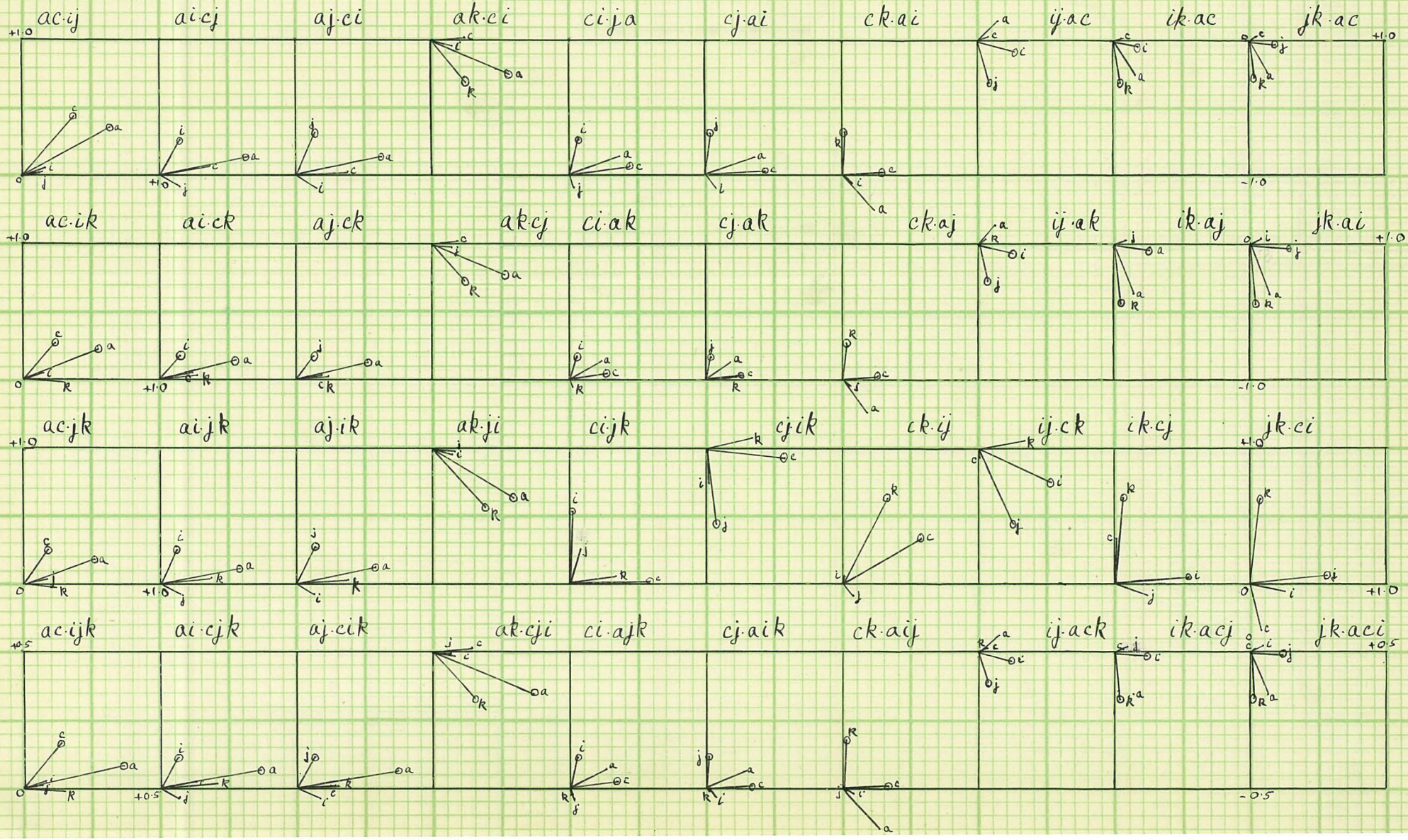
GRAPHICAL PRESENTATION OF EQUATION SEVEN



BUNCH-MAPS FOR THE SHORTER SERIES (HARVESTS 1923-1953)



BUNCH-MAPS, CONTINUED.



Bunch-maps have been prepared for the shorter series variables, however, and are presented. The main lesson learnt from studying these maps is that where a second variable is added to another one, Frisch's criterion would suggest that it is either superfluous or actually detrimental. It is obvious that the author cannot claim that any of the relations included in this study have "good" bunch-maps.

CHAPTER VI

CONCLUSIONS

In the last chapter the coefficients obtained from a number of alternative specifications of the supply function were presented. The remaining tasks are to compare the different estimates and to try to see what practical conclusions may be drawn from this study.

There are two kinds of information which may be obtained from this study. The first kind consists of equations which will give a satisfactory prediction of the future behaviour of the dependent variable. The second consists of estimates of the "structural coefficients" which occur in the underlying "true" structural relation.

For prediction, the whole equation has to be considered. When an equation is meant to be used for prediction it is termed a Prediction Equation. In time series data there are usually quite distinct relationships amongst the "independent" variables. Provided that these relationships continue to hold in the future as they have held in the past, quite good prediction can be obtained from equations whose individual coefficients are very poor estimates of the structural coefficients. Thus in (7) there is no specific allowance made for the influence of wheat price but the influence of this variable has been absorbed in the

influence attributed to fat lamb price and last year's wheat acreage. Wheat price's influence has been attributed to these two variables because it is very highly correlated with them. So long as wheat price continues to be highly correlated with the variables included (7) will continue to give quite good prediction. If wheat price ceased to be highly correlated with the other variables then (7) would probably cease to give useful prediction. In this case useful prediction would only be supplied by an equation which made specific allowance for wheat price.

The structural coefficients are the coefficients which relate the dependent variable to the independent variables in the true underlying structural equation. These coefficients are thought to be independent of one another, so that a change in one of them will leave the other coefficients unaffected. Thus the structural equation, with true values attributed to the structural coefficients, will provide good prediction even if the independents assume a pattern of values which has not even been approximated before, provided, of course, that the "true" coefficients of the past continue to be applicable in the future.

Thus there are two types of comparison which may be made. The different equations may be compared or the coefficients of a variable in the different equations may be compared.

6.1. Comparing Equations.

(1) is the most general estimate of the relation in that it includes Wheat Price (Xb) which is excluded from the other equations. The individual regression coefficients are all quite safely significant at the 63 per cent level. The coefficient of multiple determination is unsatisfactory but the "d"-statistic is

good. (1) could not be used for prediction with any confidence on account of its low R^2 but it does, however, provide the only estimate which is in any way satisfactory of the regression of wheat acreage on wheat price, so that if wheat price diverged from lamb price, this is the prediction equation which would have to be used. (2) and (3) are the only equations which would have been derived from the original data if the 95 per cent level of significance had been insisted upon. They are poor in every way. The coefficients of multiple determination are deplorably low, the "d"-statistic suggests that little faith could be placed in the hypothesis of random residuals, and the estimates of the regression of wheat acreage on red clover acreage and rainfall are satisfactory only on the hypothesis of maintained structure. Their only virtue is the significance of the partial regression coefficients at the 95 per cent level.

(4) has a satisfactory R^2 but a very low "d"-statistic. It is an unsatisfactory prediction equation because of its non-random residuals. All partial regression coefficients in (4) are safely significant at the 63 per cent level, two of them are significant at the 95 per cent level and another of them borders on significance at this level. It is probable that (4) gives a better estimate of the net regression of wheat acreage on red clover acreage and rainfall than is given by either (5) or (6).

(5) and (6) are again equations which might have been derived if the 95 per cent level of significance had been used. The R^2's in these two equations are definitely superior to the R^2's in (2) and (3), but (5) and (6) have less satisfactory "d"-

statistics than the earlier equations. It seems probable that (5) and (6) would be better prediction equation t han (2) and (3), but again, the usefulness of the estimates of the regression of wheat acreage on red clover acreage and rainfall is dependent on maintained structure. The term maintained structure is, in this case, being used a trifle loosely. Strictly, structure changes, or ceases to be "maintained", only when one of the structural coefficients assumes a new value, or the form of the structural equation is altered. Good prediction from an equation which is not the structural equation, also demands that the independent variables should continue to behave in approximately the same way as they have in the past. This may be seen intuitively if equations (4), (5) and (6) are considered. The observation of clover acreage and rainfall have been correlated in the period studied. This means that it is difficult to distinguish the influence of red clover acreage from the influence of rainfall, and the inclusion of both of them in an equation (e.g. (4)) means that neither of the regression coefficients is significant at the 95 per cent level. If only one of them is included, i.e. (5) or (6), then the regression coefficient is significant at the 95 per cent level. But some of this "significance" is due to the variable included being credited with some of the "explanation" which is really due to the excluded variable. This in turn means that if red clover acreage is included, it is impossible to tell whether its significance is due to the influence of red clover acreage, or due to this variable being credited with the influence of rainfall. Or even more simply, the coefficient which is

derived for Red Clover Acreage may be an estimate of a structural coefficient which relates either to red clover acreage or rainfall. Or still another way, red clover acreage may be nothing more than an imperfect index of the influence of rainfall. If the latter hypothesis is true, it is obviously essential that red clover acreage should continue to move with rainfall in order that a prediction equation using the red clover acreage should give a useful estimate.

(7) is definitely the best prediction equation obtained.

The desirable properties for a prediction equation which assumes maintained structure are that it should have a high coefficient of multiple determination, that it should have random residuals, and that the individual regression coefficients should at least be significant at the 95 per cent level. The coefficient of multiple determination is quite satisfactory especially as the "d"-statistic indicates that the residuals are virtually random, and all partial regression coefficients in this equation are significant at the 99 per cent level. The equation has, however, two very definite disadvantages: it assumes that wheat price will continue to behave approximately as a linear function of fat lamb price and last year's wheat acreage, and it assumes that red clover acreage and rainfall will continue to be highly correlated. It seems clear that the latter relation, at least, is due only to chance, for it is ridiculous to suggest that the farmer's decision in November-December to take a red clover seed crop is influenced by rainfall in the subsequent April. It is, of course, possible that the weather at the two periods is in some way connected and

that this influences farmers' decisions about red clover acreage. The latter thesis, however, would inspire little more confidence than the former.

Summarizing, it may be said that, provided all the relationships which have held for the shorter period 1923-53 continue to hold, then (7) will provide the best prediction equation. If, however, Red Clover Acreage and Rainfall stop moving together then an equation such as (4) would give the best prediction, especially if the specification were altered to make allowance for autocorrelation of the residuals. If wheat price and fat lamb price ceased to be highly correlated, then prediction would be an extremely hazardous occupation but an equation such as (1) would have to be used. If the relation between rainfall and red clover acreage continued to hold, the standard deviation of the wheat acreage wheat price partial regression coefficient in (1) might be reduced by suppressing either red clover acreage or rainfall.

6.2. Comparing Regression Coefficients.

The only estimate of the regression of wheat acreage on wheat price obtained in this study and which was in any way satisfactory is provided by equation (1). In all other combinations it appeared that the expected positive regression coefficient was incompatible with statistical significance.

In the introduction it was stated that one of the aims of this thesis was to be able to indicate how the acreage of wheat might be influenced. One way wheat acreage might be influenced is by altering wheat price (another way would be to levy an export tax on fat lamb).

Would the estimate of the regression of wheat acreage on wheat price be of any use in estimating the cost of influencing wheat production via wheat price? The writer is of the opinion that it would be. It is suggested that the conclusions which could be drawn from the estimate would be along the following lines:-

Firstly, it should be remembered that the data from which the estimate has been derived is not entirely satisfactory, so that an "administrator" would not expect to be provided with the answer, but rather with information which could help him to estimate the cost of altering production.

Secondly, in 95 per cent of cases, given that the distribution of the errors is normal, the value of the parameter will fall within two standard deviations of the figure estimated. It follows that in 95 per cent of cases the true regression coefficient will be between +0·599 and -0·061. But since knowledge of economic theory makes it fairly certain that the true relation of wheat price to wheat acreage is positive, it follows that the effective range between which the coefficient will lie in 95 per cent of cases is +0·599 to 0·000.

Thirdly, this could be converted to simpler figures. Instead of dealing with units of $\frac{1}{4}$d per bushel the discussion could use pence per bushel. This would give the range of probable coefficients as being between +2·396 and 0·000. This, being interpreted, means that an increase of 1d per bushel in the price of wheat known at planting is likely to increase the acreage of wheat sown something between +2,396 and 0. acres.

Fourthly, it is very unlikely that the true regression coefficient falls above the upper limit to the coefficient, in terms of probability being likely to happen in only 2·5 per cent of cases when similar propositions are made. This would enable the administrator to calculate a lower limit to the cost of increasing wheat acreage by a given amount, for the larger the influence of price on acreage the smaller will the price charge have to be to induce a given change in acreage.

Thus 200,000 acres would involve a price for wheat which was at least 3/6d per bushel in excess of the price needed to produce 100,000 acres.

This "lower limit" to the cost can be expressed another way. If the price of wheat were increased by 3/6d per bushel then in 97·5 per cent of cases the increased wheat acreage would be 100,000 acres or less. Information of this sort may be useful as indicating that a proposed programme is likely to be quite ineffective, or far too expensive.

In a similar manner, it would be possible to calculate the price which would have to be paid in order that an increase of 100,000 acres would be achieved in 50 per cent of cases.

Just where the Government chose to fix the price would be essentially a matter of judgment and would probably depend largely upon the importance of increased acreage, for, obviously, the higher the price fixed the more likely it is that the acreage aimed at would be reached or passed.

Fifthly, it could be pointed out that the system used is auto-regressive, and that a high acreage one year tends to result in a

high acreage the next; so that the cost of maintaining a certain acreage in wheat would probably be less per year than the cost of achieving that acreage in any given year.

At this stage it is evident that it would be very interesting to have the results obtained by an equation specified in logarithms, or a satisfactory specification in first differences. They would provide additional information and would help to provide a "complete picture" of the situation. It has been noted above that attempts to derive a satisfactory estimate in first differences were unsuccessful. The coefficients for a specification using logarithms could be computed quite simply from the data in Appendix Ab. If this study had needed to be made exhaustive in order to advise the Government, it would, obviously, be desirable that the logarithm form should be investigated both in the logarithm variables themselves and in their first difference form.

Wheat price and fat lamb price are highly correlated. This means that in equations (2)-(7) where wheat price is excluded fat lamb price may be credited with much of the variation in wheat acreage which should really be attributed to wheat price. Thus the estimates in equations (2)-(7) have a definite bias, and the least-biased estimate of structural coefficient is probably provided by equation (1). At the same time, it will be observed that the coefficients in equations (2)-(7) are remarkably stable, so that considerable confidence could be placed in these estimates provided wheat price remains highly correlated with lamb price. It will be noticed that the shift of the fat lamb price regression coefficient from equations (2)-(7) to (1) is negative. This is

to be expected, because in equations (2)-(7) the negative effect of lamb price is being confounded with a positive effect due to wheat price.

The arguments with respect to the coefficients associated with last year's wheat acreage follow pari passu the argument associated with lamb price. The estimates contained in equations (2)-(7) will be biased as last year's wheat acreage is highly correlated with wheat price, and the latter is excluded from these equations. In this sense (1) provides the best estimate of the structural coefficient. The shift of the regression coefficient from positive in (2)-(7) to an even higher positive value in (1) is expected as wheat price and last year's wheat acreage are negatively correlated in the form in which the variables are used. This means that a high acreage of wheat last year has been associated with a low price of wheat this year. As both influences on the acreage of wheat are positive, the exclusion of wheat price from (2)-(7) has prevented last year's wheat acreage being credited with a larger positive coefficient. The stability of the regression coefficients of last year's wheat acreage in (2)-(7) means that considerable faith can be placed in this estimate provided wheat price continues to be highly, negatively, correlated with last year's wheat acreage.

Red Clover Acreage and Rainfall have important symptoms of multicollinearity. If they are both included in the same relation they are not significant at the 95 per cent level, i.e. (1) and (4). When one of them is suppressed the other becomes significant at the 95 per cent level, but the value of its regression

coefficient shifts markedly. In equations (2), (3), (5), (6) and (7) the coefficients for red clover acreage and rainfall will be biased because the variable included will be credited with much of the variation due to the excluded variable. In (1) and (4) on the other hand, the estimates of these regression coefficients will be unreliable because of the presence of the other (multicollinear) variable. The writer feels that the latter type of bias is less dangerous than the former. If this is so, then equations (1) and (4) will give the best estimates of the structural coefficients associated with these two variables.

It was felt that some people might have difficulty interpreting the regression equations given in this thesis. Accordingly, the equations have been expressed in modified form in Appendix D. This form gives the shift of independent variables necessary to produce a change of 1,000 acres in the area of wheat sown.

In conclusion, it may be said that while the writer would not claim that any of the estimates derived were entirely satisfactory, he does believe that they correspond quite closely to the best estimates which could be obtained from the data.

APPENDIX A

a. Source and Description of Data.

Variable	Symbol	Source
Wheat Acreage	Xa	This is the Total Acreage of wheat threshed in the relevant year. The series was obtained from the Agricultural and Pastoral Statistics of the Government Statistician. The unit is 1,000 acres. The figure for a particular year refers to the acreage harvested in that year.
Wheat Price	Xb	This series was supplied to me by the Wheat Committee as representing the price of Tuscan Wheat in March, f.o.b. South Island Ports. Differences between this series and prices given by the Secretary of the Department of Industries and Commerce to the 1929 Parliamentary Wheat Committee, led to further enquiries about the series and it appears that the first ten years are unreliable. The general order of magnitude of the two series is the same. The Wheat Committee's prices had been used in the computation before the discrepancy was noticed. The unit is $\frac{1}{4}$d per bushel. The figure which corresponds to the 1922 harvest is the price in March, 1921.
Fat Lamb Price	Xc	The derivation of this series is discussed in appendix E. The unit is $\frac{1}{80}$d per lb. The

price corresponding to the 1922 harvest is for March, 1921.

Wool Price	Xd	This is the average price of wool sold at the Christchurch auctions for the auctions December-March immediately prior to planting. The figure was obtained from Dalgety's Wool Review. The unit is 1/10d per lb.
Oat Price	Xe	This is the wholesale price of Garton A Oats at Christchurch in March. The unit is 1/10d per bushel. The series was supplied by the Government Statistician and the figure corresponding to the 1922 wheat harvest is the price in March, 1921.
Barley Price	Xf	This is the wholesale price of Malting Barley at Christchurch in March. The unit is 1/10d per bushel. The series was supplied by the Government Statistician. The price corresponding to the 1922 harvest is for March, 1921.
Ryegrass Seed Price	Xg	This is the wholesale price of machine dressed Perennial Ryegrass Seed at Christchurch in March. The prices were supplied by the Government Statistician and the unit is 1d per lb. The figure corresponding to the 1922 harvest is the price for March, 1921.
White Clover Seed Price	Xh	This is the wholesale price of machine dressed white clover seed at Christchurch

in March. The unit is 10d per bushel. The price for the 1922 wheat harvest is for March, 1921. It will be noticed that all prices taken, with the exception of wool price are contemporaneous, applying, as they do, to the March prior to harvest. Wool price covers a slightly longer period.

Red Clover Acreage	Xi	The acreage has been taken from the Agricultural and Pastoral Statistics of the Government Statistician. The unit is 100 acres. For the 1922 wheat harvest the red clover acreage figure represents the acreage in red clover November 1920 - March 1921.
Rainfall	Xj	This index refers to the Days Wet at Lincoln in April. For the wheat harvest in 1922 the Days Wet in April, 1921, have been used. Obtained from the New Zealand Gazette and the Meteorology office of the Department for Air.
Last Year's Wheat Acreage	Xk	This is the same series as Xa except that the observations have been lagged one year. Thus, to correspond to the 1922 harvest the acreage harvested in 1921 has been used. The unit, again, is 1,000 acres.
Oat Acreage	Xl	These figures have been taken from the Agricultural and Pastoral Statistics and refer to the acreage of Oats Threshed. The unit is

1,000 acres. The index refers to the acreage of oats in the ground at the same time as the wheat acreage index, Xa.

Barley Acreage Xm — These figures have been taken from the Agricultural and Pastoral statistics and refer to the acreage of barley threshed. The unit is 100 acres and the index refers to the acreage in the ground at the same time as the wheat acreage, Xa

The relationships of the above variables were also examined in first differences. The same symbols have been used for the first differences as for the original figures except that a superscript (1) has been added. Thus, the total acreage of wheat is denoted Xa, and the change in the total wheat acreage from one year to the next is denoted X^1a.

APPENDIX A

b. Original Data - Symbols and Units as described in Appendix Aa.

VARIABLE

Year	Xa	Xb	Xc	Xd	Xe	Xf	Xg	Xh	Xi	Xj	Xk	Xl	Xm
1920	140	326	777	155	490	800	74	224	67	9	208	180	229
1921	220	362	787	172	657	1116	111	358	62	12	140	148	468
1922	353	362	665	92	377	840	69	252	63	7	220	171	331
1923	276	278	548	86	382	420	60	215	69	7	353	143	175
1924	174	230	783	144	412	645	81	269	135	13	276	64	213
1925	167	266	814	191	583	690	100	260	55	5	174	147	251
1926	152	338	1000	224	552	640	66	233	104	7	167	102	260
1927	220	342	740	135	566	632	77	172	66	5	152	117	299
1928	261	274	700	144	348	476	51	149	85	7	220	88	211
1929	255	274	800	187	435	540	63	138	79	11	261	73	195
1930	236	286	780	162	412	537	73	160	98	13	255	68	182
1931	249	286	660	94	488	567	90	173	47	6	236	87	240
1932	269	274	380	57	336	470	57	157	33	6	249	69	182
1933	303	222	400	65	428	470	71	272	39	8	269	116	163
1934	286	184	380	70	227	430	36	158	106	7	303	78	210
1935	225	212	600	145	295	480	57	214	116	7	286	53	184
1936	249	221	580	80	384	510	55	157	135	12	225	78	207
1937	222	229	680	112	332	453	48	147	107	7	249	75	205
1938	186	252	720	171	441	550	57	147	116	11	222	58	255
1939	189	276	640	107	427	523	78	156	88	16	186	54	269
1940	258	276	580	94	389	585	106	201	71	5	189	50	253
1941	243	276	700	127	507	585	113	398	80	10	258	72	320
1942	258	276	670	127	460	553	73	333	133	7	243	71	360
1943	287	284	700	127	502	592	80	440	235	9	258	56	287
1944	234	296	710	142	470	590	75	370	265	7	287	40	282
1945	184	296	710	141	540	637	98	330	206	13	234	78	373
1946	161	340	750	143	598	648	100	515	329	12	184	57	486
1947	141	340	790	140	588	685	141	528	346	11	161	55	530
1948	124	352	830	207	650	685	115	504	397	17	141	63	634
1949	147	384	1000	324	705	753	174	347	214	14	124	78	587
1950	125	408	1050	336	678	855	147	410	213	13	147	53	569
1951	145	494	1160	441	686	830	228	620	101	12	125	36	462
1952	90	494	2200	1215	968	950	224	618	187	12	145	46	461
1953	127	511	1300	422	1080	920	176	333	147	13	90	49	553

Xa = Wheat Acreage in original figures.

Xb = Wheat Price " " "

Xc = Fat Lamb Price " " "

Xd = Wool Price " " "

Xe = Oat Price " " "

Xf = Barley Price " " "

Xg = Ryegrass Price " " "

Xh = White Clover Price in " "

Xi = Red Clover Acreage " " "

Xj = Rainfall in " "

Xk = Last Year's Wheat Acreage in original figures.

Xl = Oat Acreage in original figures

Xm = Barley Acreage in " "

APPENDIX B

a. Zero-order correlation coefficients amongst the variables expressed in their original form. Observations for the harvests 1920-1953.

r_{ijj} =	a	b	c	d	e	f	g	h	i	j	k	l	m
i = a	+1.000	-0.602	-0.692	-0.597	-0.718	-0.530	-0.662	-0.529	-0.484	-0.558	+0.685	+0.286	-0.640
b		+1.000	+0.794	+0.709	+0.883	+0.806	+0.861	+0.661	+0.270	+0.379	-0.777		
c			+1.000	+0.962	+0.821	+0.662	+0.787	+0.589	+0.253	+0.370	-0.597		
d				+1.000	+0.730	+0.564	+0.756	+0.566	+0.191	+0.308	-0.484		
e					+1.000	+0.772	+0.848	+0.660	+0.359	+0.457	-0.780		
f						+1.000	+0.708	+0.576	+0.176	+0.373	-0.738		
g							+1.000	+0.782	+0.327	+0.453	-0.715		
h								+1.000	+0.656	+0.415	-0.464		
i									+1.000	+0.514	-0.273		
j										+1.000	-0.408		
k											+1.000		

X^1a = Wheat Acreage in first differences

X^1b = Wheat Price " " "

X^1c = Fat Lamb Price " " "

X^1d = Wool Price " " "

X^1e = Oat Price " " "

X^1f = Barley Price " " "

X^1g = Ryegrass Price " " "

X^1h = White Clover Price in first differences

X^1i = Red Clover Acreage " " "

X^1j = Rainfall in first differences

X^1k = Last Year's Wheat Acreage in first differences

X^1l = Oat Acreage in first differences

X^1m = Barley Acreage in " "

APPENDIX B

b. Zero-order correlation coefficients amongst the variables when expressed as first differences.

r_{ij} j =	a^1	b^1	c^1	d^1	e^1	f^1	g^1	h^1	i^1	j^1	k^1	l^1	m^1
i=a^1	+1.000	+0.137	-0.413	-0.329	-0.303	-0.110	-0.063	-0.110	-0.262	-0.327	+0.041	+0.308	-0.049
b^1		+1.000	+0.081	+ .008	+0.279	+0.371	+0.304	+0.190	-0.251	-0.104			
c^1			+1.000	+0.956	+0.330	+0.319	+0.282	+0.399	+0.255	+0.082			
d^1				+1.000	+0.244	+0.216	+0.270	+0.393	+0.203	+0.004			
e^1					+1.000	+0.571	+0.411	+0.235	-0.061	+0.219			
f^1						+1.000	+0.432	+0.296	+0.019	+0.184			
g^1							+1.000	+0.480	-0.489	-0.038			
h^1								+1.000	+0.222	+0.131			
i^1									+1.000	+0.288			
j^1										+1.000			

X_a = Wheat Acreage in original figures

X_b = Wheat Price " " "

X_c = Fat Lamb Price " " "

X_i = Red Clover Acreage in " "

X_j = Rainfall in original figures

X_k = Last Year's Wheat Acreage in original figures

APPENDIX B

c. Zero-order correlation coefficients amongst the variables expressed in their original form. Observations for the harvests 1924-1953.

rij j=	a	b	c	i	j	k
i = a	+1·000	-0·734	-0·747	-0·516	-0·583	+0·779
b		+1·000	+0·816	+0·325	+0·397	-0·783
c			+1·000	+0·251	+0·368	-0·611
i				+1·000	+0·532	-0·321
j					+1·000	-0·398
k						+1·000

APPENDIX C

Multicollinearity in the Original Data.

Taking the criterion of a correlation amongst independent variables with a modulus in excess of ·8 as indicative of obvious multicollinearity, the information on multicollinearity from the matrix of correlations of the original data is summarized below:-

Variable	Incompatible With.
b. Wheat Price	Oat Price Barley Price Ryegrass Price
c. Fat Lamb Rice	Wool Price Oat Price
d. Wool Price	Fat Lamb Price
e. Oat Price	Wheat Price Fat Lamb Price Ryegrass Price
f. Barley Price	Wheat Price
g. Ryegrass Price	Wheat Price Oat Price
h. White Clover Price	
i. Red Clover Acreage	
j. Rainfall	
k. Last Year's Wheat Acreage	

APPENDIX D

Summary of Results.

The various estimates of the supply function for New Zealand Wheat made in this study are described in Chapter V. They are summarized here for ease of comparison. The symbol b_{ac} has been used for the partial regression coefficient of Xa on Xc with the other variables held constant. The "other variables" have not been specified as they differ in the different relations:

Xa = Wheat Acreage in original figures

Xb = Wheat Price " " "

Xc = Fat Lamb Price " " "

X_i = Red Clover Acreage in " "

X_j = Rainfall in original figures.

X_k = Last Year's Wheat Acreage in original figures.

The seven equations presented in Chapter V are shown for easy comparison on the outer half of this page.

The estimates given in Chapter V may be expressed in simpler terms by giving the movement in the independent variables necessary to produce an increase of 1,000 acres in the area in wheat; this is given on the next page.

Equation No. as in Chap. V	Estimate of							
	b_{ab}	b_{ac}	b_{ai}	b_{aj}	b_{ak}	ρ	R^2	"d"
1	+0·269 (0·165)	-0·108 (0·032)	-0·145 (0·079)	-3·246 (2·334)	+0·507 (0·167)	~~0~~	0·713	1·790
2	—	-0·078 (0·026)	-0·192 (0·074)	—	+0·380 (0·135)	~~0~~	0·666	1·542
3	—	-0·076 (0·026)	—	-5·192 (2·210)	+0·352 (0·140)	~~0~~	0·655	1·470
4	—	-0·067 (0·019)	-0·123 (0·063)	-2·977 (1·799)	+0·392 (0·104)	~~0~~	0·810	1·258
5	—	-0·072 (0·019)	-0·171 (0·058)	—	+0·418 (0·106)	~~0~~	0·791	1·270
6	—	-0·067 (0·020)	—	-4·596 (1·676)	+0·416 (0·108)	~~0~~	0·783	1·247
7	—	-0·073 (0·015)	-0·176 (0·055)	—	+0·403 (0·092)	+0·36	0·812	1·795

Equation No. as in Chapter V	Estimate of					
	Wheat Price pence/bu.	Fat Lamb Price pence/lb.	Red Clover Acreage 1,000 acres	Rainfall Days Wet at Lincoln	Last Year's Acreage 1,000 acres	Last Year's Error 1,000 acres
1	+0·929	-0·116	-0·690	-0·308	+1·972	–
2	–	-0·160	-0·521	–	+2·632	–
3	–	-0·164	–	-0·193	+2·841	–
4	–	-0·187	-0·813	-0·336	+2·551	–
5	–	-0·174	-0·585	–	+2·392	–
6	–	-0·187	–	-0·218	+2·404	–
7	–	-0·171	-0·568	–	+2·481	+2·778

The expression "Last Year's Error" needs to be explained further. This refers to the "error of prediction" which would have occurred in the previous time period if only the regression of the independents on the dependent (as different from including the auto-regression of the error term) had been used to predict wheat acreage. An "error" of +2,778 acres, obtained in this way, in one time period tends to be associated with an increase in the acreage of wheat by 1,000 acres in the succeeding period.

APPENDIX E

The Derivation of the Index of Fat Lamb Price.

Two indices of fat lamb price were available. Unfortunately, neither series covered the entire period. The first series was supplied by the Canterbury Frozen Meat and Dairy Produce Export Co. Ltd., Christchurch. It is their Meat Schedule for Grade II lamb up to 36 lb., the units are $\frac{1}{8}$d per lb., and the series is designated X_1. The second series was derived from the Addington Market Report in The Press, Christchurch. The top price for Prime Fat Lamb was used, and the series is given below as X_2, the units are 1d per sheep. Both indices refer to the first week in March of the year concerned.

The first series ran from 1926 to the present, while the second series ran from the beginning of the period to 1937. It was decided to try to extend the first series back rather than produce the second series forward, as the meat schedule is now the price connected with lamb which is most important in determining production. This series will, therefore, be of most use in prediction.

Time March	Schedule X_1	Addington X_2	Predicted Series X_1	Index Unit X_c
1919		390	77·7	777
1920		395	78·6	786
1921		336	66·4	664
1922		279	54·7	547
1923		393	78·3	783
1924		408	81·4	814
1925		498	100·0	1000
1926	74	348	69·0	740
1927	70	312	61·6	700
1928	80	396	79·0	800
1929	78	384	76·5	780
1930	66	348	69·0	660
1931	38	205	39·5	380
1932	40	228	44·3	400
1933	38	180	34·4	380
1934	60	312	61·6	600
1935	58	312	61·6	580
1936	68	354	70·3	680
1937	72	378	75·2	720
1938	64			640
1939	58			580
1940	70			700
1941	67			670
1942	70			700
1943	71			710
1944	71			710
1945	75			750
1946	79			790
1947	83			830
1948	100			1000
1949	105			1050
1950	116			1160
1951	220			2200
1952	130			1300

The regression equation:-

$$X_1 = -2·82 + ·2065\ X_2$$

was computed and used to extend the schedule price series back to March, 1919.

The correlation between the series, r_{12}, is +0·966. The Index Used is in units of $\frac{1}{80}$d per lb.