# THE NATURE OF AGGREGATE SUPPLY

# OF

# NEW ZEALAND AGRICULTURE

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# INTRODUCTION

It is a commonplace of the early stages of economics that agriculture is the typical example of an industry with an inelastic supply curve. There is a tendency to accept the concept of elasticity without really translating the meaning of the inelastic supply of aggregate output (the supply curve of the industry) into a practical realisation of the facts. Fact and theory tend to remain in separate compartments of the mind. The advanced student, however, is in a position to appreciate the elegance of economic theory when the theory of the firm is fully related to the shape of the supply curve of the industry. This thesis is principally a study in the conditions which determine the shape of the supply curve for agriculture. This involves a detailed analysis of the supply and demand conditions of the factors of production as they affect total output.

Particular attention has been focussed in the past on the output conditions of agriculture in depression. The actual increase which took place in 1930-33 following a sharp fall in product prices, has prompted several writers to challenge the application of the classical theory of the firm to agriculture. This thesis, on the contrary, is an effort to show that such changes are compatible with the theory of the firm.

In Part I four hypotheses are derived from theoretical considerations to explain the nature of aggregate agricultural output. In Part II these hypotheses are subject to statistical verification by the use of least squares regression. Part III presents a general review of output conditions over the last thirty years.

For agriculture as a whole the supply of land is virtually fixed. Farmers apply varying quantities of other factors to a fixed area of land in order to perform certain basic tasks. The supply of capital to farming is extremely variable. In difficult times the only available supply may be in the form of cash receipts not spent on immediate costs or used as income. In more prosperous periods there tends to be a flow of capital into farming as farm returns rise and capital rationing is relaxed by lending institutions. We have no accurate measurements, however, of the volume of this flow of capital or of its changing rates of flow between periods of low and high prices. Labour, on the other hand, has been measured sufficiently well to determine both the volume and the rate of flow during different price periods. Thus when changes in demand and technology indicate a re-allocation of resources between agriculture and the rest of the economy, the movement of labour is the only apparent indicator of the changes taking place. For this reason, the initial chapter on the allocation of resources is presented in terms of the movement of labour. Greater information on the movement of capital would be highly desirable.

This analysis of the movement of labour is followed by a review of the explanations of the failure of aggregate output to decline in the depression, such as the presence of high fixed costs in agriculture, the length of the production process and the competitive structure of agriculture. While these explanations deal with aspects of the structure of farming which help to explain its behaviour in response to price changes, they have seemed to lack both clarity and completeness. A necessary preliminary to a statistical investigation would therefore seem to be some reconsideration of the theoretical relations lying behind the facts so that hypotheses may be set up for statistical treatment.

Chapter III, therefore, sets out the pure theory of the firm. From the theory we can make the necessary assumptions to derive a theory of the agricultural firm. The slope of the marginal cost curve of the firm gives us, in turn, the slope of the supply curve of the industry. If the analysis is to be satisfactory, it should be capable of explaining output at all stages of the trade cycle and not only that of depression conditions. If the depression condition is a special case, the necessary assumptions which need to be made can be clearly set forth and their implications understood.

The statistical verification of the theory of output opened two courses of action. One was to make a detailed study of several known farms (a sample) either historically or at any one point of time, the other was to analyse directly the available statistics of production. This latter course was followed. The application of regression analysis to economic time series presents an initial problem. Chapter IV deals with the precautions that are required when dealing with economic populations of this nature. The rest of Part II is taken up with the presentation of the results of regression analysis.

A modest determination of the total year-to-year variations in farm production might be expected when no one variable in the regression has a constant effect for the whole of the period under analysis. In this case, breaking the whole period down into clearly defined sub-periods, while preventing the further use of regression through lack of items, may show up the different influences which have been operating. The breaking down of the production aggregates into their components also simplifies the exposition. This is the work of Part III.

In summary form the aim of this thesis is to show:

1. That the maintenance of agricultural output in depression is explained by the inelastic supply of land and capital together with the lack of opportunity for labour elsewhere in the economy;

2. that the increase in output which occurred in two known depressions is explained by the actual increase in the supply of labour combined with an acceleration of the long-term movement towards increased efficiency;

3. that the stability of output in periods of rising prices is explained by the inelastic supply of land together with an inelastic demand for labour and a demand for capital, which, though it may be fairly elastic, cannot be met except with some lapse of time;

4. and that there is a continuous shift towards greater efficiency, and that it is accelerated when capital is more freely available under rising farm prices.

## SUMMARY & CONCLUSIONS.

In Part I of this thesis the theoretical background of changes in aggregate farm output is set out in some detail. Changes in output are shown to depend on certain relationships between the supply and demand conditions of factors of production. Any long-term increase in output is shown to depend on the adoption of technological improvements as they become available.

In Part II an attempt is made to measure year-to-year changes in factors influencing aggregate output by means of multiple regression. To avoid the distortion caused by serial correlation in the time series variables used, it was necessary to use year-to-year differences (coded) of the logs of the variables. This threw into relief the year-to-year changes where climatic variations would have an influence which has no relation to farmers' production intentions but might be regarded rather as "disturbances" to production. At the same time it would minimise the influence of the changes in technique which, though we know them to be of great long-term influence, show themselves in statistical data in the form offairly steady trends.

'Summer rainfall at Ruakura' and 'area of hay and silage cut' the previous summer proved to be the only variables reaching the 5% level of significance. The resulting linear model only explains 46.62% of the total variance of the dependent variable (R = 0.6828). The modesty of this determination is explained by the lack of suitable climatic data on a national basis, by the lack of a constant effect of variables over the time period taken and certain imperfections in the variables themselves.

This low determination is not markedly increased when dairy output is substituted for total output in the regression. ($R = 0.7210$)

The above linear model did not show the presence of serial correlation in the residuals when tested by means of Durbin and Watson's "d" statistic. When the same equation was derived in terms of the logarithmic values of the original variables, the presence of serial correlation was detected at the 5% level of significance. The use of a variable representing "time" in linear form in the logs. showed that for this particular period of years the elimination of trend also eliminates significant serial correlation in the residuals of the estimating equation.

The high standard errors of the regression coefficients between price and production prevent any positive conclusions to be drawn from the results with respect to the price elasticity of supply of aggregate output. The data is only consistent with the theoretical expectations in the negative sense that the regression shows no significant relationship between year-to-year changes in price and agricultural production.

The review in Part III shows that particular stress may be laid on the following factors in explaining increases in farm output.

1. That there is a steady flow of new techniques to farming, but that the rate of adoption of those techniques tends to be sporadic.

2. In past low price periods an adequate labour supply has enabled an increase in output.

3. That temporary increases in output are possible from an increase in effort on the part of existing farmers.

4. Increases in high price periods depend upon improvements in technology, when the rate of adoption of certain capital techniques is accelerated.

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## P A R T I

## THEORETICAL CONSIDERATIONS.

### I. FACTORS INFLUENCING THE ALLOCATION OF LABOUR BETWEEN AGRICULTURE AND OTHER USES.

In any economy, the allocation of resources between different sectors is important, and the objective of economic policy should be the achievement of an optimum distribution. We may define this optimum as that allocation which will produce the greatest satisfaction per head (1). A more recent definition is that given by Reder; "The welfare of the community is said to be a maximum if its productive resources are utilised in such a way that it is impossible to make any one person more satisfied (put on a higher indifference surface) without making at least one other person less satisfied (put on a lower indifference surface)"(2). The nearest measure there is in economics to satisfaction is real income; that is, money income deflated by an appropiate price index. Thus for a working definition we have; that allocation of resources which provides the greatest real income or product per head, or greatest total income or product.

In a closed economy, changes in the relative importance of the agricultural sector to the rest of the economy will necessitate changes in the allocation of resources. The direction of the re-allocation will depend on the relative income elasticity of demand for farm products and non-farm products and

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(1) Following J.E. Meade, "Economic Analysis and Policy" 1937, p.263.

(2) M.W. Reder, "Studies in the Theory of Welfare Economics" 1947. p.15.

relative speed of changes in technology in agriculture compared with the rest of the economy. If changes in demand took place at the same rate and in the same direction as the changes in technology the employment of resources in different uses would remain unchanged. But, in fact, the variations in demand for farm products are very different from that in other sectors. Relative changes in technology are hard to assess, so there is very little we can say on this aspect. We can point out, however, that the absolute decline of rural population in the more advanced western countries indicates that the absolute change in farm efficiency, as far as it is labour-saving, takes place at a greater rate than the absolute change in demand for farm products (3).

Changes in the conditions of demand for food depend on changes in population, taste, and income. The growth of population exerts a steady but nevertheless important force on agricultural production. Apart from the effects of changes in taste and income, and given that the larger part of farm production is food production, farm output needs to expand in step with population growth. Changes in taste are responsible for a re-organisation of farm production which can have a considerable effect on total output. This is mainly the case where the price system indicates to the producer that a lower yielding product has a higher value to consumers. Especially with rising standards of living, consumers show a preference for products of animal origin, which, owing to the demands of biological growth and maintenance, can only give a lower yield per acre as compared

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(3) J.M. Brewster, "Farm Technological Advances and Population "Growth" J.F. Ec. XXVII: 509. 1945.

with products of vegetable origin. Changes in demand between livestock products or between crop products do not have such a marked effect on total output.

The most important factor affecting the total demand for farm products is undoubtedly changes in income. As incomes increase the distribution of consumer expenditure among different items changes; the proportion of income spent on necessaries (of which food is one of the most important) decreases, although absolute expenditure will rise, while that spent on other goods and services increases(4). If we define income elasticity of demand as the ratio of the percentage change in the amount of a commodity purchased to the percentage change in income, we find that the income elasticity of demand for food as a whole is usually less than one. Thus, as real income of the community rises, a greater proportion of consumer demand is for goods and services other than those basically produced on the farm.

This concept necessarily views agricultural products as a whole, as there exists a very broad possibility of effective substitution in the case of agricultural resources in producing alternative farm products. As already noted, this substitution can, in one sense, markedly affect total output. The income elasticity of demand, in the case of an individual product and especially livestock products, may well exceed one. Also, we are speaking of the demand for farm products as they leave the farm gate; one of the effects of higher real income being that consumers prefer more services attached to the original farm products. Thus the elasticity of demand at the farm gate is considerably lower than at retail. It is clear, then, that the demand for products

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(4) Colin Clark, "Conditions of Economic Progress" 1951.
A.G.B. Fisher, "Progress and Security" 1930.
T.W. Schultz, "Agriculture in an Unstable Economy" 1947.

of agriculture as a whole, given that the major part of production is for food consumption, declines proportionately to that for other sectors of the economy.

Changes in technology have far-reaching effects on the allocation of resources. Changes in productivity are directly responsible for the increase in real income of the whole community, while increased productive efficiency enables a greater demand to be satisfied with a given quantity of resources. Since the increase in farm efficiency takes place at a greater rate than is required by an increasing population or expanding market, there is a tendency for the demand for resources used in agriculture to decline. The demand for certain of these resources will be greater in the non-farm sector, where they are required to produce the new goods and services demanded by a community with a rising level of real income. But since land cannot shift to any significant degree, and capital usually has to move into farming rather than out (except in high income periods) the only visible movement which takes place owing to these changes is that of labour. Combined with a tendency towards a higher birth rate in rural areas, we have the main ingredients of what is commonly known as the"urban drift."

How is an optimum allocation of resources to be achieved? Clearly, resources must be allocated to that use where the value of their marginal products are highest. These will, in turn, be higher in those uses where demand is greater. Now, as we have already seen, the direction of changes in demand depends upon income elasticity of demand. Therefore, "given that the existing distribution of resources is at an optimum, (which implies that there is no involuntary unemployment) and that there is a secular growth of the national product due to the accumulation of capital and technical progress, it may be concluded that, in order to maintain an optimum distribution of resources, industries should expand at rates determined by the income elasticity of demand for their product. That is, expansion should be such that the composition of the increment of output will be that which consumers will wish to buy with the increment of income"(5). Unless resources are transferred according to this principle, there will be a loss of national product or welfare. It follows that any delays or immobilities in the process of adjustment will interfere with the optimum allocation, and hence reduce the national product.

The presence of a large export trade in primary products complicates the application of these principles to New Zealand as agricultural production is undertaken in response to an overseas demand of variable magnitude. This trade enables the United Kingdom to maintain a higher industrial population than would otherwise be the case; whereas New Zealand, (among other countries) is given the opportunity to supply farm products to a total of over three times her own consumption and is thereby able to keep a larger percentage of population in farming. Complete specialization, however, is inhibited by the need for service industries to be located round their markets and by increasing costs of production and transport charges. Thus the optimum allocation of resources in a dependent economy such as New Zealand, will be where factors are distributed between agriculture and the rest of the economy in accordance with the practical and economic possibilities of providing secondary and

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(5) B.D. Giles, "Agriculture and the Price Mechanism". Oxford Studies in the Price Mechanism, 1951. p. 198.

tertiary goods and services with the existing supply of resources. In general, industries protected from competitive imports will reduce the national product, although economic criteria may not be considered as the sole determinant of public policy.

We can now see whey the so-called drift to the towns takes place. Clearly it would be more correct to call it " a re-arrangement of labour and capital resources in response to modern techniques of production" (6). Besides the basic factor of changing technology the urban drift is complicated by other factors. The most familiar of these is the differential birth-rate between town and country. Table I shows the average number of dependent children under sixteen per married man and per married man with children for various selected occupations. Between the two years available it appears that the proportion of families with children has declined, although there is some evidence that these families have been having more children. However the data clearly indicates the higher birthrate in agricultural and pastoral occupations. The rate also does not appear to have declined over the period. Although the differential birthrate is usually attributed to differences between town and country, it would probably be more accurate to emphasize the differences between while-collar and manual occupations. Be that as it may, a higher birth-rate in rural occupations, cut off as they are from other occupations, is a constant factor exerting a downward pressure on rural wages.

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(6) H.M. Wadham & F.L. Wood, "Land Utilization in Australia." 1947. p.350.

TABLE I : AVERAGE NUMBER OF DEPENDENT CHILDREN UNDER SIXTEEN PER MARRIED MAN IN VARIOUS OCCUPATIONS.

SOURCE: Census reports, 1936 and 1945.

| | 1936 | | 1945 | |
|---|---|---|---|---|
| | Per Married Man | Per Married man with children | Per Married Man | Per Married man with children |
| Agricultural and pastoral. | 1.48 | 2.37 | 1.47 | 2.38 |
| Non-precious metals and electrical fittings. | 1.29 | 2.05 | 1.275 | 2.07 |
| Building Construction and Road Maintenance. | 1.45 | 2.28 | 1.41 | 2.38 |
| Transport and Communication. | 1.42 | 2.15 | 1.36 | 2.18 |
| Financial and Commercial | 1.175 | 1.96 | 1.05 | 1.99 |
| Clerical and Professional. | 1.15 | 1.89 | 1.13 | 1.96 |

Arguing from economic theory we would expect wages to be proportional to the marginal product in both town and farm firms, and finding that wages tend to be significantly lower in rural areas, we must conclude that the value of the marginal product of labour on farms is lower than in town firms. Clearly, we can argue further that a transfer of labour from the farms to other sectors of the economy would raise the national product. But the theory of perfect competition tells us that wage rates will always tend to equality in different occupations. Why is it then that rural wage rates have been consistently lower? (See Table IV). I think the disparity can be explained by the non-monetary considerations at work.

Besides the higher rural birthrate, lack of alternative training, payment in kind, preference for "the land" and an element of inertia are all factors which have exerted a downward effect on rural wages in the past. A force in the opposite direction is provided by the greater availability of the so-called "amenities" in the towns. But this factor is only fully operative in periods of full employment, when the movement of labour away from the farms tends to be excessive and hence more apparent. At such times the normal transfer of labour, which economic progress requires, is more likely to be visualised in terms of its "net advantages" rather than in an actual wage difference. It is now possible, therefore, to substitute the equality of "net advantage" of labour (7) for that of wage equality in order to satisfy the theoretical requirements. The resulting margin between town and country wage levels will vary as the relevant circumstances alter. When the employment situation in the towns is not so favourable, the attraction of the amenities is not so great, and the margin between the wage levels increases. In times of widespread unemployment, the rural wage level may be expected to decline in far greater proportion than that of the city, as the net advantage will consist of a large factor representing the security of rural employment. The opposite may be expected as the economy enters full employment; farm wages would increase at a greater rate as the fear of unemployment in the towns disappeared and the normal movement was resumed.

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(7) A. Marshall, "Principles". 8th Edition. p.73.

The movement of labour is further governed by the occupational status of the various categories of farm workers. The farm operator or owner will weigh his ownership of land and advantages of being his own boss etc., against the attraction, if any, of other occupations for which he has little training or preference. It thus happens that during a period of low returns, he will accept a lower reward than that offering elsewhere so as to remain in farming. Farm owners are, in fact, the stable element in the farm labour force. As they form over fifty per cent of the force in New Zealand (fifty-two per cent, excluding managers, according to the 1945 Census), there is no marked movement out of farming as perhaps might be expected in a period of low prices, but instead they are willing to accept whatever labour reward current farm prices provide for them after costs have been met. Their attachment to the land is a historic factor which has tended to keep farm labour rewards at a level lower than the rest of the economy.

But without this attachment to the land, the hired worker is the mobile element. He will more closely balance the farm wage plus the perquisites going with the job (house, meat, milk, wood, etc.,) against the town wage with a higher cost of living, but locality advantage of being near the "city lights" and educational institutions etc.. If the worker has a strong desire to own land one day, there will be added reason to stay on in hard times. But available evidence (8) indicates that a large proportion of hired workers on farms are youths, usually from the cities, who are looking for an outdoor life and are willing to put up with a few minor discomforts. But once

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(8) Employment Gazette, No.1, Vol.I, 1951. p.31.

burdened with family responsibilities, however, they are bound to look for town employment unless good farm accommodation is available. But the behaviour of all hired workers of any age is closely related to ruling economic conditions.

In depression, higher wages may exist in the towns, but they carry with them the fear of unemployment. With dole and soup-kitchens in the towns and works schemes, we can visualise a perimeter of marginal workers, who for reasons of pride, family support etc., will accept whatever employment is available rather than go unemployed. In the depth of a depression, security and the prospect of meals and a bed may have been sufficient reward to some down-and-out itinerant workers. Part of Table II shows the marked increase in working rural population which actually did take place in 1930-36 in New Zealand. Probably family labour was held back on the farms as well as more hired workers being available. The increased numbers do indicate that at the time the net advantage lay in farming with at least security of employment, if not a very high reward.

The actual situation in New Zealand altered rapidly with the introduction of the newly elected Labour Government's "insulation" policy, with its associated aim of full employment, and, later, the war (1939-45). The first markedly decreased the advantage which farm work had had in terms of security from unemployment, while the war not only further reduced the number of hired workers, but cut into the operator's family in many cases. The war thus accelerated the rate of adoption of many labour-saving devices, so that since its conclusion there has been no marked indication of a large-scale return of labour to the land to replace this excessive drain of workers.

These latter events have been taking place when the earlier objective of full employment had already been achieved. The change in prices which took place over the same period and also the exigencies of war both made it apparent to the farmers that greater production was a desirable objective, and that the fixed market conditions of the thirties was past. But such an increase could not take place when the labour required had been drawn off the farms at a rate far in excess of that at which it could be replaced by other factors. Had recovery taken place more steadily, the movement of labour out of farming would have been much slower and wage levels would have remained more or less unequal. As it is, wage rates for equivalent types of work in town and country are about equal, and the possibility exists that an even greater rural wage is required to balance present net advantages of town employment such as availability of overtime and employment in protected industries competing for the existing labour supply.

Nevertheless we must not lose sight of the fact that in the past, periodic bouts of depression have tended to shape the nature of rural wage rewards by tradition. With no easily available alternative employment, and no unionism or wage-fixing authority (up to 1936), rural workers have in past low price periods accepted very low wages rather than be unemployed. Farm employers in their turn become accustomed to these awards and have psychological difficulty in making wage adjustments when alternative opportunities are available for the workers. Under such circumstances, the movement of the more mobile elements out of agriculture can hardly be deplored, as long as the standard of town wage reward being offered in competition with farm wages is the product of the changing real balance of farming and non-farming industries and not the temporary and "unfair competition" generated jointly by inflation and its related need for import control.

If present full employment policies are successful, the farm community will need to make permanent adjustments to this situation, and realise that the factors making for lower wages and prices in depression make for high wages and prices in full employment conditions. In this case, wages of rural hired workers plus other advantages (housing etc.) must at least be commensurate with town conditions, if not with the conditions that the owner operator now enjoys.

## II. THEORIES OF FARM OUTPUT.

The increased output which occurred in farming during the depression of the early thirties has occasioned considerable comment in the literature. It would appear that economists of the time thought that here was an exception to the theory of supply and demand which specified that a reduced price indicated to the producer that less of his product was desired. The theory holds, however, if we can assume that other prices remain unchanged. But given certain relations among price changes of products and factors, it is possible to show that farmers' behaviour is entirely consistent with the theory of the firm. This chapter reviews the various theories brought forward to explain such variations in agricultural output, while the following chapter will deal with the modifications required of the theory of the firm to take in this special case. It is then possible to set out a generalised theory of the farm firm which should be capable of explaining all variations in farm output throughout the trade cycle.

Let us first look at the facts which the theories attempt to explain. Table II presents various selected time series indicative of the conditions which existed.

Farm production increased by over twenty percent between 1928-29, and the depth of the depression in 1932-33, while export prices declined by over forty per cent. Factory production (Group IV), on the other hand, declined by approximately twenty per cent between 1930 and 1933. Farm costs declined, but not by as much as export prices. The index of farm expenditure (less rent and interest) shows a decline of twenty-seven per cent, the weekly wages of hired workers by

TABLE II. PRODUCTION TRENDS 1928 - 36.

NOTE: Original data and sources presented in Appendix A.

| Years | Farm Production | Export Prices | Group IV Production | Farm Expenditure | Farm Labour Est. | Cows in Milk | Farm Weekly wage |
|---|---|---|---|---|---|---|---|
| 1928-29 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| 1929-30 | 105 | 78 | 106 | 100 | 106 | 108 | 98 |
| 1930-31 | 106 | 59 | 97 | 89 | 114 | 114 | 85 |
| 1931-32 | 106 | 53 | 83 | 76 | 121 | 121 | 67 |
| 1932-33 | 122 | 53 | 86 | 73 | 123 | 132 | 63 |
| 1933-34 | 125 | 67 | 89 | 74 | 126 | 139 | 64 |
| 1934-35 | 122 | 66 | 105 | 76 | 128 | 140 | 66 |
| 1935-36 | 128 | 75 | 115 | 81 | 129 | 140 | 84 |

| Years | Area Hay and Silage | Area T.D. Super or Lime | Westfield Price Super | Cultivated Land | H.P. on Farms | Land Prices. |
|---|---|---|---|---|---|---|
| 1928-29 | 100 | 100 | 100 | 100 | 100 | 100 |
| 1929-30 | 118 | 111 | 100 | 100 | 109 | 96 |
| 1930-31 | 126 | 105 | 100 | 100 | 138 | 86 |
| 1931-32 | 132 | 89 | 100 | 99 | 132 | 85 |
| 1932-33 | 160 | 103 | 85 | 100 | 138 | 65 |
| 1933-34 | 144 | 95 | 82 | 100 | 140 | 77 |
| 1934-35 | 149 | 113 | 82 | 102 | 145 | 92 |
| 1935-36 | 164 | 121 | 82 | 103 | 155 | 87 |

thirty-seven per cent, and land prices thirty-five per cent. Inputs show varying effects; farm labour, cows in milk, and area cut for hay and silage all show a marked increase while cultivated land appears insensitive to changes. Horse-power on farms, apart from an apparent lapse in 1931-32, shows a continued increase. The area top-dressed with super or lime shows a marked price effect. The fall in price at Westfield in 1933 appears to have encouraged an increase in the area sown. (Actually, there is a significant positive correlation between area top-dressed and export prices for the preceding season. See Chapter VI.).

What then are the special theories which have been developed to explain these facts? There are five, to the consideration of which we now turn.

(1) High Fixed Costs - The belief that high fixed costs are responsible for the failure of farmers to reduce output during depression has achieved more general acceptance than any other explanation. But the statement usually infers that labour is a fixed cost because of the prevalence of the family unit in farming. This can only be true if we regard the farm family as drawing a constant absolute amount out of the farm returns to maintain their standard of living. With changing price levels, and an almost equal proportion of hired workers, labour cannot be regarded as such a fixed cost, although the quantity of family labour may not alter.

The more correct interpretation seems to be that farm wages, whether in the form of returns to the operator or paid wages, are more variable than fixed in a period of depression. With an actual increase of rural workers in the period (see Table II) we can agree with D. Gale Johnson that "Hired workers are willing apparently to offer their services at prices which firms believe are no higher than the value of the marginal product, and so continue to be employed" (1). Owners and prospective owners will accept almost a nil return rather than take up another occupation.

But the land and the capital equipment involved in farming remain fixed. The employment of both these factors clearly did not decline in the depression (Table II). We can imagine that owners with a high equity in their enterprise would accept a considerably lower return on their investment before being forced to close down by low prices. But there remains those who had incurred high amortisation payments in the previous period of speculative buying. This is one real incentive for certain farmers to increase output. How they would increase output is not explained. As early as 1931, however, Government relief was provided and undoubtedly many private mortgagors were lenient in such times of difficulty. In discussing this aspect, K.O. Campbell goes as far as to say; "It cannot be said that the burden of fixed charges was viewed with grave concern by the average Australian farmer." (2).

But this seems to be going too far. Many New Zealand farmers probably made alterations to their production plans, so as to increase the surplus left over for themselves, before actual relief was available. High fixed costs on their own, however, do not explain the constant or increased employment of factors. Rather are they explained by "either (a) inelastic supply curves together with highly flexible factor prices or (b) changes in the marginal

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(1) D. Gale Johnson "The Nature of the Supply Function for Agricultural Products". American Economic Review XL: 542, 1950.
(2) K.O. Campbell "Australian Agricultural Production in the Depression". Economic Record XX: 60, 1944.

opportunity costs of the factors with the business cycle. The first explanation is pertinent to physical capital assets and land; the second to labour, feed and livestock."(3) These depression explanations will be taken up at a later point (Ch.III).

(2) "Farmers Try to Offset Lower Prices with Increased Output"(4). This is based on the fact that the supply curve of labour in depression tends to be backward sloping. Farm owners react to low income by working harder, and hired workers tend to work harder to retain their jobs in a time of general unemployment.

But the hypothesis that the dimunition of return to a self-employed operator leads to an increased expenditure of effort is not all-embracing. Not all sellers of their own product can be expected to react in this way, although the majority probably will (5). "If the farmer is more influenced by his need for increased money revenue, he will increase his own expenditure of effort. If he is more impressed by the meagreness of the return he will decrease his expenditure of effort."(6).

The farmer's reaction as an entrepreneur will be to try to lower his cost curve, as he evidently does not work back along it by reducing output. To this end, he will cut such cash costs as fertiliser and wages, as well as his own return. Further, we would expect the entrepreneur to substitute towards cheap factors, which in this case are his own labour and that of his hired worker or workers and farm-produced inputs. Such

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(3) D. Gale Johnson, op. cit. p. 543.
(4) D. Gale Johnson, op. cit. p. 543.
(5) J.R. Hicks "Value and Capital" 1948, p.36-37.
(6) J.K. Galbraith & J.D. Black "The Maintenance of Agricultural Production in Depression", J.Pol.Ec.XLVI: 305, 1938.

increased effort "because it may only be a substitution for other factors need not lead to increased output."(7) Johnson presents a similar conclusion, "...output is probably maintained by a small increase in the quantity of labour supplied by a given number of workers."(8)

While the nature of farm production precludes any large substitution of effort for other factors, we cannot ignore the effects of an increased rural population in the period concerned. The close movement of cows milked, and hay and silage cut, with rural labour, suggests that the actual shift in the supply schedule of labour is important in any explanation of increased output in the depression.

(3) "Agriculture Has a More Competitive Structure Than the Rest of the Economy." (Johnson)

It is generally accepted that the farm firm conforms to the assumption of a perfect market for its products at least. No individual firm is in a position to influence prices. This is to be compared with the so-called monopolistic firm, which is often in a position to influence price by variations in output. Such variations in output are possible by varying the employment of variable factors. The farm firm, on the other hand, takes price as given and makes adjustments not by moving along a given cost curve but by bodily moving it downwards and sometimes to the right. This is possible because factor costs change in proportion more readily than in the case of monopoly. Clearly, any firm, agricultural or otherwise, which can make the necessary cost adjustments will maintain output during a period of low product prices.

Thus perfect competition, in the sense used here, need not necessarily be confined to agriculture. The structure and

(7) Galbraith and Black, op. cit. p. 314.
(8) Johnson, op. cit. p. 544.

movements of the farm cost curve will be discussed in the next chapter.

(4) Technological Peculiarities of Agriculture.

The recognised production period in livestock production is two to three years. In shorter periods, it would not be possible for farmers to alter output quickly owing to changed price conditions. "Farmers will find it advantageous to complete the production process as long as price equals or exceeds the marginal cost of completing the production process as of any moment of time."(9)

But at the end of such a period a change should be evident. Table II indicates some of the decisions New Zealand farmers made. Although a slight lapse of investment in machinery is evident, the number of cows milked and hay and silage saved increased rapidly. Clearly, technological peculiarities were responsible for some of the delayed effects of the depression, but cannot be said to explain the actual increase in output which occurred, except in the sense that the increased output was in part explained by the sustained development of an earlier period.

(5) Subsistence Production.

There is little data available on the occurrence of uneconomic units in New Zealand farming. Generally, the assumption is made throughout this thesis that the farms under discussion are on a commercial scale. Tn this case, the amount produced for sale far exceeds that consumed on the farm, and hence total output is influenced very little by home consumption.

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(9) Johnson, op. cit. p. 544.

The seller of his own product presumably makes a substitution and an income adjustment in response to a change in price, just as the consumer of a good reacts to price changes. The difference between the two lies in the fact that for the seller the two effects usually move in the opposite direction (10).

We would therefore expect the farmer to eat more meat and consume more cream in the depression, if dominated by the substitution effect, and less of each if dominated by an income effect. Table III presents an analysis of stock slaughtered on New Zealand farms per head of working rural population. Cattle beasts have been weighted by a factor of four to bring the weight of the animal into line with other stock units. We also assume that total rural population increased in proportion to the numbers of workers. The consumption of meat in the depression years can be seen to have altered markedly. The 1929 figure appears similar to the 1945-51 average, so that farm consumption of meat must have increased by approximately 55 per cent between 1928-29 and 1932 -33, and yet have returned to its normal level by 1937-38. Presumably the lowered value of his product encouraged the farmer to eat more of it, thus substituting home-grown meat for cash foods.

A similar analysis for the consumption of cream on dairy farms in the depression would yield interesting results if practicable. One suspects that the income effect may well prove to be the more dominant!

But the negative effect of increased farm consumption of meat on farm production is neglible compared with the total

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(10) J.R. Hicks, op. cit. p. 38.

TABLE III. MEAT CONSUMPTION ON FARMS 1928 - 51.

Sources: (1) Agricultural and Pastoral Statistics 1928-51.
(2) Estimates of Labour, Appendix B.

| YEAR | ANIMAL UNITS CONSUMED (1) (thousands) | LABOUR WORKING UNITS EST. (2) (thousands) | SLAUGHTER UNITS PER WORKING UNIT. |
|---|---|---|---|
| 1928-29 | 646.4 | 137 | 4.7 |
| 1929-30 | 693.5 | 138 | 5.0 |
| 1930-31 | 897.5 | 140 | 6.4 |
| 1931-32 | 1003.5 | 142 | 7.0 |
| 1932-33 | 1040.6 | 146 | 7.1 |
| 1933-34 | 909.2 | 150 | 6.1 |
| 1934-35 | 801.3 | 151 | 5.4 |
| 1935-36 | 767.3 | 150 | 5.1 |
| 1936-37 | 717.5 | 147 | 4.9 |
| 1937-38 | 658.7 | 145 | 4.5 |
| 1938-39 | 665.3 | 141 | 4.7 |
| 1939-40 | 683.1 | 138 | 4.9 |
| 1940-41 | 643.7 | 135 | 4.7 |
| 1941-42 | 653.5 | 130 | 5.0 |
| 1942-43 | N.A. | 125 | - |
| 1943-44 | N.A. | 120 | - |
| 1944-45 | N.A. | 118 | - |
| 1945-46 | 511.3 | 119 | 4.3 |
| 1946-47 | 524.7 | 120 | 4.4 |
| 1947-48 | 521.3 | 122 | 4.3 |
| 1948-49 | 533.2 | 123 | 4.35 |
| 1949-50 | 558.0 | 125 | 4.35 |
| 1950-51 | 564.6 | 125 | 4.5 |
| 1951-52 | | | |

N.A. - Not available.

production of meat. We must conclude that this small proportion which home consumption bears to total production on New Zealand farms makes a subsistence theory of output untenable.

Most of the previous explanations of the behaviour of agricultural output in depression have been found to be incomplete. Workers' effort per man alone would probably have a small effect, but a shift in the supply schedule of labour appears important. High fixed land and other capital costs, while providing an incentive, do not actually explain how output was maintained.

The review has brought to light several factors which do not seem to fit into the previously accepted theories. The next chapter will be devoted to developing a theory which can take these considerations into account, and which, it is hoped, will also be capable of explaining variations in output at any stage of the trade cycle.

## III. THE THEORY OF THE FIRM IN RELATION TO AGGREGATE OUTPUT.

Following classical tradition, any theory explaining the supply curve of an industry must be derived from a study of the individual firms making up the industry. This chapter sets out the accepted theory of the firm, with particular emphasis on the output conditions.

### The Assumptions.

To simplify the exposition, we can first set out the usual assumptions upon which the theory of the firm is built. Having then derived the basic theoretical model, any modifications required by the removal of the assumptions can be added. We assume perfect competition and a state of full employment. This involves (i) that the demand for output is perfectly elastic to the firm, (ii) that the price level is stable, (iii) that the number of firms is great enough for the price of a factor to be independent of how much of it any one entrepreneur buys, and (iv) that the guiding principle of the entrepreneur is one of profit maximisation. The analysis is static, so we can ignore the effects of changing technology in the meantime.

### The Pure Theory of the Firm.

The firm consists of the entrepreneur combining the various factors of production to produce a given product. He will combine them in the cheapest possible way with his entrepreneurial ability so as to produce maximum returns at ruling prices. If the price of all the factors is given, as it can be for any one entrepreneur, the least cost combination of factors will be given by the condition that the ratio of the marginal products to their prices are equal.

Thus if the $\frac{\text{Marginal Product of A}}{\text{the Price of A}}$ is greater than $\frac{\text{The Marginal Product of B}}{\text{the Price of B}}$ it would pay the entrepreneur to substitute A for B, since he can get a larger product for the same expenditure, or he can get an equal product at lower cost (1).

The total output of the firm is thus a function of the marginal products of factors and the number of units of each employed. Total Output $= \sum$ (Marginal products of factors x units of factors). (2).

The formal proof of the marginal conditions has been set out by J.R. Hicks (3). He emphasises that at the equilibrium position, both marginal product and average product must be decreasing. We will have no cause to challenge the assumption of diminishing returns upon which his analysis is based (4). Given this assumption, Hicks shows that his simple case of one factor and one product can be extended to any degree of generality, "The technical opportunities which confront an enterprise are indeed usually fairly complicated. In order to produce a particular product, several factors will generally be required; very often too, it will pay better to produce a number of joint products than to produce one product in isolation." (5) This situation would be found whenever a complementary relationship existed between two or more products. Thus our theory allows of substitution between products in a multiple enterprise firm, for output will clearly be maximised where a given set of resources are combined in the most productive manner.

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(1) J.R. Hicks, "Theory of Wages." 1931, Ch.I.
(2) G. Stigler, "Theory of Price." 1949, p.130.
(3) J.R.Hicks, "Value and Capital." 1948, p.80.
(4) See P.W.S.Andrews, "Industrial Analysis in Economics" Oxford Studies in the Price Mechanism, 1951, p.150.
(5) J.R. Hicks, "Value and Capital." 1948, p. 85.

Changes in output can only come about by changes in the quantities of factors employed (under given production conditions). An increase in real price of output will raise the marginal product of factors to the entrepreneur, and will therefore lead him to demand a greater quantity (at previous prices). Under given conditions of supply and demand and price of factors, this will lead to an increased employment of factors, as returns can be increased, and hence an increase in output results. A decline in the price of real output will lower the marginal products of factors. At previous prices, the entrepreneur will demand smaller quantities and output will decline.

Clearly the effect of improved technology will be to increase the marginal product of a given quantity of a factor. Thus changes in demand will work through the price of the final product, while changes in efficiency will work through the productivity of a given factor to bring about changes in output.

Changes in the price of factors can also affect output. A decline in the price of one factor relative to others, would mean a substitution towards that factor to produce the same output at lower cost, or higher output at the same cost as before. The opposite would hold for a rise in its price. Now if the major proportion of factor prices declined or increased at a greater rate than product prices, the result would be a rise or fall in output respectively. Intermediate cases will thus exist where output may be just maintained at its previous level, or where output does not decline as much (say) as a fall in product prices would lead us to expect.

Our assumption that the supply schedules of the factors of production have perfect price elasticity is unrealistic. Not all factors can be supplied to the entrepreneur just when he is prepared to pay the ruling price for them. Any degree of inelasticity in a factor's supply schedule will necessitate an adjustment of more flexible factors to it in the production plans.(6). The greater the degree of inelasticity, the less responsive will be the firm output to changing prices. Such inelasticity has been variously attributed to immobility of factors between occupations (7), to the fixity of supply as in the case of land (8), or to scarcity of some major factor (9).

The elasticity of the demand schedules for the factors by the entrepreneur will depend upon the elasticity of substitution between factors in the production process. If this elasticity of substitution is high, a slight increase in the price of a factor will lead to a great deal of substitution of other factors for it under conditions of perfectly elastic supply of factors, and hence the supply of the product will be elastic. Conversely, low substitutibility between factors combined with relative fixity of one of the main factors such as land, leads to an inelastic supply function of the product. The elasticity of supply of the product will therefore be governed by the elasticity of supply of scarce factors, and by the elasticity of substitution of elastic factors for inelastic factors.

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(6) J. Robinson, "Economics of Imperfect Competition." 1948, p.122.

(7) K. Boulding, "Economic Analysis." 1948, p.240.

(8) A.P. Lerner, "Economics of Control." 1947, p.168.

(9) J. Robinson, op. cit. p. 122.

Now if we assume one factor only fixed, and other factors are combined with it to achieve optimum output, the law of variable proportions tells us that, after a point, the marginal product will decline. The rate of this decline will depend, of course, on the elasticity of substitution between factors. The shape of the marginal product curve will, in turn, give us the shape of the marginal cost curve, if the prices of the variable factors are known and constant. This can easily be derived by dividing the price of the factors by their appropriate marginal products, if prices remain constant (10).

Further, if the costs of the variable factor are a low proportion of total costs, then the variable costs (which vary with output) must, after a point, increase rapidly. If the prices of the variable factors rise owing to greater demand, variable costs must increase even still more steeply. Thus different firms will have different reactions to price changes, according to the nature of their cost structure. Those firms with a high proportion of variable costs will have a flatter cost curve. This will give the entrepreneur greater flexibility in his efforts to maximise returns. Changes in the elasticity of supply of factors, or in their prices, will enable him to work fairly closely to our theoretical model. But when variable costs are a low proportion of total costs the marginal cost curve rises steeply. The entrepreneur, with a very inelastic supply of fixed factors and very inelastic demand for variable factors, will tend to use all the factors in almost fixed proportions, and hence be unable to alter output significantly in response to a change in price of either factors or products.

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(10) G. Stigler, op. cit. p. 126.

Summary of Pure Theory of the Firm.

In the simple case, the output of the firm is dependent on changes in prices and technology. We have seen that the presence of inelastic supply functions of fixed factors and low elasticity of substitution between fixed and variable factors leads to an inelastic supply function for the product. The supply function of the industry will also be inelastic. The more inelastic the function the less important changes in price become in inducing changes in output, and the more important changes in efficiency will become. In an industry with a more elastic supply function, changes may come about owing to changes in prices, as well as productivity, while the freer availability of resources will enable entry of new firms into the industry.

The Theory of the Farm Firm.

These principles can now be applied to the farm sector of the economy. What are the characteristics of the agricultural firm? What, in fact, is the shape of the supply curve for total agricultural output? The shape of the farm cost curve is derived in the following pages, and then the conditions of total supply of agricultural output are set out.

It is significant that Marshall based his particular equilibrium analysis of the firm on a representative wheat farm (11). Agricultural production was clearly subject to diminishing returns, and the market for the products fitted the assumptions of perfect competition. In general, the demand curve for the product is infinitely elastic to the individual producer. In the following discussion the short period is

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(11) A. Marshall, "Principles." 8th Edition, Book IV.

taken to mean a period of two to three years, a period in which we might expect the farmer to show some response to price, if any, while the long period is taken to mean the passage of time of a decade or more.

The farm firm, then, for any short period, is characterised by a large proportion of fixed factors out of the total. In a period of one year, variable factors will be quite small, being mainly those associated with entrepreneurial skill (time of operation, fertiliser treatments, etc.). The cultural practices necessary to produce a given output of crop or livestock are fixed within fairly narrow limits, and thus give the factors their theoretical property of low substitutibility. Given this narrow range of variation in proportions together with short term fixity of supply of some of the major factors, our theory tells us that the agricultural firm must have, after a point, a steeply sloping marginal product curve for the variable factors. Since the proportion of variable factors is small, the proportion of variable costs will also be small. The typical marginal variable cost curve of the agricultural firm will, after a point, slope steeply upwards. Classically, the marginal cost curve slopes upwards to the right because of (i) low substitutibility between factors and (ii) rising prices of variable factors as firms competed for them.(12). It is the property of low substitutibility which is important for the agricultural firm. Different degrees of substitutibility are clearly evident in the following two figures (Figure 1). The longer the time period allowed the greater is the proportion of variable to fixed costs.

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(12) J. Robinson, "Economics of Imperfect Competition" 1933, p.122.

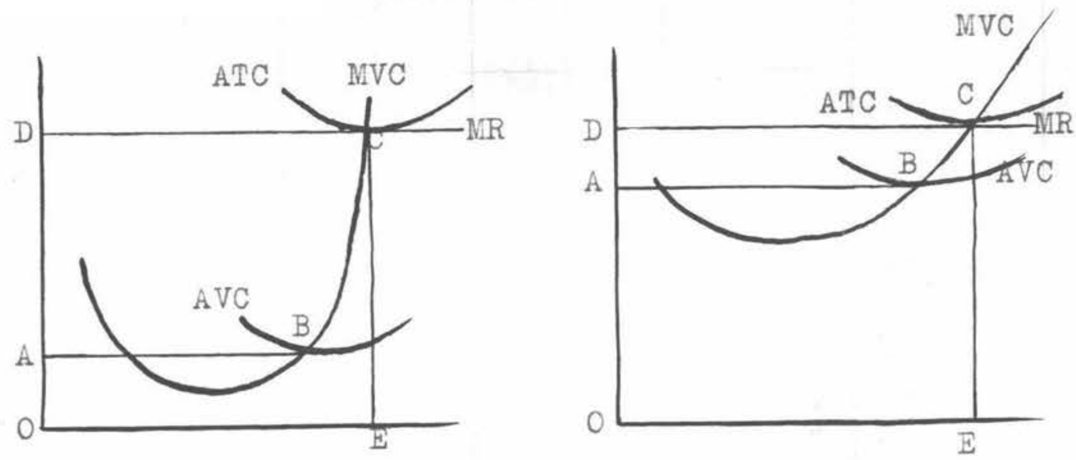


Figure 1. Relationship of variable to fixed costs.

Where the average variable cost curve intersects the marginal variable cost curve, marginal costs, at that point, are equal to average costs. If we draw the horizontal line AB, from this point to the vertical axis, the area ABCEO represents variable costs, while the remainder represents fixed costs. The greater proportion of variable costs in the second diagram allows greater adjustments to be made, for the marginal cost curve is less steep.

The more fixed the relation of the various factors in the production process, the less the demand for any one of them can vary.

Generally, we find in farming that with the size of holding fixed, there is a fairly fixed rate of capital and labour (at a given state of technology) that combine with land. We find that "the decision to produce a crop or livestock product involves the decision to perform a sequence of tasks, all of which must be performed or none at all" (13). Hence the demand for all

(13) C. Gislason, "The Nature of Aggregate Supply of Agricultural Products." J.F.Ec. XXXIV: 85, 1952.

factors tends to be inelastic as cultural practices dictate to a large degree the proportion of factors used to a given proportion of land. This is only true of the short run, for we find in the longer period, that changes in technology have made the elasticity of substitution between factors quite high.

Factors Affecting the Elasticity of Supply of Aggregate Agricultural Output.

The elasticity of supply of total farm output depends upon the interaction of farmers' inelastic demand for factors with varying supply conditions. In some cases, the demand for factors is wholly dominant over the supply conditions, but when shifts in the demand curve take place, or indivisibilities are overcome, the supply conditions of factors assume greater importance. The "market" conditions of each of the main three factors, land, labour and capital are treated in turn.

Land.

The supply of "land" has very low price elasticity in the short run, owing to the lack of alternative uses, and the small changes which can be made in its quantity through investment or disinvestment (14). Even in the long run, it remains relatively inelastic. The farmer can only meet changes in factor prices, in the short run, through a limited number of other variable factors, as his demand for land is fixed historically. Hence a general decline in prices affects the supply of the land to the individual farmer only so far as depreciation and depletion exceed maintenance expenditure (15). The actual price of land to the farmer will depend on the size of his equity in it.

(14) Johnson op. cit. p. 563.
(15) Ibid p. 555.

A small equity means existence of a high mortgage, with consequent high interest charges, and possibly principal repayments in addition. Such mortgage costs may well have been incurred in a period when the price of land exceeded its long-term productive value. In the short term, this would act as an incentive to use the land to its maximum productive value. These payments have previously been analysed in the literature as high fixed costs. In the case of a high equity in the land, the price elasticity can be nearly zero, as the farmer-owner will accept zero return, in the short run, when there is a lack of alternative opportunities. Hence the supply of land does not cause the supply curve to shift, nor does it modify the slope of the curve in periods of changing prices.

Labour

The supply curve of "labour" shifts with the level of income and employment in the rest of the economy. The reasons for this have already been presented in Chapter I. It remains to determine the influence of the labour "market" on the output conditions. The following discussion is based on Figure 2. Labour is considered as the sole variable factor with all others fixed. The DD curve shows the additional quantity produced by adding small units of the variable factor to a fixed quantity of the remaining factors employed. It represents the value of the additional resources to the farmer, and therefore is the demand curve for the productive factor. In actual practice, labour is available only in large lumps as most farms employ one, two or three men, beside certain seasonal and other day labour. Hence the farmer may find himself at a position such as $E_1$, where the value of the product of the last unit of labour employed is in excess of the wage paid, but the value added by another whole labour unit would only yield a product somewhat less than the ruling wage. Thus, in normal circumstances, the labour requirement is more likely to be determined by demand conditions rather than those on the supply side (16).

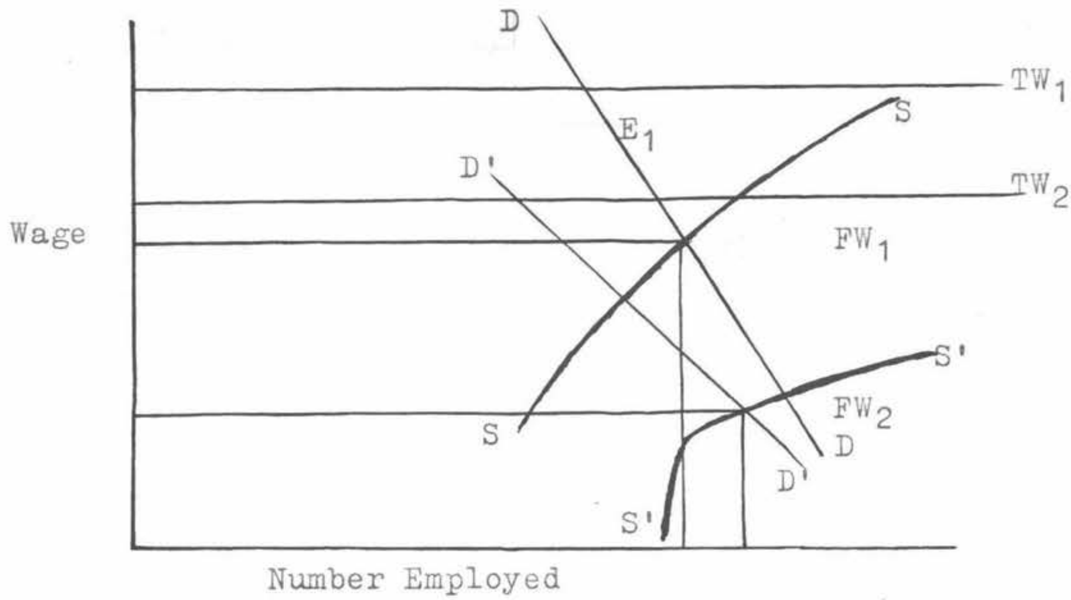


Figure 2. Changes in the farm labour situation.

$TW_1$ and $FW_1$ represent the levels of town and farm wages under conditions of full employment. The space between these represents the non-cash advantages of employment between the two. The demand for labour is inelastic as already explained. The supply of labour to farming at such times is fairly elastic(SS). Below the farm wage level any decline in farm wages would favour the advantages of town employment with a consequent drain of labour out of farming. A rise in rural wages above the full employment level, or an increase in rural amenities, such as housing, would attract a reasonable supply of workers.

In the unemployment situation the margin between the wage levels widens (see Table IV), owing to the security of farm

(16) Gislason, op.cit. p. 91.

occupations from unemployment. The new wage levels are shown by $TW_2$ and $FW_2$, and the relevant demand curve for labour is shown by D'D'. In this case, however, the supply of labour below the going wage level is highly inelastic, as workers have no alternative occupations available. This is shown as the lower part of the S'S' curve. Above the going farm wage, the supply of labour is even more elastic than formerly, as security of employment plus even a modest wage would attract a large number of workers.

The initial fall in product prices in a depression would cause a fall in the demand for labour, with the result that the DD curve falls slightly to the left. In practice, however, the increased amount of effort expended at such times may well shift the DD curve somewhat to the right. But as the unemployment situation in the towns develops, the possibility of rural employment, even at a very much reduced wage, has an added attraction. The low wage willing to be accepted may actually make wages cheaper in terms of the price of the product. In fact, this was the case in New Zealand dairyfarming (Table IV) (17).

Labour became cheaper in terms of the product, such that the physical amount produced by an additional unit of labour need not be so great. On many farms, these considerations would be sufficient to justify the employment of an additional man, not because the increased demand for labour at its lower real cost is fully of this magnitude, but because it may be sufficient to overcome a "bump" in the amount of labour employed. The farmer may shift from a situation where he needed, say, two and a half men, but actually had employed two, to a situation where he could employ and obtain three.

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(17) W.M. Hamilton, "The Dairy Industry in New Zealand." 1944, p. 109.

TABLE IV. NOMINAL WEEKLY WAGE RATE ADULT MALES FARM AND NON-FARM.

Sources: (1) N.Z. Year Book 1947-49, p. 635.
(2) W.M. Hamilton, "Dairy Industry in New Zealand." p. 109.

| YEAR | FARM | NON FARM | FARM / NON FARM | LBS. OF BUTTERFAT TO PAY DAIRY FARM WAGES |
|---|---|---|---|---|
| | 1926-30 = 1000 | | | |
| 1929 | 822 | 1076 | 76.4% | 25.6 |
| 1930 | 809 | 1080 | 74.9% | 29.2 |
| 1931 | 701 | 1015 | 69.1% | 25.7 |
| 1932 | 550 | 959 | 57.4% | 18.3 |
| 1933 | 516 | 929 | 55.5% | 24.0 |
| 1934 | 528 | 933 | 56.6% | 26.6 |
| 1935 | 541 | 954 | 56.7% | 26.8 |
| 1936 | 694 | 1028 | 67.5% | 26.0 |
| 1937 | 824 | 1100 | 74.9% | 37.6 |
| 1938 | 849 | 1152 | 73.7% | 36.5 |
| 1939 | 859 | 1173 | 73.2% | 39.1 |
| 1940 | 866 | 1210 | 71.6% | 38.9 |
| 1941 | 874 | 1263 | 69.2% | 39.1 |
| 1942 | 927 | 1315 | 70.5% | 39.3 |
| 1943 | 992 | 1343 | 73.9% | 41.6 |
| 1944 | 1002 | 1357 | 73.8% | |
| 1945 | 1139 | 1454 | 78.3% | |
| 1946 | 1259 | 1518 | 82.9% | |
| 1947 | 1322 | 1570 | 84.2% | |
| 1948 | 1470 | 1634 | 90.5% | |
| 1949 | 1547 | 1721 | 89.9% | |
| 1950 | 1681 | 1827 | 92.0% | |
| 1951 | 1919 | 2073 | 92.5% | |

The lower rewards paid or accepted in periods of low prices thus have the effect of lowering the marginal cost curve. These are the main costs which farmers can significantly lower in low price periods. Under full employment, however, the inelasticity of the demand for labour and the wide range of alternative employment only tend to increase wage costs of production, and thus allow little increase in output to take place.

Capital.

The amount of equipment required to carry out the production process, at any one period, is fixed within fairly narrow limits. Thus in the short run, the value of the physical marginal product of capital may, after a point, diminish quite rapidly. But in a longer period, the slope of this curve is probably much less, and hence the farmer's long-term demand for capital may be quite elastic. On the physical side, however, it is impossible to double capital equipment in a short space of time, owing to lack of adaption to production plans and also the sheer inability of the retailing organisations to supply everybody at once.

In a period of low farm prices, the farmer has little or no surplus to invest in capital equipment of any sort. The lenders of money, owing to the general uncertainty of farming, as well as low prices, are extremely reluctant to finance new investment at such times. The fixed proportion of factors in the farm pattern make it impossible for the farmer to employ less machinery and other equipment. As there is also no alternative use for it, he goes on employing the same stock of equipment, probably putting in extra patience and willingness to make-do in the way of repairs. Owing to the precarious capital position of the farmer, the supply of capital "is very inelastic whenever the demand price is below the price of new equipment" (18). The decline in cash inputs at such times would only cause a slight decline in productivity, for the existing equipment would continue to be used, with possibly the postponement of depreciation if not maintenance. An analysis of machinery imports, and the output of New Zealand machinery and farm implement firms, over these years, might show the rate at which farm equipment was replaced owing to sheer obsolescence or mechanical failure.

At a time of full employment, however, the relative prosperity of farming makes the supply of capital very much more elastic. Capital-rationing to farmers is relaxed by lending institutions, and the farmer himself is in a position to invest higher receipts in capital assets. Not only can the farmer substitute capital at a higher rate, as necessitated by the drain of labour to the cities in such times, but the general liquidity enables the more rapid adoption of technological changes involving large doses of capital at a time. We may note, in passing, that many new techniques have not required important investment by farmers adopting them in the past (e.g. new seeds, new manures, new feeding methods etc.), in which case they may well be adopted at a greater rate in depression. But the effect of higher cash investment by farmers in a high price period is to increase the rate at which new capital equipment is adopted to a level somewhat in excess of the long-term trend in availability of better machines and depreciation

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(18) Johnson, op. cit., p. 548.

of existing machines, as well as taking in any slack which had existed previously. This fact has widespread implications for variation in demand for capital equipment at different stages of the trade cycle. This analysis suggests that it will be of increasing importance in the future, as more and more of the farm operations, traditionally the work of labour, are carried out by machines.

In so far as capital investment increases efficiency, the greater capitalisation in times of high prices and full employment, represents an actual shift of the supply curve of agriculture to the right. But the shift is not great, as the fixed proportion that equipment plays in the farm pattern cannot be altered quickly. In times of low prices and capital rationing, we have seen that even disinvestment can have little effect on the supply curve, except lower it slightly as maintenance and depreciation are deferred.

Changes in Technology.

There remain the effects of changing technology to be taken into account. In the short run, the high proportion of fixed costs, low substitutibility between factors, and operation of diminishing returns, soon lead to a rapid increase in marginal costs, if an increase in output is required. But in the long period, the elasticity of substitution between factors is much higher. The substitution of capital for labour is widespread, and takes place in a one-way direction. Without technological advance, the substitution of factors may be consistent with unchanged output. But in the long period, innovations do take place and the gradual substitution of capital for labour has been accompanied by an increase in output.

There has been, technically, a shift of the production function. But higher investment per worker is not the same thing as technological change. Higher investment per worker may be indicated merely by a rise in wages making the replacement of labour by machinery cheaper in the long run, or may be necessary owing to a physical shortage of labour. High investment per worker may be incidental to the adoption of many technological changes which increase absolute efficiency. It is not necessarily so, as some new methods require little or no cash outlay. Owing to the greater availability of capital during a period of high prices, the rate of adoption of technological changes may be greater at such times. Such increases in output as take place, are probably explained partly by the shift in the production function and partly by the greater output per worker which results from the greater application of capital. The relative importance of each is admittedly conjectural (19).

In one sense, land and capital have been highly substitutable. If techniques and improved methods of production are conceived in terms of the capital invested to produce them, then capital has been substituted for land in a very productive manner. Not only is capital investment labour-saving, it is also land-saving in this sense (20). With improved techniques the whole supply schedule moves to the right, and even in periods of low prices, the adoption of techniques involving no extra outlay, may cause a shift of the supply curve to the right.

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(19) Johnson, op. cit., p. 556.
(20) Gislason, op. cit., pp.86-94, 96.

Relative changes in prices between products and factors may alter the extensive margin of cultivation (21). Lands hitherto not considered worthwhile breaking-in are settled. The exact position of the margin is difficult to place as there is a large factor of inertia, a certain amount of which is justifiable on the grounds of risk, in accepting the financial responsibility involved. This is reflected in the large amount of State development which is taking place at present in New Zealand. In this sense, land is not a completely fixed factor, and hence the cost curve of the industry cannot be regarded as so steeply sloping (22). At any one period, however, the total supply of land is fixed to the farm community, although individual farmers may alter the size of their properties by buying additional land, or moving into new properties nearer the optimum size for their entrepreneurial ability.

SUMMARY.

The elasticity of supply for agriculture as a whole, is derived from the shape of the relevant portion of the marginal cost curve of the representative farm firm. Owing to the steepness of this curve, in the area of the price line, the supply function for agriculture is highly inelastic - other prices being given. As prices do change in a downward direction, there is little scope for a decline in output, as the cost curve of the firm falls just as quickly, with the result that there is a tendency for the supply curve to steepen, if anything, as

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(21) Gislason, op.cit., p. 86.
(22) Ibid pp.89-90.

reduced rewards are accepted. In terms of the factor analysis, the maintenance of output in depression is explained by the inelastic supply of land and capital assets, together with the change in the farm labour situation when unemployment is widespread elsewhere. Although the demand for labour and capital, at a given price, would probably fall in such times, their inelastic supply offsets the tendency to use them in smaller quantities (23). The reward paid to factors would decline considerably. This theory is consistent with the behaviour of non-agricultural firms which also maintained output in the depression. Group I industries, in particular, had one input that was extremely important from a cost standpoint. This input was an agricultural product. "Since the alternative costs of these products fell sharply, the same volume of products would be available for processing at a much lower price that would clear the market."(24).

The actual increase in output which took place in New Zealand in 1930-33, is explained by the shift of the labour supply schedule to the right, as wages tended to become cheaper in terms of the product, and possibly by the increase in effort on the part of existing workers. This latter hypothesis is difficult to verify and deserves further investigation. The changes in the labour situation enabled a greater use of farm-produced inputs, which coming at the end of a period of development, especially in dairyfarming, increased total output considerably. The introduction, in this period, of non-cash technological improvements is an additional factor of importance. These details will be further discussed in Chapter VII.

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(23) Gislason, op.cit., p. 90.
(24) Johnson, op. cit., p.554.

The stability of farm output under full employment is derived from the inelastic supply of land, coupled with the nature of agricultural output when transcribed into demand for factors of production (25). The steep slope of the marginal product curve for labour, particularly, prevents an expansion in output, even if the supply conditions of labour are elastic. Although capital is more freely available, it is difficult to assess the relative importance of actual technological improvements as against mere labour-saving devices. Some attempt at this assessment will be made in Chapter VII.

Finally, D. Gale Johnson (26) has posed the question; what is the response of agricultural output to a fall in price under conditions of full employment? The possibility of this situation appears theoretically impossible in view of cyclical conditions of inelastic total demand for primary products. But the implication of full employment policies in the future may well bring about a situation where this question would require an answer. We have no period so far in history, (for which accurate data is available), where high levels of employment have coincided with declining relative farm prices. This analysis suggests, and no more than suggests, that output would decline under such conditions. But the normal shift in the production function over time, may soon compensate for this decline (27).

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(25) Gislason, op. cit. p. 90.
(26) Johnson, op. cit. p. 554.
(27) Johnson, op. cit. p. 557.

# PART II

## STATISTICAL TESTING OF THEORY

### IV. THE USE OF LEAST SQUARES REGRESSION ON TIME SERIES.

In recent years, there has been increasing criticism of predictions based on regressions derived from time series. In particular, the relationship between successive observations, has given correlation coefficients of unusually high values, and corresponding low standard errors of estimate (1). In general, the data must meet four essential conditions - independence, normality, homogeneity and identification.

By "independence" is meant that in each series used each observation is independent of every other observation. The independence of observations at successive points of time must be satisfactorily established. This requires, in the first place, that the natural units into which the data fall are independent (2). Production data for New Zealand, being purely seasonal in character, stands up to this criterion. A second requirement is that the successive values are not related. Some difficulties of nomenclature have arisen in this connection. Yule and Kendall (3) and Durbin and Watson (4)have called such

(1) See for example, A. Sturges, "The Use of Correlation in Price Analysis". J.F.Ec.XIX: p.699, 1937, and review of "The Theory and Measurement of Demand." (H.Schultz) by G. Tintner, J.F.Ec.XXI: p.610, 1939.
(2) See M. Ezekiel, "Methods of Correlation Analysis." 2nd Edition p. 354, and G.U. Yule and M.G. Kendall, "Introduction to Theory of Statistics." 14th Edition,(1950)p.610.
(3) Yule and Kendall, op. cit. p.639.
(4) J. Durbin and G.S. Watson, "Testing for Serial Correlation in Least Squares Regression." I, Biometrika, XXXVII, p.409, 1950.

properties of variable "serial correlation". Tintner (5), apparently following American usage, refers to it as "auto-correlation". In this thesis, the former name is used, while auto-correlation is taken to mean schemes where lagged values of the dependent variable occur as independent variables (6).

If serial correlation is present the regression breaks down at three points (7).

(i) The estimates of the regression coefficients though unbiassed, need not have least variance.

(ii) The usual formula for the estimate of variance from regression is no longer applicable and is liable to give a serious under-estimate of the true variance.

(iii) The "t" and "F" distributions, used for making confidence statements, lose their validity.

The presence of serial correlation in the variables will also result in the error terms of the regression model being serially correlated. According to Durbin and Watson (8), it will only rarely be the case that the independent variables are serially uncorrelated while the errors are serially correlated. Thus if we can establish that the error terms in the regression model are independent, the procedure is valid, whether or not the observations themselves are serially correlated.

Various tests have been devised for this purpose. Moran (9) has provided a "circular" test for serial correlation in residuals. Such a test is generally not suited to time series,

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(5) G. Tintner, "Econometrics." 1952, p.187.
(6) Durbin and Watson, op. cit., p.410.
(7) Durbin and Watson, op. cit., p.410.
(8) Ibid, p.411.
(9) P.A.P. Moran, "A Test for Serial Independence of Residuals." Biometrika, XXXVII, p.178, 1950. Quoted by Tintner, op. cit., p.250.

as such series may have a wide disparity between the first and last values owing to trend. Von Neumann (10) has devised a test of independence of successive observations in a given series by taking the ratio of mean square successive differences to the variance, and plotting the resulting distribution when the series is purely random. Similarly, Durbin and Watson (11) have prepared a distribution for a test of the residuals from regression, for a model with the error term randomly distributed. Both of these tests are non-circular.

Since a considerable number of time series were to be tested for significant association with the volume of farm production, all variables were converted to first differences between years, to overcome the effects of serial correlation on the resulting coefficients and tests of significance. On finding the variables with a significant effect at the five per cent level, we can derive the appropiate supply or production function. We can then test this model according to the distribution of Durbin and Watsons' "d" statistic. Since the purely random value of the statistic is two, we can enter the tables for negative serial correlation with the statistic "4-d". Such a test will show whether the use of first differences has overcorrected for positive serial correlation. It is now possible, of course, to go back to the variables in their original form, which have been shown significant by first differences, and re-calculate the regression model. A test applied to the residuals of this model will show the extent of positive serial correlation in the equation using the original data. The possibility may also

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(10) J.Von Neumann, "Distribution of the Ratio of the Mean Successive Difference to the Variance." Annals of Math. Stat. XII, p.367 (1941). Quoted by Tintner,op.cit.,p.252.

(11) Ibid, II, XXXVIII, p.157, 1951.

exist that first differences do not fully correct for positive serial correlation. In this case subsequent differences may be taken, although this leads on to very doubtful ground for purposes of interpretation (12).

The "normality" condition in least squares regression is that the error terms of individual values be distributed normally and independently. The usual tests of significance, and calculation of variance from regression, depend on ninety-five per cent of the values being distributed within a distance of approximately twice the standard deviation from the mean. We cannot place any measure on the normality of the distribution of the error terms in such a short series, but it is possible to establish that each residual is independent of the residuals adjacent to it in time, by testing for serial correlation.

The correct calculation of variance cannot be made until the assumption of "homogeneity" is met. For this, we must assume that the variance of the dependent variable associated with a given value of any independent variable, is the same as the variance associated with any other given value. Also, the homogeneity of the residuals from regression must be assumed. This can be verified by an inspection of the actual residuals, when the significant independent variables are isolated.

By "identification" is meant that the causal relationships between variables can be established logically. This will be carried out as each is introduced. Since only single equations are to be used, the econometric problem of identifying equations does not arise (13).

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(12) Yule and Kendall, op. cit., p.319.
(13) G. Tintner, op. cit., p.133.

The use of economic time series incorporating a considerable growth of the population constitutes a further problem. Such evidence of trend in the variables can be dealt with by introducing "time" as a variable into the analysis, or by taking first differences. The use of time as an additional variable is least preferable as it implies that the trend is at a constant rate, if a linear function is chosen, or according to the properties of whatever curvilinear function is taken (14).

Finally, the transformation of all variables into logarithms allows for the association between variables to be expressed as a proportional rather than additive effect. Besides presuming some normality on the individual variables, the transformation makes variables with different magnitudes comparable. It also makes the partial regression coefficients comparable between data, expressing relevant elasticities directly.

Least squares regression was thus computed using the first differences of logarithms of the original data. The coded variables were used in linear equations of the form,

$$y = b_1 x_1 + b_2 x_2 + \dots\dots\dots + b_n x_n + e$$

where e represents a random error term of zero mean and constant variance, where y is the deviation of the dependent variable from its mean, $x_1, x_2 \dots\dots x_n$ the corresponding deviations of the independent variables, and $b_1, b_2 \dots b_n$ are the partial regression coefficients.

The transformation of the original data to the working variables may be set out as in Table V.

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(14) F.C. Mills, "Statistical Methods" (Revised) Ch.XI.

TABLE V. CODING OF VARIABLES.

| YEAR | AREA TOP-DRESSED | LOG. | +Δ | -Δ | ADD CONSTANT OF 900 | CODED VARIABLE USED |
|---|---|---|---|---|---|---|
| 1928-29 | 2.385 m.ac. | 0.3775 | | | | |
| 1929-30 | 2.651 " | 0.4234 | 459 | | 1359 | 136 |
| 1930-31 | 2.871 " | 0.4581 | 347 | | 1247 | 125 |
| 1931-32 | 2.454 " | 0.3899 | | 682 | 218 | 22 |
| 1932-33 | 2.438 " | 0.3870 | | 29 | 871 | 87 |
| 1933-34 | 2.249 " | 0.3519 | | 351 | 549 | 55 |
| 1934-35 | 2.684 " | 0.4288 | 769 | | 1669 | 167 |

The logarithmic differences were taken to four decimal places so as to provide a check when rounding off the new variable to three places. The negative values are removed by adding throughout a quantity at least equal to the highest negative difference.

The solution of equations was carried out by the Doolittle Method (15). This method provides a check on the working at every stage, thus avoiding tedious recalculation in the case of a mistake in working.

From the values of the partial regression coefficients it is possible to derive the partial correlation coefficients and the multiple correlation coefficient. For three independent variables, $X_1$, $X_2$, $X_3$, the sum of squares explained is given by :

$$S\hat{y}^2_{123} = Sx_1y(b_{y1.23}) + Sx_2y(b_{y2.13}) + Sx_3y\ (b_{y3.12})$$

(15) M. Ezekiel, op. cit. Appendix 1, pp.464-470.

where $Sx_1y$, $Sx_2y$, and $Sx_3y$ are the sums of products of deviations of each independent variable with the dependent variable from their means, and $b_{y1.23}$, $b_{y2.13}$, and $b_{y3.12}$ are the corresponding partial regression coefficients. These coefficients can be tested for significant difference from a random population where the regression coefficient equals zero, by calculating the following "t" statistic, (16)

$$t_{.05} = \frac{b-0}{s_b}$$

where the coefficient must be at least "t" times its own standard error for the appropiate degrees of freedom. In actual practice, it is not necessary to calculate this statistic as the partial correlation coefficient is more satisfactory for testing variables.

The effect of any one independent variable is shown by the square of its zero order correlation coefficient. The addition of subsequent variables to the explanation of the total variance of the dependent variable, requires the re-calculation of the partial regression coefficients for each variable added, so as to obtain the appropiate value of explained variance. If $X_1$ and $X_2$ have already been considered, the additional explanation added by $X_3$ is given by:

$$r^2_{y3.12} = \frac{S\hat{y}^2_{123} - S\hat{y}^2_{12}}{Sy^2 - S\hat{y}^2_{12}}$$

where $S\hat{y}^2_{123}$ is the sum of squares explained by the three variables together, $S\hat{y}^2_{12}$ the sum of squares explained by $X_1$ and $X_2$ alone, and $Sy^2$ the total sum of squares to be explained. The square

(16) G. Snedecor, "Statistical Methods." 1950, p.119.

root of $r^2_{y3.12}$ gives the partial correlation coefficient. It may be tested for significance by calculating the appropriate "F" ratio or entering an "r" table for n-m degrees of freedom, where n is the total number of years and m is the total number of variables.(17). Such a table shows in what proportion of cases the correlation could occur by chance when the true correlation in a very large "population" of such yearly figures were really zero.

The final selection of variables for a supply function must be made on the basis of the significance of the partial correlation coefficients. If these coefficients are significant at the desired level, we then know that the partial regression coefficients, and the multiple correlation coefficient, will also be significant at the same level. The partial correlation coefficients are, therefore, the primary criteria of selection used in the following sections of this thesis.

If $S_y^2$ is the total variance of the dependent variable from its mean, then R, the multiple correlation coefficient is calculated from the ratio,

$$R^2_{y.123} = \frac{S\hat{y}^2_{123}}{Sy^2}$$

where $R^2_{y.123}$ is the proportion of sums of squares of deviations of the dependent variable from its mean explained by the combined effects of the independent variables. Those sums of squares unexplained, that is the deviations of the actual Y values from the estimated Y values must be explainable by other variables not taken into account or finally unexplainable.

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(17) G. Snedecor, "Statistical Methods." 1950. p.149.

The significance of the multiple correlation coefficient can be calculated from the ratio of the variance explained to that unexplained, and entering the "F" table with the correct degrees of freedom (18). Alternatively, an "R" table can be used for n-m degrees of freedom and m variables (19).

Having chosen those variables significant for the supply function, we can proceed to calculate the estimated values of the dependent variable. The differences or residuals, between Y estimated and Y actual, can be conveniently used to apply the Durbin and Watson test for serial correlation. Their statistic, "d", is given by,

$$d = \frac{\Sigma(\Delta z)^2}{\Sigma z^2} \qquad (20)$$

where $\Sigma(\Delta z)^2$ is the sum of the squares of the mean successive differences of the residuals, and $\Sigma z^2$ the sum of squares of residuals. This latter quantity is, of course, the sum of squares of the dependent variable unexplained by the independent variables, and when divided by the degrees of freedom gives the square of the standard error of estimate of regression.

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(18) Snedecor, op. cit., p.222.
(19) Ibid, p. 351.
(20) Durbin and Watson, op. cit. II, p.157.

## V. AN AGRICULTURAL PRODUCTION FUNCTION FOR NEW ZEALAND.

This and the following section present an analysis of the main factors which influence farm output on the production side. Factors on the supply side will be considered subsequently. Besides the traditional factors of land, labour and capital, indices representing important farm inputs, and effort exerted by farm workers, are discussed below. Sources of all statistics are given in Appendix A.

"Area under cultivation" was chosen as most representative of "land". It includes area in field crops and area in sown grasses and clovers. An inspection of the actual figures extracted shows little variation from year to year. Since the analysis uses first differences of logarithms, the yearly change in area must be considered as insignificant, as it is no greater than that caused by the encroachment of urban land and variations in enumeration. Further variation, as far as production is concerned, also takes place owing to the deterioration of existing pastures which come under the Yearbook definition. For these reasons land as an independent variable was not proceeded with.

The period under review has been marked in its latter stages by the rapid substitution of machines for labour on farms. Although no detailed factual evidence is available, it seems fairly certain that the investment in machinery has been associated with a higher capital input. This investment has not depended so much on the farmer's desire to replace labour as relative prices and productivity would dictate, but rather on making up for a physical shortage of labour. This in turn depends largely on the availability of capital resources. The Agricultural and Pastoral statistics are collected as at January 31st., and hence are taken for purposes of analysis as the machinery used in the previous seven months and following five months, so as to be comparable with the June production year. The representative index actually consists of the aggregate of horse-power installed as electric motors, internal combustion engines and the rating of farm tractors. The collection takes place, of course, only outside borough boundaries. Figures were not collected for the three war years - 1943, 1944, 1945. These have been interpolated graphically.

Data for farm working population have never been collected systematically for New Zealand. To obtain a reliable and consistent series of figures, all the available estimates were collected together; the most accurate were then selected as a basis for interpolating the final series. This is shown in Appendix B. The validity of using an estimate of this nature in first difference regression analysis is open to question, and places a serious limitation on any results derived from it.

Two series are available of the New Zealand Farm Expenditure Index. There is the weighted aggregate index of all items of farm expenditure as defined on Page 687, 1932 Yearbook. There is also the same index with the contribution of rent and interest eliminated (1). The latter is the more valuable.

Both indices are only available to 1944. The use of the Government Statistician's Retail Price Index was investigated

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(1) Private communication from Dr. H.B.Low, Massey Agricultural College.

as a means of continuing the series into later years, and although the result appeared reasonable the adaption was not pursued further. This was mainly owing to price effects. The index only measures change in price of items bought by the farmer, and not the volume. If a suitable price index of production expenses of farmers was available, its deflation by the second farm expenditure series might possibly have given a rough measure of farm inputs. Since no such expenses index has been calculated, and the available figures do not cover the period concerned, the farm expenditure index as such was not proceeded with in the time series analysis.

The figures for area top-dressed with fertiliser or lime are collected in the same way as the details of horse-power on farms, milking machines, etc. The area for 1929 thus represents areas mostly top-dressed in 1928, and which we can reasonably expect to influence production most in the June year of 1928-29. The larger the number of farmers who top-dress to lengthen the seasonal growth of grass, the more correct this interpretation would be. But, in fact, a large number of farmers put on fertiliser when they can obtain it, and when finance and time are available. Lime is not nearly so specific as phosphatic fertilisers, as it is not "fixed" to such an extent in the soil, nor has it an immediate effect on growth. Rather it works by creating a favourable environment for clovers which in turn manufacture nitrogen for grass growth. Clearly this is a long-term effect, at least longer than the production years taken for this analysis.

The only other series of farm inputs available on a national scale is area cut for hay or silage, including lucerne. These figures are also collected in the Agricultural and Pastoral schedules, but in this case the farmer is asked to provide the figure for the production season, i.e. June years. Assuming that hay and silage stored in one season will influence production the following season by improved winter feeding, the series is used with a lead of one year.

An inspection of the figures, however, shows a marked seasonal variation which may not be unrelated to production in the same year. This could be caused by the fact that in a year of reliable and well-spread rainfall, a given number of stock can be pastured on a smaller area, and more grass is available for hay-making particularly. On these grounds, area cut for hay and silage is introduced into the preliminary regression analysis without a lead.

Following the theoretical analysis in Chapter II, we may expect that changes in the effort put forward might have some influence on total output. The main conclusion was that effort tended to maintain output in the face of a decline in other factors rather than increase it. If the supply curve of labour is backward sloping, we might look for some relationship between income and production. The most accurate figure for this purpose would be an index of real net farm income. As no such figures are available, Gross Farm Income was considered. It was rejected because it introduced an unstable price element into the analysis, and because no price indices exist which are satisfactory for deflating income statistics.

As an alternative to Gross Farm Income, Nominal Weekly Farm Wages was considered. While it remains uncorrected for price changes, it is an accurate record of the return farm workers were willing to accept in the depression years, and what has been provided for them since 1936. The rewards of the farm owner can be postulated as moving in approximate sympathy with the actual worker's wage. The use of logarithms is of great value when a variable of this nature is introduced, as clearly, any reaction on the part of the farmer will only be in proportion to the change in rewards.

Another criticism of the use of Gross Farming Income would be that our dependent variable, the volume of farm production index, is actually derived from it. The Government Statistician describes it thus: "For the compilation of these index numbers, a computation has been made for each of the seasons 1928-29 to 1949-50 showing what the annual aggregate value would have been had 1938-39 prices been constant throughout the period. From the resultant aggregates, index numbers have been compiled which measure the movements in the volume of production; for, since prices were assumed to be constant, volume is the only variable factor in the aggregates."(2) The value aggregates include estimates of farm produce consumed on the farm, and materials sold to other farmers (stud stock is an exception), although products of kitchen gardens and production of green fodder crops, including hay and silage, are not included (3). It is also to be noted that the original income figures on which the volume figures are based, include butter and cheesemaking and meat freezing. These additions do not invalidate the figures as long as the computation is made on the same definition over the whole period. Our statistical technique is concerned with the year-to-year changes in the aggregates and not the aggregates themselves.

(2) N.Z.Year Book, 1947-49, p.880.
(3) Ibid 1943, p.253.

Preliminary Results of Statistical Analysis.

In this thesis, the experimental work consists of an inquiry into the scope of statistical method as applied to economic time series, rather than an actual collection of data. The order in which the variables were tried in the following analysis thus had no pre-determined experimental logic, but rather represents a course of trial and error.

Table VI (folded leaf, end of chapter) shows the zero-order correlation coefficients between pairs of variables, when the latter are used in the form of coded first differences of the logarithms of the original time series. The failure of any of the variables to reach the five per cent level of significance with farm production is disappointing. It does not, however, preclude one or more of the variables having a significant relationship in the multiple correlation.

The significant correlation between horse-power on farms and area top-dressed in the same January year indicates the long-term dependence of top-dressing on mechanical factors, among others. It also indicates the line of direction of further investigation, where both variables may prove to be commonly associated with some third factor. As may also be expected, changes in the rural labour force are significantly associated with changes in the rural wage level. This inverse relationship reflects the dependence of movements in farm labour on the general wage level. When all wages are high under full employment, urban migration takes place, but when wages are low with the possibility of unemployment, rural migration tends to take place. We may also note the low coefficient between successive values of hay and silage ($r_{69}$ = -0.1580). In this series, at least, correlation between successive values in the original time series is offset by the use of first differences.

The selection of variables for further testing at this stage is somewhat arbitrary. The zero-order correlation coefficients of 'labour on farms', 'horse-power on farms' and 'farm wages' with total production are all sufficiently small to allow the fairly safe assumption that no manner of eliminating variance caused by other explainable factors will raise them to a significant level. This method of selection cannot be absolute, but considerably simplifies the calculations which follow. Since 'horse-power on farms' is significantly associated with 'area top-dressed' it cannot be dispensed with in this way, but must be retained for further testing in the partial coefficients.

The results of this testing are presented in Table VII. The independent effect of horse-power is very small, as might be expected ($r_{y2}$ = 0.0499, $r_{y2.5}$ = -0.0982). Although slightly larger than its zero-order coefficient, the independent effect of top-dressing gives too small a result to be relied upon ($r_{y5.2}$ = 0.2973). When hay and silage saved the previous season is taken into account as well, a significant portion of the remaining variance is "explained" ($r_{y6.25}$ = 0.4633). Hay and silage saved the same season does not reach the necessary level of significance in either case presented ($r_{y9.25}$ = 0.2674, $r_{y9.256}$ = 0.3812). When hay and silage saved the same season is held constant with horse-power and top-dressing, hay and silage saved the previous season has a somewhat higher determination than before ($r_{y6.259}$ = 0.5266).

The removal of serial correlation in residuals or error terms necessitated the use of first differences of yearly values of the variables in this analysis. The results presented above show just how potent the use of first differences is in eliminating factors which are commonly thought to determine the volume of farm production. While our theory tells us that these are the factors which affect farm output in the long run, there is no satisfactory method of statistical analysis available which can measure this affect through time, without violating one of the fundamental assumptions of statistical method. A further analysis with time as an independent variable, and without first differences, may yield satisfactory results.

In the process of eliminating correlation between successive error terms by first differences, trend over the whole period is also removed. Thus an additional explanation of the low zero-order correlation coefficients with production lies in the fact that the non-significant variables, while moving through time with approximate sympathy to production, do not have strong specific year-to-year effects. This does at least point to the direction of further isolation of effective variables.

Higher determination could possibly be obtained by taking a specific area, and studying the effect of the most important variables already mentioned, either through time or in a static situation, or by the introduction of new variables not already taken into account. This latter possibility acts as the starting point for the next chapter.

The interpretation of results up to this point is not altogether straightforward. It will be recalled that $X_9$ was included in the analysis on the assumption that changes in area cut for hay and silage in the same season would be indicative of a good growth season, and hence have a marked effect on production for that year. But the analysis failed to show that this relationship was significantly different from zero. It has shown, rather, that the reserves of feed saved the year before are more important. This might be explained by a good season one year showing up as a good production season the following year, owing to a general improvement of conditions, but the more likely explanation is that breeding stock, (especially cows), enter the new production season with built-up body reserves. This is all that can be said at this stage; further interpretation will be possible when more variables have been tried in the analysis.

TABLE VI. ZERO ORDER CORRELATION COEFFICIENTS BETWEEN FARM PRODUCTION AND SELECTED VARIABLES.

where $Y$ = Farm Production

$X_2$ = Horse-Power on Farms

$L$ = Labour on Farms

$X_5$ = Area Top-Dressed

$X_6$ = Area Hay and Silage Lead one Year

$X_8$ = Farm Wages

$X_9$ = Area Hay and Silage

$n$ = 21

TABLE VII. PARTIAL CORRELATION COEFFICIENTS OF FOUR FACTORS AFFECTING ANNUAL CHANGES IN FARM PRODUCTION.

TABLE VI.

| | Y | $X_2$ | L | $X_5$ | $X_6$ | $X_8$ |
|---|---|---|---|---|---|---|
| $X_2$ | 0.0499 | | | | | |
| L | 0.2062 | -0.1547 | | | | |
| $X_5$ | 0.2858 | 0.4682* | 0.1619 | | | |
| $X_6$ | 0.4227 | - | - | - | | |
| $X_8$ | 0.0389 | 0.1098 | -0.4662* | 0.3219 | - | |
| $X_9$ | 0.3162 | -0.0049 | 0.3306 | 0.2060 | -0.1580 | -0.2436 |

* Significant at 5% level.

TABLE VII.

| SUMS OF SQUARES PREDICTED BY: | DEGREES OF FREEDOM | PARTIAL CORRELATION COEFFICIENTS | RESULT |
|---|---|---|---|
| $X_2$ | 19 | $r_{y2} = 0.0499$ | N.S. |
| $X_2, X_5$ | 18 | $r_{y5.2} = 0.2973$ | N.S. |
| | 18 | $r_{y2.5} = -0.0982$ | N.S. |
| $X_2, X_5, X_6$ | 17 | $r_{y6.25} = 0.4633$ | S. |
| $X_2, X_5, X_9$ | 17 | $r_{y9.25} = 0.2674$ | N.S. |
| $X_2, X_5, X_6, X_9$ | 16 | $r_{y9.256} = 0.3812$ | N.S. |
| | 16 | $r_{y6.259} = 0.5266$ | S. |
| 5% Points of | 19 | $r = 0.433$ | |
| Significance | 18 | $r = 0.444$ | |
| (Snedecor, p.351) | 17 | $r = 0.456$ | |
| | 16 | $r = 0.468$ | |

## VI. A SUPPLY FUNCTION FOR NEW ZEALAND AGRICULTURE.

A specific factor which has not been so far taken into account is that of price. But before analysing price effects, the elimination of some of the year-to-year variation caused by seasonal changes is desirable. With this objective, the use of rainfall statistics was investigated. Another index measuring the movement of labour was also tried.

The results presented in the previous chapter emphasised the importance of those factors which have a specific year-to-year effect on production. The method adopted to correct for serial correlation throws into relief changes in production which must be caused by climatological seasonal variations, so that it is desirable to find out how much of the changes in production are to be thus accounted for. When such seasonal variation is accounted for, it might be possible to isolate factors affecting the true part of the production function, and which also may allow some other significant variable to show itself in a more favourable light.

To find a suitable series of figures to represent these weather variations presented a problem to this investigator. The influence of rainfall was considered more important than that of temperature because of the extent of grassland farming in New Zealand. The main production effect of rainfall was believed to be its presence or absence in mid-summer, its presence enabling stock to be carried over until the autumn flush set in, and its absence depressing production (especially that of cows) to a level from which little recovery is possible. Accordingly, meteorological records for the last twenty-three years were examined against the relevant production data so as to obtain an estimate of the most influential months. Eventually, December, January, February and March rainfall totals were extracted for Ruakura Animal Research Station, Hamilton, as being representative of the Waikato; November, December, January and February totals were extracted for Hastings and Ashburton as representing the east coast of both islands. A review of these figures indicated, with one or two exceptions, that January and February were the two most critical months. That this cursory method of finding the most influential months was inaccurate, did not emerge until somewhat late in the analysis. In retrospect, several possible combinations of the various months should have been tested at the outset. Two variables were actually made up from the data. The first was the combined total of rainfall for the three reporting stations for the two months of January and February. The second consisted of the Ruakura totals alone. Their zero-order correlation coefficients with changes in farm production are shown with others in Table VIII.

The Ruakura figures appear to be the more acceptable for the purposes of removing seasonal variation from production. The use of this particular series indicates the great importance of variations in dairy output in explaining variations in total production.

The ratio of nominal farm weekly wages to non-farm nominal weekly wages was thought to express roughly one of the forces leading to the movement of labour between agriculture and the rest of the economy. The resulting ratio does not show a significant relationship with production. The ratio of farm to non-farm wages seems more likely to be connected to changes in export prices. Changes in export prices, in turn, affect the unemployment situation, which is probably a greater determining factor in the rural employment situation than the actual ratio of wages. The margin between the wage levels varies according to several considerations for which we have no way of measurement. Since the labour supply has no significant relationship with production (Table VI), and export prices are not anticipated to be highly associated, it is not unreasonable that the ratio of wages is even less significant.

The Export Price Index, based on June years, was then introduced into the analysis. Its effects were tried with prices given a one year, a two year, and a three year lead on the related production year. The resulting zero-order correlation coefficients are all non-significant. At the same time a new variable was created, by dividing the June year Export Price Index by an extrapolated version of the old Farm Expenditure Index (see Appendix A). It was hoped that the farmers' response to real price may have been more important than actual prices (1). The coefficient shows that this hope was not realised ($r = -0.0553$).

The significant year-to-year correlation between export prices in June years and the following January years of area top-dressed with super or lime is in line with our expectations that cash inputs on the farm tend to be reduced when prices fall, and increased again as prices rise. The assoication of area top-dressed with horse-power on farms (Ch.V.), and its apparent

(1) This data was later re-calculated, see p.78.

relationship with the price of super (Ch.VII), suggest again that export prices are the more causative factor in the relationship.

The dependence of hay and silage on the same season's rainfall will be discussed under the partial analysis. But the difference between the two coefficients of rainfall on hay and silage is explained by the inclusion of the 1949-50 data in the coefficient of 0.6926 and the exclusion of the 1927-28 data. The 1927-28 data do not show the same association with area of hay and silage cut as that of 1949-50. Such results indicate the necessity for longer time series in an analysis of this nature.

The Partial Analysis.

The results of the multiple correlation analysis are presented in Table IX. The most influential single factor affecting annual changes in the volume of farm production is found to be the variable representing climatological changes. It seems that the influence of mid-summer rainfall in the Waikato on dairy production is so great, that a significant partial correlation coefficient with aggregate output for New Zealand is obtained. The effect on aggregate production is significant when compared with previous season's area cut for hay and silage ($r_{y1.6}$ = 0.4827) and also when the effect of previous season's area cut for hay and silage, previous January year of area top-dressed with phosphate and lime and export prices two seasons previously are held constant ($r_{y1.456}$ = 0.4845). Present season rainfall did not quite give a significant partial correlation when previous season's rainfall and previous season's area cut for hay and silage were held constant ($r_{y1.67}$ = 0.4462).

TABLE VIII. ZERO-ORDER CORRELATION COEFFICIENTS BETWEEN SELECTED VARIABLES.

| | FARM PRODUCTION (Y) | HAY AND SILAGE ($X_9$) | AREA TOP-DRESSED ($X_5$) | HAY AND SILAGE LEAD ONE YEAR ($X_6$) | EXPORT PRICES LEAD ONE YEAR ($X_3$) |
|---|---|---|---|---|---|
| Ruakura Rainfall ($X_1$) | 0.4472* | 0.6926** | | | |
| Ruakura, Hastings, Ashburton Rainfall. | 0.3663 | | | | |
| Ruakura Rainfall previous year ($X_7$) | 0.0887 | | | 0.5736* | |
| Farm Wages | | | | | |
| Non-Farm Wages | 0.0274 | | | | |
| Export Prices lead three yrs. | -0.1933 | | | | |
| Export Prices lead two years ($X_4$) | -0.2706 | | 0.3060 | -0.2024 | 0.3443 |
| Export Prices lead one year ($X_3$) | -0.1097 | -0.2024 | 0.5252* | -0.2118 | |
| Deflated Export Prices lead two yrs. | -0.0553 | | | | |

** Significant at 1% level.

* Significant at 5% level.

As $X_6$ and $X_7$ are significantly correlated between themselves ($r_{67} = 0.5736$), they probably explain the same variations in production, and thus do not markedly alter the effect of $X_1$ in the partials. By itself, $X_7$ has a very low correlation with production ($r_{y7} = 0.0887$). The similarity of the partial regression coefficients indicates that the effect of present season's rainfall is a fairly constant and independent one ($b_{y1.26} = 0.3280$, $b_{y1.6} = 0.3055$, $b_{y1.456} = 0.2826$).

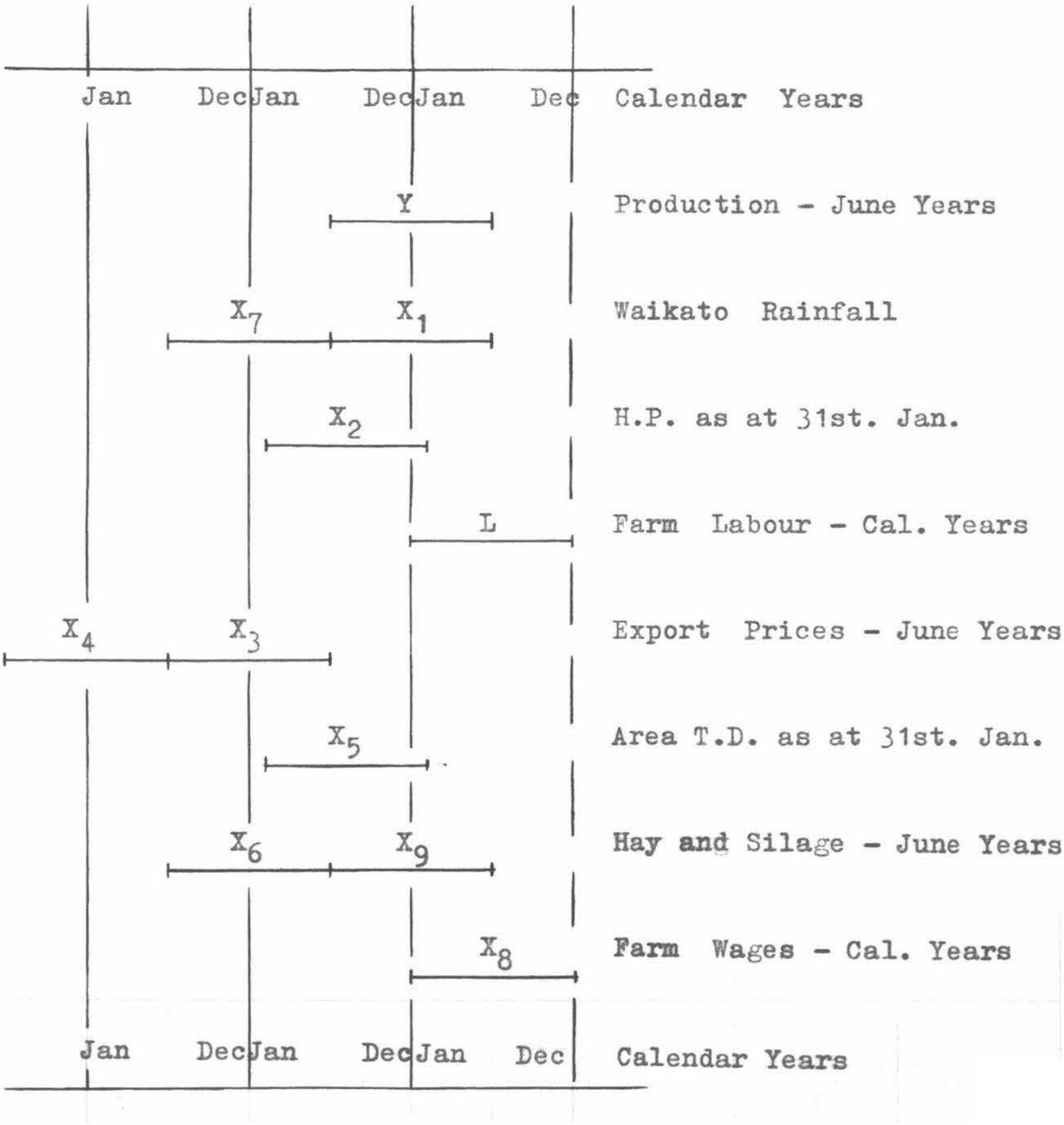
The only other factor giving a significant partial correlation was area cut for hay and silage in the previous season. Holding previous season's rainfall constant does not alter its significance ($r_{y6.7} = 0.4558$), nor is it altered when present season's rainfall is held constant ($r_{y6.1} = 0.4579$). But when area topdressed the previous January year, export prices two years previously and same season's rainfall are held constant, area cut for hay and silage the previous year was not quite significant ($r_{y6.145} = 0.4386$).

It will be recalled that present season's hay and silage, $X_9$, was included in the preliminary analysis as an index representing seasonal changes. That hay and silage cut does vary with the climatic conditions was demonstrated by the zero-order correlation coefficient obtained ($r_{19} = 0.6926$). With this relatively high coefficient it is not surprising that neither of the partial correlations are significant, ($r_{y1.9} = 0.3325$, $r_{y9.1} = 0.0110$) although rainfall is clearly the more important. Two coefficients were also computed to demonstrate that previous season's rainfall did not have a significant effect in the partials ($r_{y7.6} = -0.2073$, $r_{y7.16} = 0.0658$). The change in sign between these two coefficients indicates a negative relationship between successive values of Ruakura rainfall interacting with a significant positive relationship between hay and silage and rainfall in the same year. ($r_{17} = -0.4188$, $r_{67} = 0.5736$)

The effects of export prices two seasons previous to the production year were next examined. Since its simple correlation with production is negative ($r_{y4} = -0.2706$), the variables most likely to raise the partial correlation coefficient are those with high positive correlations with export prices, as well as with production. This is readily seen as each variable is added in the following discussion. Both variables found to be significantly associated with production so far have low correlation coefficients with export prices. ($r_{14} = 0.1168$, $r_{64} = -0.2024$). Thus the partial correlation of export prices on production with rainfall and hay and silage held constant is not much greater than the zero-order correlation coefficient between export prices and production. ($r_{y4.16} = -0.3087$ while $r_{y4} = -0.2706$). But when area top-dressed, which has a higher positive correlation with export prices ($r_{45} = 0.3060$) but not such a high correlation with production ($r_{y5} = 0.2858$) is held constant as well, the determination of export prices is considerably increased although not to a significant level. ($r_{y4.156} = -0.4092$). Without the negative effect of hay and silage, $X_6$, the determination is even higher ($r_{y4,15} = -0.4523$).

'Export Prices one season previous' to the production year has a very low coefficient on its own ($r_{y3} = -0.1097$). But this export price variable has a significant correlation with area top-dressed in the over-lapping January year ($r_{35} = 0.5252$). Thus the partial correlation coefficients show an increase in

GRAPH I PLACING OF VARIABLES IN TIME



determination where $X_5$ is included. ($r_{y3.5}$ = -0.3186, $r_{y3.15}$ = -0.2580, $r_{y3.56}$ = -0.2394). But when hay and silage and rainfall only are held constant, and top-dressing is absent, the coefficient drops even lower than the zero-order coefficient ($r_{y3.16}$ = -0.0383).

'Area top-dressed' shows the same pattern. Its zero-order coefficient is positive ($r_{y5}$ = 0.2852), but the negative correlation of export prices one season previous with production, and the significant positive correlation between area top-dressed and prices ($r_{y3}$ = -0.1097, $r_{35}$ = 0.5253) increase the determination of area top-dressed in the partials. ($r_{y5.3}$ = 0.4060). When hay and silage and/or rainfall are included the determination is not so high, as they have positive correlations with production, and low correlations with area top-dressed ($r_{y5.16}$ = 0.2475, $r_{y5.13}$ = 0.3104). When export prices two seasons previously are included the determination is increased again ($r_{y5.146}$ = 0.3690) owing to the positive correlation with top-dressing ($r_{45}$ = 0.3060) and negative correlation with production ($r_{y4}$ = -0.2706).

Derivation of Prediction Equations.

We have established, therefore, that there are only two variables, January - February rainfall at Ruakura, $X_1$, and Hay and Silage of previous year, $X_6$, which can be said to be significantly associated with changes in the volume of farm production. It is now possible to derive prediction equations from these two variables, which, in turn, allow the test for serial correlation in residuals to be carried out.

TABLE IX. PARTIAL CORRELATION COEFFICIENTS OF SELECTED FACTORS AFFECTING ANNUAL CHANGES IN THE VOLUME OF FARM PRODUCTION.

where $Y$ = Volume of Farm Production

$X_1$ = January, February rainfall, Ruakura.

$X_3$ = Export Prices one season previously.

$X_4$ = " " two " "

$X_5$ = Area Top-dressed preceding January year.

$X_6$ = Hay and Silage cut previous season.

$X_7$ = January, February rainfall previous season.

$X_9$ = Hay and Silage cut same season.

$n$ = 21

TABLE IX.

| SUM OF SQUARES PREDICTED BY: | DEGREES OF FREEDOM | PARTIAL CORRELATION COEFFICIENTS | RESULT |
|---|---|---|---|
| $X_6$, $X_7$ | 18 | $r_{y7.6} = -0.2073$ | N.S. |
| | | $r_{y6.7} = 0.4558$ | S. |
| $X_1$, $X_6$, $X_7$ | 17 | $r_{y1.67} = 0.4462$ | N.S. |
| | | $r_{y7.16} = 0.0658$ | N.S. |
| $X_1$, $X_9$ | 18 | $r_{y9.1} = 0.0110$ | N.S. |
| | | $r_{y1.9} = 0.3325$ | N.S. |
| $X_1$, $X_6$, $X_9$ | 17 | $r_{y9.16} = -0.1017$ | N.S. |
| $X_1$, $X_6$ | 18 | $r_{y6.1} = 0.4579$ | S. |
| | | $r_{y1.6} = 0.4827$ | S. |
| $X_1$, $X_4$ | 18 | $r_{y1.4} = 0.5009$ | S. |
| | | $r_{y4.1} = -0.3633$ | N.S. |
| $X_1$, $X_4$, $X_6$ | 17 | $r_{y4.16} = -0.3087$ | N.S. |
| $X_1$, $X_4$, $X_5$ | 17 | $r_{y4.15} = -0.4523$ | N.S. |
| $X_1$, $X_4$, $X_5$, $X_6$ | 16 | $r_{y1.456} = 0.4845$ | S. |
| | | $r_{y6.145} = 0.4386$ | N.S. |
| | | $r_{y5.146} = 0.3690$ | N.S. |
| | | $r_{y4.156} = -0.4092$ | N.S. |
| $X_1$, $X_5$, $X_6$ | 17 | $r_{y5.16} = 0.2475$ | N.S. |
| $X_1$, $X_3$, $X_5$ | 17 | $r_{y3.15} = -0.2580$ | N.S. |
| | | $r_{y5.13} = 0.3104$ | N.S. |
| $X_3$, $X_5$, $X_6$ | 17 | $r_{y3.56} = -0.2394$ | N.S. |
| $X_1$, $X_3$, $X_6$ | 17 | $r_{y3.16} = -0.0383$ | N.S. |
| $X_3$, $X_5$ | 18 | $r_{y3.5} = -0.3186$ | N.S. |
| | | $r_{y5.3} = 0.4060$ | N.S. |
| 5% Points of | 19 | $r = 0.433$ | |
| Significance | 18 | $r = 0.444$ | |
| (Snedecor, p.351) | 17 | $r = 0.456$ | |
| | 16 | $r = 0.468$ | |

Using January - February rainfall at Ruakura and previous season's hay and silage, the following equation was computed:

$$\hat{Y} = a + \underset{(0.1326)}{0.3055}\, X_1 + \underset{(0.0824)}{0.1789}\, X_6$$

where a is the constant term in the equation, and the figures in brackets the standard errors of the partial regression coefficients(2). The value of the multiple correlation coefficient, R, equals 0.6065, that is, the variables, $X_1$ and $X_6$ "explain" 36.78 per cent of the year to year variance in total farm production. The ratio of the variance "explained" to that "unexplained" gives an "F" ratio of 5.27 for 18 degrees of freedom when the 5% point = 3.55.

At this late stage, a re-examination of the Ruakura rainfall revealed a production effect which had hitherto not been taken into account. The total fall for March showed a considerable effect in some years. Accordingly, the rainfall index was altered to include this month. The new prediction equation took the form:

$$\hat{Y} = a + \underset{(0.1604)}{0.4996}\, X_1 + \underset{(0.0761)}{0.2212}\, X_6$$

The regression of these two factors on production now "explains" 46.62 per cent of the total variance of the dependent variable (R = 0.6828). The "F" ratio is increased to 7.9, which is significant at the one per cent level (1% point = 6.01).

Since the rainfall index refers to a mainly dairying district an index of butter-fat produced at the pail was introduced into the analysis in place of the total production variable. The regression model derived took the form:

$$\hat{Y} = a + \underset{(0.2211)}{0.8007}\, X_1 + \underset{(0.1049)}{0.3205}\, X_6$$

---

(2) A useful test of significance of the regression coefficients is that they must be at least twice their own standard error. ($t_{.05}$ = 2.11, d.f. = 17)

The value of R is now 0.7210, that is, this equation accounts for 51.98 per cent of the total variation in year to year changes in dairy production as measured at the pail. The use of dairy output has increased the homogeneity of production but dairying is still a large part of total production, and the factors which prevent the determination from being higher in dairy output also keep that of total output down.

Testing for Serial Correlation.

As outlined in Chapter IV, the presence of serial correlation in the regression equation can be tested by a comparison of the mean square successive differences and the variance from regression. Since we have used first difference analysis, we will be concerned with testing against the introduction of negative serial correlation in the residuals. The equation derived for this purpose was:

$$\hat{Y} = -16.867 + 0.4996 X_1 + 0.2212 X_6$$

The sum of squares of successive differences of residuals is 12568, while the sum of squares of deviations from regression is 5477. Thus the "d" statistic = $\frac{12568}{5477}$ = 2.2946. Since we are testing for negative serial correlation, we enter Durbin and Watson's 5% table with the statistic 4 - d, which equals 1.7054. Since $d_l$ = 1.13 and $d_u$ = 1.54 at the 5% limit of significance with twenty-one items, we can conclude that there is no evidence of significant negative serial correlation in the residuals. Evidently, the small amount of serial correlation in the residuals is of the low order which we would expect to happen by chance in a large proportion of cases when twenty-one items are taken from an infinite population in which the true correlation was zero. We can conclude, therefore, that the residuals may be regarded as a random series, and that the ordinary tests of significance of the contribution of each variable by its partial correlation coefficient may be used.

The distribution of the residuals is plotted in Graph II, diagram III. A discussion of these follows shortly. The calculation of residuals and Durbin and Watson's "d" statistic is set out in detail in Appendix C.

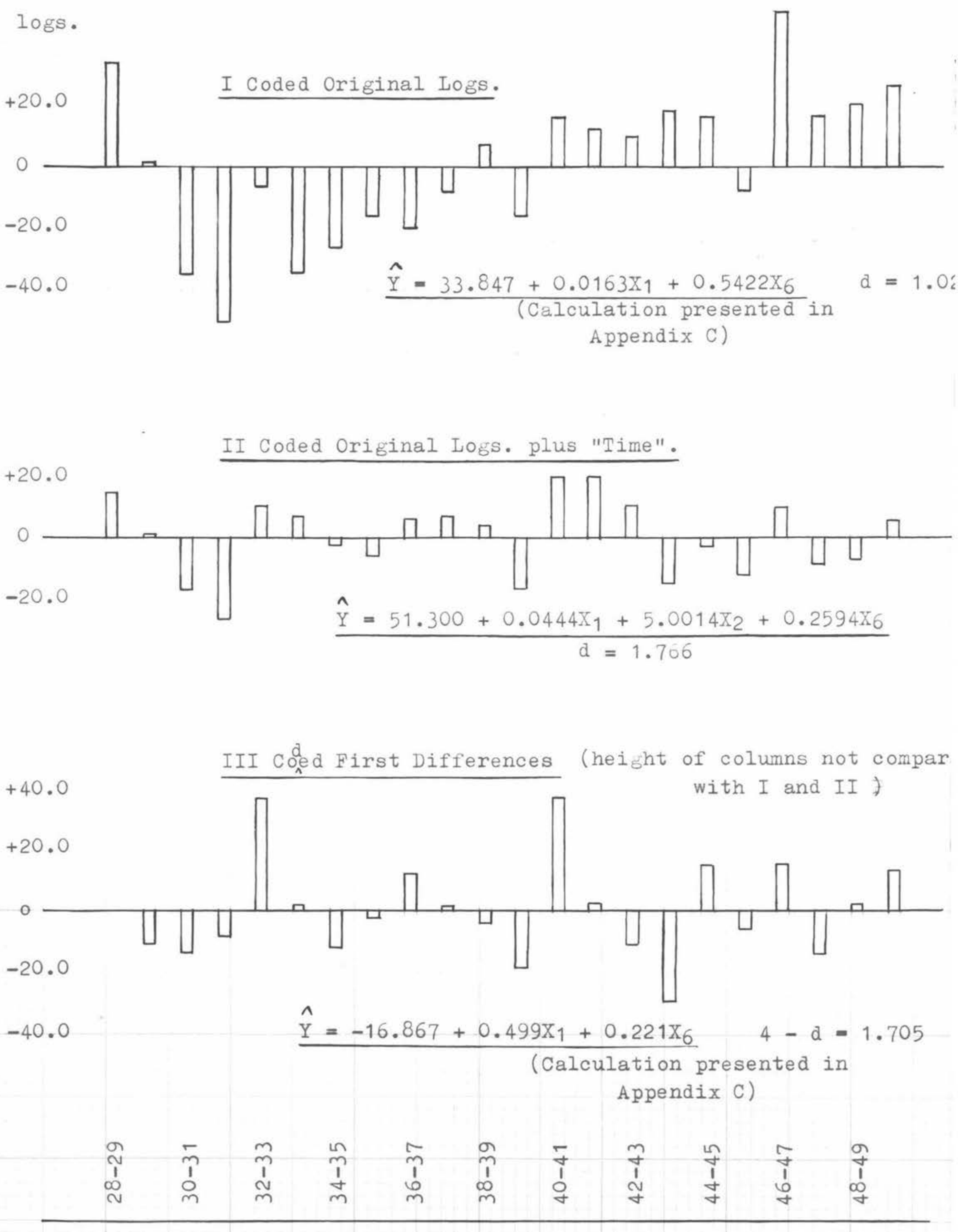
Now that the significant variables have been identified, it is instructive to compute the regression equation using Y, $X_1$ and $X_6$, not in the form of first differences, but in the original logs. with the subtraction of a constant from each series to make for ease of computation. The following equation was obtained:

$$\hat{Y} = 33.847 + 0.0163 X_1 + 0.5422 X_6$$

The value of the multiple correlation coefficient, R, is 0.8812, that is, 77.65 per cent of the year to year variations are accounted for by this model. The value of the "d" statistic is 1.020, that is, the result shows an amount of positive serial correlation which would only happen by chance in less than five per cent of cases of 21 items drawn from a population in which the true correlation was zero. Thus, the usual tests of significance based on residuals are vitiated in this case, and the total determination cannot be relied upon. The test for independence of residuals is not satisfied.

Many regression models have used the introduction of a variable representing time, as a means of overcoming the effect of related successive values of variables. This only holds true, of course, where there is a significant trend shown in the

GRAPH II DEVIATIONS FROM REGRESSION



period taken for analysis. The addition of a linear time variable to the previous equation actually eliminates 75.18 per cent of the remaining variance ($r_{y2.16} = 0.8670$). The prediction equation now becomes:

$$\hat{Y} = 51.300 + 0.0444 X_1 + 0.2594 X_6 + 5.0014 X_2,$$

where $X_2$ is the variable representing time. The value of $R^2$ is 0.9445! The value of the "d" statistic is 1.766. In this case, therefore, the use of time in the original data has satisfied the test of independence on the residuals, but only at the expense of an over-estimation of determination.

The distribution of the residuals in these two models derived from the coded original logarithms are shown in Graph II. The relation between successive values is clearly of a high order in the first diagram. The second shows the effect on the distribution of residuals when "time" as a variable is introduced in this particular period. The height of columns is comparable between these two diagrams, and shows the reduction in the variance of regression when "time" is included. The third diagram is not comparable in height owing to the difference in the units used, but it does show that the variance of regression is fairly high and that in some years there is a marked divergence between the estimate and the actual figures for production.

In the equation derived from the coded original logarithms, and without time as a variable, it was shown that the usual tests of significance are vitiated. The question which must now be asked is, does the introduction of "time", satisfying as it does the "d" test for independence of residuals, make the use of the tests of significance valid? The answer depends on the interpretation of the assumptions of independence. If successive values of a major independent variable are correlated in a significant manner, the number of independent items may be seriously reduced. In this case, the tests of significance are practically useless, because of the doubt thrown on the number of degrees of freedom. For example, the correlation between successive items of $X_6$ in the original logarithms is 0.7856, although that between successive values of $X_1$ is only -0.0549. It is therefore impossible to maintain that we really have 21 independent items in the original logarithmic series of $X_6$, and there is, of course, even less independence in the items of the series representing time.

The Elasticity of Supply of Aggregate Agricultural Output.

It was pointed out in Chapter IV that the use of logarithmic transformation of variables enables their elasticity to be measured directly. Thus, the regression coefficients of export prices, $X_3$ and $X_4$ , give us the elasticity of supply, that is, the change in output following a given change in price. Table X presents the relevant information on price elasticity computed in the regression analysis. The first part of the table shows the aggregate response to changes in actual prices, while the second part shows the response to changes in real prices. Details of the deflation of the Export Price Series are given in Appendix A.

TABLE X 1. ELASTICITIES OF PRICE VARIABLES IN REGRESSION OF VARIOUS FACTORS ON NEW ZEALAND FARM PRODUCTION.

where Y = New Zealand Volume of Farm Production.

$X_1$ = January, February, March Ruakura Rainfall.

$X_3$ = Export Prices with one year lead.

$X_4$ = " " " two " "

$X_{4'}$ = " " " three " "

$X_5$ = Area Top-dressed.

$X_6$ = Area cut Hay and Silage with one year lead.

| PARTIAL REGRESSION COEFFICIENT | $X_3$ | $X_4$ | STANDARD ERROR | PROBABILITY OF "t" |
|---|---|---|---|---|
| $b_{y3}$ | -0.0449 | | 0.0931 | $>0.5$ |
| $b_{y4}$ | | -0.1105 | 0.0906 | 0.3 - 0.2 |
| $b_{y3.1}$ | -0.0357 | | 0.0860 | $>0.5$ |
| $b_{y3.5}$ | -0.1468 | | 0.1030 | 0.2 - 0.1 |
| $b_{y3.15}$ | -0.1114 | | 0.1012 | 0.3 - 0.2 |
| $b_{y4.1}$ | | -0.1342 | 0.0812 | 0.2 - 0.1 |
| $b_{y4.15}$ | | -0.1699 | 0.0818 | 0.1 - 0.05 |
| $b_{y4.56}$ | | -0.1296 | 0.0857 | 0.2 - 0.1 |
| $b_{y4'}$ | | -0.0822 | 0.0957 | 0.5 - 0.4 |

TABLE X 2.

where $X_3$ = deflated Export Prices one year ahead.
$X_4$ = " " " two years "
$X_{4'}$ = " " " three " "
$X_{4''}$ = " " " four " "

| PARTIAL REGRESSION COEFFICIENT | $X_3$ | $X_4$ | STANDARD ERROR | PROBABILITY OF "t" |
|---|---|---|---|---|
| $b_{y3}$ | +0.0205 | | 0.1016 | $>0.5$ |
| $b_{y4}$ | | -0.1408 | 0.0958 | 0.2 - 0.1 |
| $b_{y4'}$ | | -0.1341 | 0.0959 | 0.2 - 0.1 |
| $b_{y4''}$ | | 0.0464 | 0.0984 | $>0.5$ |
| $b_{y4.5}$ | | -0.1839 | 0.0932 | 0.1 - 0.05 |
| $b_{y3.16}$ | 0.0998 | | 0.0783 | 0.3 - 0.2 |
| $b_{y4.16}$ | | -0.1251 | 0.0721 | 0.2 - 0.1 |
| $b_{y4'.16}$ | | 0.0511 | 0.0806 | $>0.5$ |

It is difficult to say whether farmers are more influenced by nominal or by real prices. As far as farmers are "cost conscious" it is real prices that are important. But year-to-year improvements (say) in nominal prices may create a favourable impression in the mind of the farmer, so that he fails to allow for the real effect of rising costs. Allowance must also be made for the feeling of security which accompanies higher prices, whatever the ratio of costs to prices. The actual response of farmers, if any, must be somewhere between these two extremes. Accordingly, price elasticities are presented taking both cases into account.

In the case of nominal Export Prices, the use of partial analysis raises the significance of the regression coefficients, although not to the five per cent level. When rainfall and area top-dressed are held constant, nominal export prices one season before gives a regression coefficient which could occur by chance in about twenty-five per cent of cases if the twenty-one items came from a population in which true correlation was zero. Export prices of two seasons before, have a lower probability with the same two factors held constant, but still does not quite reach significance ($P = 0.07$). Other combinations of variables are presented to show the wide range of the regression coefficients.

The analysis of real export prices shows a generally higher relationship between price and production for different lead values of prices than nominal export prices, but still does not expose a relationship significant of the five per cent level. The partial regression coefficient which might be expected to have the highest value after an inspection of the inter-relationships between variables, was calculated from this data to explore the limits of partial regression analysis. It shows, that when area top-dressed ($X_5$) is held constant, real export prices two seasons before have a relationship with production which could occur by chance in about eight per cent of cases where the items come from a population in which the true correlation was zero. However, we are finally concerned with the values which partial coefficients of Y on export prices ($X_4$) may have when the influences of the two established variables $X_1$ and $X_6$ are eliminated. Using the "monetary" form of $X_4$ we have $b_{y4.16}$ is $-0.1036$ with $P = 0.2$; when the "real" price measure, deflating export prices by an index of farm costs, is used $b_{y4.16}$ becomes $-0.1251$ with $P = 0.11$.

It is difficult to place the correct emphasis on probabilities of this nature. J. Tinbergen has said, "It should be kept in mind, however, that even then the most likely values of the regression coefficients are those found by the calculations. An explanation based upon such calculations still has the advantage of not being contradictory to observations, which is more than can be said of quite a number of theories." (4). The high standard errors obtained, however, indicate that whatever the population elasticity, it is not to be known with significant accuracy from this data, except in a negative sense, that the data are consistent with the theoretical expectations that the short-term supply curve may be vertical or even backward sloping. However, it is worth noting that the partial $b_{y4}$ in combination with various other variables remains of the same order of magnitude and remains consistently negative. This rather strengthens the presumption that we are dealing with a systematic and real influence from $X_4$, although the amount of that influence is not strong enough to establish statistical significance in such a short series.

The results show, however, that the elasticity of supply of aggregate output to aggregate export prices over a time period of one and two years respectively is highly inelastic. The values of the coefficients do not enable us to say whether the one or two-year supply function is the more inelastic. It does appear, however, that the coefficients of two-year elasticity are the more reliable.

The availability of dairy prices and butterfat output make it possible to break down the aggregate into one of its components. Table XI shows the elasticity of supply of dairy output calculated with nominal dairy export prices.

(4) J. Tinbergen, "Econometrics." 1951, p.206.

TABLE XI. ELASTICITIES OF PRICE VARIABLES IN REGRESSION OF VARIOUS FACTORS ON NEW ZEALAND DAIRY OUTPUT.

where $Y$ = Butterfat at pail.

$X_1$ = January, February, March Ruakura Rainfall.

$X_3$ = Dairy Export Prices with one year lead.

$X_4$ = " " " " two " "

$X_5$ = Area top-dressed.

$X_6$ = Area hay and silage with one year lead.

| REGRESSION COEFFICIENT | $X_3$ | $X_4$ | STANDARD ERROR OF REGRESSION COEFFICIENT | PROBABILITY OF "t" |
|---|---|---|---|---|
| $b_{y3}$ | -0.1995 | | $s_{by3}$ = 0.1487 | 0.2 - 0.1 |
| $b_{y4}$ | | -0.0945 | $s_{by4}$ = 0.1543 | >0.5 |
| $b_{y3.1456}$ | -0.1639 | | | |
| $b_{y4.1356}$ | | -0.0155 | | |

In this case, it is possible to say that the supply function of dairy output is inelastic over a period of one and two years respectively. Then, with the reservations already made above, the hypothesis can be put forward for further testing that the response period in dairy-farming is more clearly of one year than two, and that the supply schedule of dairy products has a tendency to be backward sloping in the one year period. The actual conditions which appear to allow this "income" effect to express itself in the dairy farming sector as compared with other farm sectors are discussed in Chapter VII.

# PART III

## EMPIRICAL TESTING OF THEORY.

### VII. A REVIEW OF CHANGES IN OUTPUT IN NEW ZEALAND 1920 - 1951.

"I am inclined to suspect that these conclusions may be no further from the truth than those derived from regression analysis, which is itself beset with many dangerous pitfalls, and which tends to conceal the essentially provisional nature of all possible results behind the imposing but sometimes deceptive facade of a complicated mathematical technique. The two methods should, however, be regarded as complementary rather than competitive." (1)

This chapter is devoted to a year-to-year description of changes in aggregate output. The explanation runs in terms of the items which make up the aggregates. The lack of figures before 1928-29 for the volume of farm production limited the regression analysis to the period 1928-50. This does not limit the testing of the theory in earlier periods. In particular, the data for the 1920-22 depression in farm prices is available. We have postulated that output tends to be maintained or increased in periods of low prices owing to the continued use of land and equipment already in the farmer's possession and the lack of alternative employment for workers at the margin. We must thus ask if the theoretical relationships can be seen in the data, or if other influences can be isolated which prevent these relationships from showing. From 1928-29 we have the results of the regression analysis as well, on which to base explanations of changes in output.

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(1) T. Wilson, "Fluctuations in Income & Employment." 1947, p.90.

The whole period, in which evidence for the theory being advanced is sought, falls naturally into the following sub-periods:

| | |
|---|---|
| 1920 - 22 | The Post-War Depression |
| 1930 - 33 | The Great Depression |
| 1934 - 39 | The Fixed Market |
| 1939 - 45 | The Wartime Effort |
| 1945 - 51 | The Post-War Expansion. |

I. The Post-War Depression, 1920-22.

The relevant data to this section is presented in Table XIII. Wool prices began to decline early in 1920, and by the end of the 1920-21 season had declined fifty-five per cent from their immediate post-war level. Then in the 1921-22 season dairy prices dropped by thirty-two per cent and meat prices by fourteen per cent, resulting in a decline of the aggregate export price index of twenty-four per cent. Farm output, on the other hand, increased by eleven per cent over the same season, according to Fawcett and Patton's figures. The physical increase can be explained by the increase in hay and silage saved the season before and a rapid expansion of cows in the dairy industry, and by a decline in total sheep as at April 30. The reduction of over two million sheep between April 30, 1919, and April 30, 1920, reflects the reaction farmers made to falling wool prices. It is worthy of note that wethers slaughtered on farms for home use increased temporarily (See Chapter II).

The depression was too short-lived to pull the sticky cost items of the index of farm expenditure or rural wages down very far. Both show a decline in 1921-22, an indication that such inputs tended to fall in price, even in the short run. The increase in wethers slaughtered in 1921-22 supports the view that farmers spent less on living expenses thus reducing direct costs. Apart from this tendency for costs to fall with prices, other relationships are almost completely disguised under the general process of land development. The labour force was expanding quite rapidly under the soldier settlement scheme, while the stage of most of the development involved so much hard work that there must have been little scope for any further expansion of output from this direction. Consistent with the theoretical postulate that the farmers demand for labour is quite inelastic, is the somewhat scattered evidence of extra cows milked on sheep farms, poultry keeping by farmer's wives and increased sales of small fruits. Such sidelines absorb a tremendous amount of extra effort expended, without affecting output figures to any marked extent.

Over the twenties as a whole farm output expanded rapidly. The farm labour force apparently increased by about four per cent, cows in milk by sixty-five per cent, total number of sheep by twenty per cent. Butterfat production per cow increased from the region of 150 lbs. per cow to 210 lbs. per cow (2). The period was characterised by the liberal post-war land settlement policy of the government and the subsequent speculation in land which took place. Although Revaluation Boards were set up in 1923, the burden of fixed debt for many farmers remained high. Meat and wool prices, with minor fluctuations, maintained their wartime levels, but dairy prices did not recover to the same extent after the 1921-22 depression. This period of development appears to have been stimulated by the long period of rising prices from 1900 in spite of the 1921-22 lapse, and by optimistic faith in the security of the main overseas market.

(2) 9th Annual Report, N.Z. Dairy Board, p. 19.

TABLE XIII. CHANGES IN PRODUCTION 1917 - 1923.

(Source: See Appendix A.)

| YEAR | OUTPUT LIVESTOCK UNITS. | EXPORT PRICES INDEX 1909-13 = 1000 | HAY AND SILAGE THOUSAND ACRES. | COWS IN MILK JAN.31 (th.) | SHEEP APRIL 30. (m.) |
|---|---|---|---|---|---|
| 1917-18 | 2604 | 1798 | 111.2 | 710.6 | 26.538 |
| 1918-19 | 2874 | 1851 | 131.6 | 732.3 | 25.828 |
| 1919-20 | 3027 | 1823 | 117.1 | 782.7 | 23.914 |
| 1920-21 | 3038 | 1687 | 161.8 | 890.2 | 23.285 |
| 1921-22 | 3475 | 1270 | 187.4 | 1015.3 | 22.222 |
| 1922-23 | 3362 | 1554 | 175.5 | 1124.6 | 23.081 |

| YEAR | WETHERS SLAUGHTERED ON FARMS (th.) JAN 31 | FARM WAGES INDEX 1926-30 = 1000 | ALL GROUPS WAGES INDEX 1926-30 = 1000 | FARM EXPEND. INDEX. 1914 = 1000 |
|---|---|---|---|---|
| 1917-18 | 345.8 | 1382 | 1264 | 1460 |
| 1918-19 | 350.6 | 1468 | 1360 | 1510 |
| 1919-20 | 385.8 | 1518 | 1470 | 1660 |
| 1920-21 | 423.3 | 1526 | 1677 | 1606 |
| 1921-22 | 473.5 | 1499 | 1716 | 1543 |
| 1922-23 | 423.3 | 1528 | 1637 | 1593 |

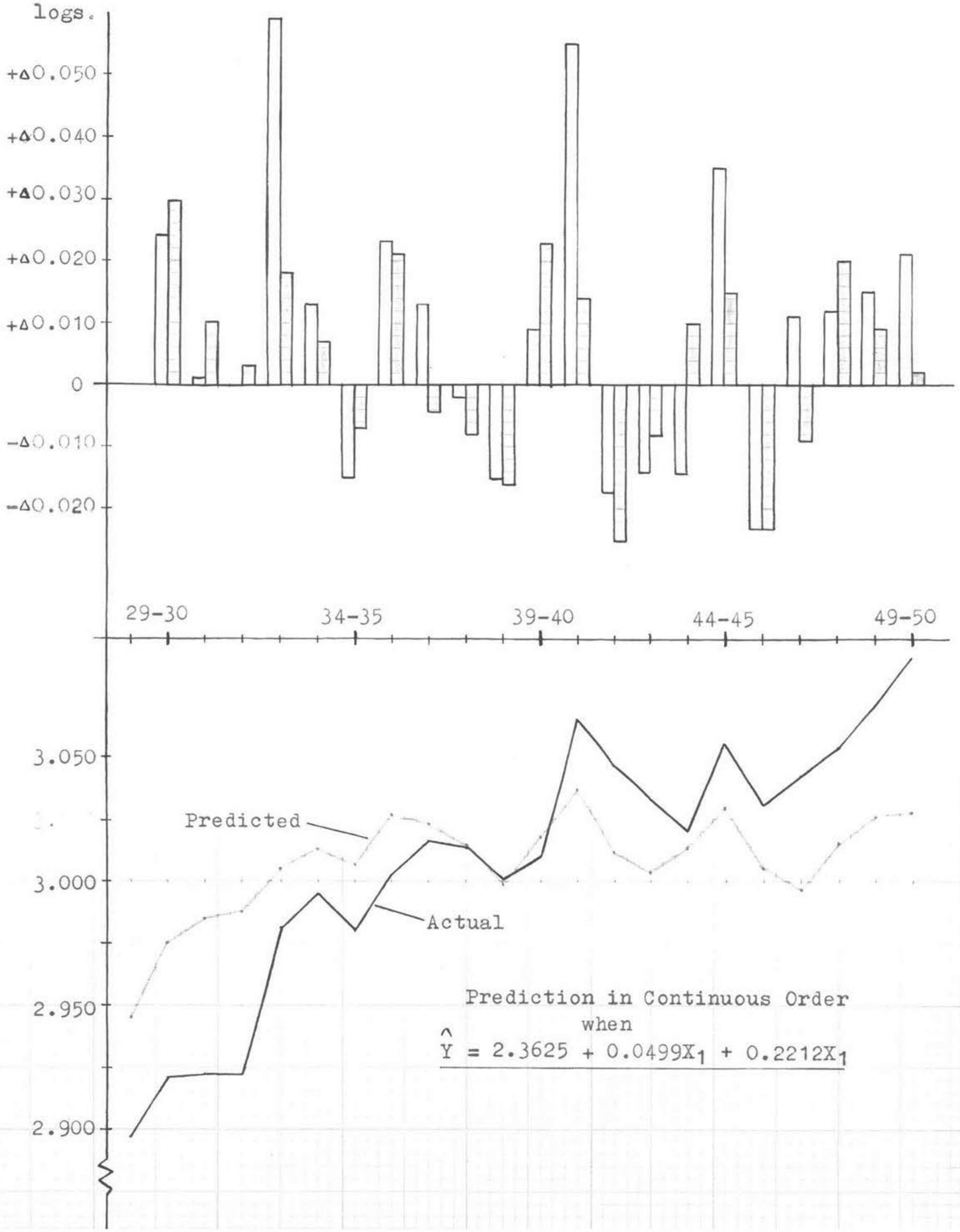
## II. The Great Depression 1930 - 1933.

Overseas prices for agricultural produce started to decline in the 1929-30 season. In the next three seasons they fell by over forty per cent while farm output increased by twenty per cent. What were the forces at work?

The changes predicted in the regression analysis of rainfall and hay and silage on production are shown in Graph III. The first part of the graph is a comparison of the actual changes which took place from year-to-year with those estimated from the regression equation. Each yearly value of the estimate is independent of every other value. The second half of the graph presents the trend-free estimate of production computed from the original logarithms. The trend is removed by the application of b coefficients, computed from first differences, to the original logarithm values of the variables. The removal is not complete, as the hay and silage series is used in the computation without any of its trend removed. To put trend back into the prediction data, it is necessary to add a constant amount throughout equivalent to the difference between the average trend of hay and silage and the average trend of actual changes in production.

For the seasons 1929-30, 1930-31 and 1931-32 a continuous increase in production was predicted somewhat in excess of that which actually took place. This is explained by the rainfall variable, in particular, failing to record the drought conditions of 1930-31 and 1931-32. Then when seasonal changes became highly favourable to production in 1932-33, the rainfall index was inadequate to measure the change which took place.

GRAPH III CHANGES IN OUTPUT-ACTUAL(OPEN COLUMNS) AND PREDICTED(COLOURED COLUMNS)



These inaccuracies are inherent in a variable of this nature, where not only the total rainfall is important over the summer months but also its spread. After all, there would not be a great deal of benefit, if the total rainfall for the three summer months, fell in a period of a few days.

How did the components of the aggregate change in these seasons? The 1928-29 season had been a record dairy year showing an increase of ten per cent on a butterfat basis over the previous year. Another eight per cent increase was recorded the next season, but the following two only recorded increases of 2.5 and 5.3 per cent respectively (3). Lambs slaughtered increased markedly in the 1930-31 season from 6.6 million (in 1929-30) to 8.2 million and increased further to 8.8 million the following season (1931-32). Sheep slaughtered, other than lambs, increased steadily from 3.5 million in 1928-29 to 5.2 million in 1931-32, though the total number of sheep and breeding ewes showed a decline over this period (Table XIV). Although both butterfat production and fat lamb production increased a little between 1930-31 and 1931-32, the change appears to have been lost in the compilation of the aggregate.

In the 1932-33 season, however, butterfat increased by seventeen per cent, while lambs slaughtered increased to 9.8 million, an increase of eleven per cent; the greater volume of butterfat is no doubt explained by the rapid increase of milking cows which had been taking place, an increase from 1.56 million to 1.70 million cows being recorded from 1931-32 to 1932-33. This expansion may well have taken place on farms other than predominantly dairying.

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(3) N.Z. Dairy Board Annual Reports, 1929-35.

TABLE XIV. CHANGES IN PRODUCTION 1928 - 36.

| YEAR | VOLUME FARM PRODUCTION (1938-39 = 100) | EXPORT PRICES (1909-13 = 1000) | FARM LABOUR (th.) | COWS (th.) | SHEEP (m.) |
|---|---|---|---|---|---|
| 1928-29 | 79 | 1492 | 112 | 1291 | 29.051 |
| 1929-30 | 83 | 1168 | 119 | 1389 | 30.841 |
| 1930-31 | 84 | 881 | 128 | 1478 | 29.792 |
| 1931-32 | 84 | 795 | 135 | 1562 | 28.691 |
| 1932-33 | 96 | 792 | 138 | 1703 | 27.755 |
| 1933-34 | 99 | 995 | 141 | 1795 | 28.649 |
| 1934-35 | 96 | 979 | 143 | 1807 | 29.076 |
| 1935-36 | 101 | 1121 | 144 | 1802 | 30.113 |

| YEAR | SHEEP SLAUGHTERED (m.) | LAMBS SLAUGHTERED (m.) | BUTTERFAT (m. lbs.) | TOP DRESSED ACRES (m.) | HAY & SILAGE ACRES (th.) |
|---|---|---|---|---|---|
| 1928-29 | 3.507 | 6.197 | 289 | 2.385 | 351 |
| 1929-30 | 3.992 | 6.651 | 314 | 2.651 | 413 |
| 1930-31 | 4.263 | 8.197 | 322 | 2.497 | 442 |
| 1931-32 | 5.233 | 8.827 | 339 | 2.125 | 465 |
| 1932-33 | 4.356 | 9.853 | 397 | 2.438 | 562 |
| 1933-34 | 3.556 | 8.825 | 426 | 2.249 | 506 |
| 1934-35 | 3.942 | 9.765 | 409 | 2.684 | 524 |
| 1935-36 | 3.260 | 8.755 | 425 | 2.882 | 577 |

Sources quoted in Appendix A.

It has already been noted (Chapter II) that fertilizer applied increased markedly in the 1932-33 season owing to a fall in its price. It should also be noted that in this season the government granted a fertilizer subsidy of eleven shillings per ton in recognition of the reduced cash position of dairy farmers. A further decline in overseas prices of dairy products in the 1933-34 season is associated with a reduction in the area top-dressed in spite of the subsidy which had been renewed for another year (4).

The increase in dairy production over the depression period, after making allowances for seasonal conditions is associated with more cows in milk, a greater labour force, and a greater area cut for hay and silage in the previous season. Due allowance must also be made for the fact that low prices interrupted a period of rapid expansion in the dairy industry. The increase in hay and silage indicates an attempt on the part of farmers to get the greatest output from a limited supply of cash resources. At that stage in its development dairy output appears to have been particularly responsive to such inputs as could be supplied by the efforts of the farmer. The increase in sheep and lambs slaughtered, on the other hand, is explainable almost purely by seasonal effects or by the depletion of adult capital stock. In general, sheep output appears unresponsive to varying farm produced inputs.

Although the indices of rural weekly wages, land prices and farm expenditure (less interest and rent) did not fall to the same extent as export prices (Table II), we showed in

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(4) 8th Annual Report, N.Z. Dairy Board, p.4, 1933.
9th " " " " " p.4, 1934.

Chapter III that dairy farm wages did fall at a greater rate than the price of butterfat at the depth of the depression. We can thus conclude that both the rewards accepted by farmers for their own labour and capital and the wages paid to hired labour were the principal cost factors which fell sufficiently to allow production to be maintained if not increased. The physical increase which did occur was principally an effect of the cumulative development of the previous decade aided by an increased labour force, and secondarily explained by the pressure towards an increase in efficiency which resulted from the reduced economic position of the farming community.

III. The Fixed Market, 1934-1939.

In the later thirties the difficulties arising out of the Ottawa Conference began to have their effect and farm output ceased to expand. Prices had not recovered their pre-depression levels; while the threat of meat quotas and dairy tariffs from the United Kingdom did not recede. The number of cows milked reached its peak in 1934-35 and then declined almost continuously right through to 1946. The record killing of lambs in 1932-33 was not approached again until the 1937-38 season. This latter record killing of lambs was not offset by smaller killings of adult sheep, which suggests that marginal farmers in dairying were beginning to change over to fat lamb production.

The prediction of output over these years was not greatly inaccurate. In one season, 1936-37, the sharp drop in summer rainfall from the previous year, although still adequate, predicted a decline in output when an increase actually took place. Both the 1934-35 and 1938-39 seasons experienced poor climatic conditions, although both lower outputs were predicted by lower hay and silage cut in the previous season. The drop in hay and silage in 1933-34 was from the very high level of 1932-33, but does possibly suggest a psychological reaction to the rock-bottom prices received for dairy produce in the previous season. The actual drop in 1934-35 may also reflect to some extent the reduced areas top-dressed during the worst of the depression. Again, in 1937-38, the changing labour situation plus a realisation of the growing futility of expanding production may have depressed the area of hay and silage cut (5). From the the second part of Graph III it can be seen that the rate of expansion of the early thirties did not continue into the late thirties. The wide availability of labour, and the increase in effort put forward in the early thirties, probably absorbed all the easily achieved gains or "excess capacity", so that when the economic pressure was relieved, output tended to become stabilised.

IV. The Wartime Effort 1939 - 1945.

The outbreak of war in 1939 rapidly changed the whole situation. The United Kingdom offered to take the maximum of food that could be produced. The 1939-40 season had already started when war was declared, thus little response to the demand for increased output is noticeable in the data. Weather conditions, however, were favourable in the dairying areas, so that in spite of a further fall in the number of cows milked, butterfat production rose 7.5 per cent. A higher killing of lambs was accompanied by a fall in sheep numbers, again indicating that such a short-term increase from the sheep industry can only come about through a depletion of stock. More important were the preparations farmers made for the following season.

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(5) 13th and 14th Annual Reports, N.Z. Dairy Board, 1938,1939.

Cows in milk showed a temporary increase, high stocks of hay and silage were held over, while area top-dressed reached an all-time record of 4.6 million acres, twice the area covered in the pre-depression years. The climatic conditions then turned out to be most favourable and another 8.1 per cent increase in butterfat production was recorded, in spite of the growing labour shortage. As in 1932-33, the rainfall variable again failed to predict this great seasonal boost to production. In this case, part of the loss of effect is explained by a high summer rainfall the previous season which thus over-predicted production in that year (1939-40) while subtracting from that for the season following. The good conditions also resulted in a new record killing of lambs, reaching for the first time, twelve million. (1928-29, 6.2 million.)

Without accurate figures of the movement of labour out of farming for the 1940-41 season in particular, it is difficult to know just how much of the increase in output can be attributed to an increased effort by the remaining labour complement. The 1941 Dairy Board Report does refer to the outstanding effort made by the farming community. These circumstances thus differ from those of 1932-33 in that there was no increase in the actual numbers of workers accompanying the marked increase in output. The increase must be explained purely in terms of seasonal effects or in terms of effort. I think the seasonal change is the more important, as in both cases production had been depressed a year or two before by drought conditions. In this period productive effort builds up and is only fully expressed when climatic conditions are favourable. In the case of the 1940-41 season, our rainfall and hay and silage data underestimated completely this effect of good weather conditions on planned output. The greatest increase in effort, as measured by hay and silage cut, seems to have come a year previous to that which actual output figures would indicate.

Such a high level of production could not last. Dairy production declined the following season by 9.4 per cent and then by 8.3 per cent the following season (1942-43). Lambs and sheep slaughtered also fell off from this peak year until 1944-45 (See Table XV). The decline in these two years was fairly accurately predicted by rainfall and hay and silage. From 15.9 inches in 1940-41, rain dropped to 5.89 inches in 1941-42 and 4.79 inches in 1942-43. As well as hay and silage, area top-dressed also declined, mainly owing to the lack of labour, although fertilizer supplies were held up. In the following year (1943-44) a quick upward movement to 13.15" of rain predicted an increase in output when an actual decrease took place. The fall was predicted by hay and silage in 1942-43, which then reached its lowest level since 1937-38, although its effect was drowned in the regression by the big change in rainfall. In this season, production reached its lowest war-time level, mainly owing to the decreased labour force, the shortage of supplies and reduced inputs.

The release of 8,200 workers up to March 1943, after the Japanese drive in the Pacific had been stopped, appears to have had little effect in preventing the decline in production in that season. In March 1944, however, another 4,115 men were released from home-defence forces to work specifically on farms, while schemes for a Women's Land Service, holiday employment for students and teachers, and an Army and Air Force Harvesting Scheme

TABLE XV. CHANGES IN PRODUCTION 1939 - 1946.

| YEAR | COWS (m) | TOP-DRESSED ACRES (m.) | HAY AND SILAGE ACRES (th.) | LAMBS SLAUGH-TERED (m.) | SHEEP SLAUGH-TERED(m.) |
|---|---|---|---|---|---|
| 1939-40 | 1.719 | 4.187 | 594.2 | 10.160 | 4.439 |
| 1940-41 | 1.759 | 4.649 | 575.1 | 12.037 | 5.151 |
| 1941-42 | 1.756 | 4.212 | 555.3 | 11.700 | 4.633 |
| 1942-43 | 1.714 | 3.470 | 488.9 | 11.251 | 4.310 |
| 1943-44 | 1.647 | 3.370 | 573.6 | 10.607 | 1.552 |
| 1944-45 | 1.678 | 3.646 | 601.1 | 10.780 | 4.717 |
| 1945-46 | 1.661 | 3.653 | 483.4 | 12.742 | 5.440 |

Sources quoted in Appendix A.

were inaugurated; and 4,286 men of the 9,000 released from the Third Division in the Pacific were working on farms by November 1944 (6).

The hay and silage figure for 1943-44 was thus much improved and an increase of eleven per cent took place in dairy production the following season, when climatic conditions were also favourable. Again, the rainfall data from Ruakura failed to measure effectively the increase in production which took place. In the following season, (1945-46) drought conditions prevailed, and in spite of an increase in the area of hay and silage saved the previous good season, the rainfall index accurately predicted the fall which took place (Graph III). The loss in production amounted to 16.9 per cent in the Auckland province compared with the average of the previous four seasons (none of which had been

(6) Report of National Service Dept. 1946, p.36.

particularly high) (7). Total butterfat declined by 13.8 per cent from the figure of the previous season.

Apart from the records quoted above, there is little information on the rate of return of servicemen and others to the land toward the end of the war (Appendix B). If the rate of return was as low as we suspect, it is necessary to search for other factors which can explain the increase in output which resulted after the war.

## V. The Post-War Expansion.

The post-war period has seen a remarkable new era of farm expansion. The security provided by the long-term produce agreements with the United Kingdom and increased payouts to primary producers (although not necessarily at world parity) have resulted in a new confidence in overseas markets. There is every indication that a continued expansion is possible for some years, depending on weather conditions.

In spite of a sharp drop in hay and silage saved in the dry season of 1945-46, actual production increased in 1946-47. With only a small increase in rainfall the prediction equation had forecast a fall in output. With varying degrees of accuracy, the equation predicted the increases in production which actually did take place in the following three seasons (1947-50). The high rainfall figure for 1948-49 somewhat obscured the effect of a moderate summer rainfall in 1949-50.

The expansion in dairy output looks to be the most prominent. Cows in milk, hay and silage, and area top-dressed have all risen considerably since 1945-46. If the rural labour force has remained at about the same level, as I think it has, the

(7) 22nd Annual Report, N.Z. Dairy Board, p.9, 1946.

increased output can only result from greatly increased efficiency. That the technological situation is altering rapidly is emphasised by the doubling of horse-power installed on farms between 1945-46 and 1950-51. Milking machines have only increased from 31,805 to 37,176 over the period,so it is evident that not only has mechanisation greatly increased but that techniques (particularly those of milking) have also changed rapidly.

Sheep and crop production do not appear to be on so rapid an increase. The substitution of capital for labour in these farming areas will probably only compensate for the loss of labour without encouraging any marked increase in output. Sheep and lambs slaughtered over this latter period appear quite stable, although the interpretation of sheep statistics has become more difficult with the high prices of wool working out its effects. At the time of writing the provisional figure for 1950-51 total sheep in the Dominion as at May 1 is 34,786,000 which is a marked increased from the 32,483,000 of the 1947-48 season. This data bears a close similarity to the same data for 1917-19.

It is also apparent that farm wages have risen much more rapidly than non-farm wages (Table IV). If wages for equivalent occupations are almost equal, as the trend of the index numbers would indicate, then an examination of recent movements in the farm labour force is required to determine where the net advantages of labour are located. What evidence that is

TABLE XVI. CHANGES IN PRODUCTION 1945-1951.

Sources quoted in Appendix A.

| YEAR | VOLUME OF FARM PRODUCTION INDEX 1938-39 = 100 | EXPORT PRICES INDEX 1909-13 = 100 | COWS IN MILK (m.) | AREA HAY & SILAGE SAVED (th.acres) | AREA TOP-DRESSED SUPER OR LIME (m. acres) |
|---|---|---|---|---|---|
| 1945-46 | 107 | 204 | 1.661 | 483 | 3.653 |
| 1946-47 | 110 | 255 | 1.657 | 583 | 4.260 |
| 1947-48 | 113 | 282 | 1.713 | 606 | 4.684 |
| 1948-49 | 117 | 274 | 1.746 | 648 | 5.062 |
| 1949-50 | 123 | 389 | 1.845 | 630 | 5.738 |
| 1950-51 | 126 | 467 | 1.898 | 729 | 6.326 |
| 1951-52 | | | 1.901 | 821 | 6.462 |

| YEAR | HORSE-POWER ON FARMS (th.) | SHEEP SLAUGHTERED (m.) | LAMBS SLAUGHTERED (m.) | TOTAL SHEEP (m.) |
|---|---|---|---|---|
| 1945-46 | 538.0 | 5.440 | 12.742 | - |
| 1946-47 | 599.3 | 5.177 | 11.826 | 32.681 |
| 1947-48 | 666.1 | 4.925 | 12.798 | 32.483 |
| 1948-49 | 780.2 | 4.794 | 12.445 | 32.844 |
| 1949-50 | 1000.0 | 4.434 | 12.588 | 33.856 |
| 1950-51 | 1134.1 | 3.704 | 11.605 | *34.786 |
| 1951-52 | 1295.2 | 5.215 | 12.436 | *35.290 |

* as at 30th June formerly 30th April.

available seems to indicate that the farm labour force has been fairly stabilised since the war with no marked movement either in or out. In this case, it would appear that present wages being paid on farms are sufficient to counteract external influences. The actual wage paid, of course, may well exceed the award on which the index numbers are based. But this holds equally true of the components of "town" wages, so we cannot place too much weight upon it. While wool prices are buoyant the labour situation in the higher and more remote sheep country does not appear to be so critical. But it seems inevitable that major re-adjustments to the full-employment labour situation will have to be made in farm areas where technological improvements have a limited application.

The increase in both sheep and dairy production is largely dependent on the wider applications of phosphatic fertilizer. Land development on the part of both individuals and state have both increased in the last few years. In the more developed areas, on the other hand, improvements in techniques of farming mainly compensate for the loss of labour, while the secure income position of the owner probably precludes any marked increase in effort from that quarter.

The buoyant prices and renewed interest of some lending institutions (especially the state) in the land, have changed the situation from one of capital rationing to one of capital expansion. The doubling of investment in rated horse-power alone (mainly tractors) in the last six years has had a profitable and stimulating effect on output.

Future increases in output depend largely on the widespread application of cheap fertilizer and the rapid adoption of land-saving techniques as they become available. Given full employment, the future of the farming industry thus depends on extending the boundaries of knowledge and on the extension of that knowledge to the farming community. If there is confidence in the future, the capital and labour facilities to produce more will automatically be made available.

Finally, we may now ask what reliability can be placed on the two variables found to be significant in the regression analysis. It will be recalled that approximately 50% of the year-to-year changes in output were accounted for. The modesty of this total determination appears to lie in the variables themselves. Firstly, the fact that the rainfall data is derived from only one station and for only one period of the year is a serious limitation. A more accurate variable representing weather changes would be difficult to compile, and is somewhat beyond the scope of this thesis. With such a low number of independent items available, the separate components of climatic changes by districts or by seasons cannot be analysed separately. Probably the most promising avenue of investigation would be to narrow down the area to be studied so that more factors in the environment could be held constant.

Secondly, various outstanding influences on production in some years have not had a constant effect over the time period taken for analysis. This is well demonstrated by the influence of patriotism in the early stages of the war. Changes in confidence also are not reflected in any one variable. We just cannot allow for the effect of the security which followed the introduction of guaranteed prices.

Then how much allowance should be made for the movement in the production function? It is a trend factor which, with development, cannot be specifically allowed for in an analysis based on first differences. Some variables may well undergo a qualitative change over a period of years such that their effect on production changes in the total period. For instance, is the conservation of grass in the form of silage more efficient than in the form of sun-cured hay? The text-books say that it is! Thus we may suspect our variable, $X_6$, of not being completely homogeneous, as different proportions of hay and silage are saved over a period of years. Finally, of course, there remains imperfections in the variables themselves, or random elements not measurable in any regression.

If the qualitative element of $X_6$ is not changing too rapidly, we can at least say that $X_1$ and $X_6$ are variables of a type which can be expected to carry on their effects into the future, without their "populations" varying too much. We can then regard future years as giving sample values of $X_1$ and $X_6$ likely to have the ordinary statistical relation to the samples from the years actually taken. If regard is always paid to the limitations imposed by the modest determinations, these variables can be used for future predictions.

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## APPENDIX A. ORIGINAL DATA USED IN ANALYSIS AND SOURCES.

| YEAR | EXPORT PRICES 1909-13 = 1000 (1) | FARM EXPENDITURE 1914 = 100 (2) | LAND VALUES 1911-14 = 1000 (3) | OUTPUT LIVESTOCK UNITS (4) | HAY AND SILAGE (5) |
|---|---|---|---|---|---|
| 1917 | 1655 | 125 | 1485 | 2749 | 111.2 |
| 1918 | 1684 | 135 | 1833 | 2604 | 131.6 |
| 1919 | 1776 | 155 | 2047 | 2874 | 117.1 |
| 1920 | 1806 | 160 | 2262 | 3027 | 161.8 |
| 1921 | 1713 | 180 | 2023 | 3038 | 187.4 |
| 1922 | 1363 | 165 | 1640 | 3475 | 175.5 |
| 1923 | 1610 | 150 | 1680 | 3362 | 189.0 |
| 1924 | 1788 | 157 | 1629 | 3467 | 229.6 |
| 1925 | 1893 | 157 | 1593 | 3597 | 224.7 |
| 1926 | 1544 | 153 | 1650 | 3594 | 225 |
| 1927 | 1525 | 153 | 1118 | 3832 | 289 |
| 1928 | 1683 | 162 | 1474 | | 280 |
| 1929 | 1623 | 162 | 1479 | | 351 |
| 1930 | 1283 | 162 | 1417 | | 413 |
| 1931 | 984 | 145 | 1279 | | 442 |
| 1932 | 892 | 123 | 1253 | | 465 |
| 1933 | 896 | 118 | 958 | | 562 |
| 1934 | 1109 | 119 | 1135 | | 506 |
| 1935 | 1102 | 123 | 1366 | | 524 |
| 1936 | 1250 | 132 | 1294 | | 577 |
| 1937 | 1440 | 156 | 1398 | | 543 |
| 1938 | 1367 | 161 | 1289 | | 483 |
| 1939 | 1324 | 166 | 1260 | | 555 |
| 1940 | 1524 | 175 | 1514 | | 595 |
| 1941 | 1553 | 179 | 1377 | | 576 |
| 1942 | 1586 | 187 | 1443 | | 555 |
| 1943 | 1650 | 199 | 1757 | | 490 |
| 1944 | 1733 | 232 | 1497 | | 574 |
| 1945 | 1865 | | 1391 | | 601 |
| 1946 | 2040 | | 1465 | | 483 |
| 1947 | 2555 | | 1436 | | 583 |
| 1948 | 2825 | | 1427 | | 606 |
| 1949 | 2765 | | | | 648 |
| 1950 | | | | | 630 |
| 1951 | | | | | 729 |
| 1952 | | | | | 821 |

(1) Export Prices Index, calendar years, 1909-13 = 1,000. The breakup of the aggregate index is given in respective Year Books. The aggregate quoted in this case includes timber and minerals. See N.Z. Year Book, 1947-49, p.626.

(2) Farm Expenditure Index. (less Interest and Rent) 1914 = 100. Method of collection is defined in 1932 Year Book. Calculated for calendar years. Not calculated since 1944. Figures rounded. Source: Land Prices and Land Valuation in New Zealand. Unpublished Ph.D. thesis, H.B. Low.

(3) Index of Price per acre. 1911-14 = 1,000. Calendar years. Source: H.B. Low, Ibid.

(4) Production of Lamb, Mutton, Wool, Butterfat, Beef and Calf. Based on Standard Values. E.J. Fawcett and W.N. Paton. N.Z. Year Book, 1929, p.990. These are the only output figures available before 1929 which have been corrected for changes in the value of money. Production years.

(5) Area cut on all farms for Hay and Silage (including lucerne). Thousands of acres. Farmers are asked to fill in schedules as at June 30. Published in Annual Statistics of Agricultural and Pastoral Production.

| YEAR | VOLUME OF FARM PRODUCTION (6) 1938-39 = 100 | AREA CULTIVATED (m. acres) (7) | HORSE-POWER ON FARMS (8) (th.) | MILKING MACHINES (9) | INTEREST ON MORTGAGES (10) |
|---|---|---|---|---|---|
| 1928-29 | 79 | 19.09 | 133.7 | 18756 | 6.46 % |
| 1929-30 | 83 | 19.16 | 145.9 | 20415 | 6.35 |
| 1930-31 | 84 | 19.01 | 185.1 | 22547 | 6.25 |
| 1931-32 | 84 | 18.85 | 177.0 | 23222 | 6.28 |
| 1932-33 | 96 | 19.03 | 184.0 | 24350 | 5.88 |
| 1933-34 | 99 | 19.19 | 187.6 | 25178 | 5.56 |
| 1934-35 | 96 | 19.50 | 193.4 | 25630 | 5.06 |
| 1935-36 | 101 | 19.67 | 207.8 | 26181 | 4.73 |
| 1936-37 | 104 | 19.59 | 228.1 | 27331 | 4.60 |
| 1937-38 | 104 | 19.66 | 261.6 | 28192 | 4.65 |
| 1938-39 | 100 | 19.69 | 291.6 | 28970 | 4.58 |
| 1939-40 | 102 | 19.66 | 334.2 | 29564 | 4.69 |
| 1940-41 | 116 | 19.91 | 372.8 | 30878 | 4.69 |
| 1941-42 | 111 | 19.83 | 410.7 | 31487 | 4.73 |
| 1942-43 | 108 | 19.98 | - | - | 4.72 |

| YEAR | (6) | (7) | (8) | (9) | (10) |
|---|---|---|---|---|---|
| 1943-44 | 105 | 19.83 | - | - | 4.63 |
| 1944-45 | 113 | 19.73 | - | - | 4.51 |
| 1945-46 | 107 | 19.97 | 538.0 | 31805 | 4.10 |
| 1946-47 | 110 | 20.10 | 599.3 | 32596 | 3.95 |
| 1947-48 | 113 | 20.10 | 666.1 | 33461 | 3.90 |
| 1948-49 | 117 | 20.12 | 780.2 | 34114 | |
| 1949-50 | 123 | | 1000.0 | 36316 | |
| 1950-51 | 126 | | 1134.1 | 37176 | |
| 1951-52 | | | 1295.2 | | |

(6) Volume of Farm Production Index. June years. As defined in N.Z. Year Book. One decimal point available for regression analysis, but not for publication according to policy of Census and Statistics Department. Accurate Series kindly provided by Mr. A. Edridge, Statistics Dept.

(7) Area Under Cultivation. Juhe years. As defined in N.Z. Year Book, 1947-49, p.901. Areas cut for hay, seed or ensilage are excluded. In millions of acres.

(8) Horse-Power Installed on Farms. Thousands. As at 31st January. Includes rated horse-power of all electric motors, internal combustion engines and farm tractors. Not collected in 1943, 1944, 1945. Published in Annual Statistics of Agricultural and Pastoral Production.

(9) Milking Machines Installed on Farms. As at January 31st. Published annually in Statistics of Agricultural and Pastoral Production.

(10) Average Rate of Interest on Mortgages newly registered. Source: Official Year Books and H.B. Low, Ibid. From 1946 onwards loans to servicemen (mostly at 3%) have reduced the average considerably. Lands Sales Court came into operation October 1943.

| YEAR | BUTTERFAT ( m.lbs.) (11) | AREA TOP-DRESSED (m.acres) (12) | WESTFIELD PRICE OF SUPER (£ per ton) (13) | SHEEP SLAUGH-TERED (m.) (14) | LAMBS SLAUGH-TERED (m.) (15) |
|---|---|---|---|---|---|
| 1928-29 | 289 | 2.385 | 4.875 | 3.507 | 6.197 |
| 1929-30 | 314 | 2.651 | 4.875 | 3.992 | 6.651 |
| 1930-31 | 322 | 2.871 | 4.875 | 4.283 | 8.197 |
| 1931-32 | 339 | 2.454 | 4.875 | 5.233 | 8.827 |
| 1932-33 | 397 | 2.438 | 4.125 | 4.356 | 9.853 |
| 1933-34 | 426 | 2.249 | 4.00 | 3.556 | 8.825 |
| 1934-35 | 409 | 2.684 | 4.00 | 3.942 | 9.765 |
| 1935-36 | 425 | 2.882 | 4.00 | 3.260 | 8.755 |
| 1936-37 | 442 | 3.326 | 3.80 | 3.463 | 9.357 |
| 1937-38 | 436 | 3.874 | 3.80 | 3.885 | 10.007 |
| 1938-39 | 401 | 4.017 | 3.80 | 4.702 | 9.962 |
| 1939-40 | 432 | 4.187 | 3.80 | 4.439 | 10.160 |
| 1940-41 | 467 | 4.649 | 3.80 | 5.151 | 12.037 |
| 1941-42 | 438 | 4.212 | 4.00 | 4.633 | 11.700 |
| 1942-43 | 408 | 3.470 | 4.00 | 4.310 | 11.251 |
| 1943-44 | 389 | 3.370 | | 1.552 | 10.607 |
| 1944-45 | 433 | 3.646 | | 4.717 | 10.780 |
| 1945-46 | 374 | 3.653 | | 5.440 | 12.742 |
| 1946-47 | 410 | 4.260 | | 5.177 | 11.826 |
| 1947-48 | 420 | 4.684 | | 4.925 | 12.798 |
| 1948-49 | 457 | 5.062 | | 4.754 | 12.445 |
| 1949-50 | 471 | 5.730 | | 4.434 | 12.588 |
| 1950-51 | 498 | 6.326 | | 3.704 | 11.605 |
| 1951-52 | | 6.462 | | 5.215 | 12.436 |

(11) **Total Butterfat Production, including estimates for butterfat in milk and cream sold for human consumption, used and lost on farms etc. Source: N.Z. Year Book, 1951-52, p.435 and earlier Year Books.**

(12) **Area Top-dressed with either phosphate or lime, in year preceding January 31. Published in Annual Statistics of Agricultural and Pastoral Production. Definition has only been constant since 1932-33. Earlier values were interpolated by Hamilton, N.Z.J.Sc.T. 26A: p.20.**

(13) **Price of Fertilizer per ton, f.o.b. Westfield, 1st. March. Quoted by Hamilton N.Z.J.Sc.T. 26A: p.20.**

(14) (15) Slaughtering of Stock by March 31. years. Total killings which include export works, abattoirs, rural slaughterhouses and killings on farms. Estimates of the latter were not collected during the three years ended March 31st, 1945, but estimates have been included for those years. Sources: N.Z. Year Book, 1951-52, p.437, and earlier Year Books.

Table II. (a) Group IV Factory Production. Index of volume of production of manufacturing sector.
Source: N.Z. Year Book, 1950, p.423.
(b) Cows in milk as at 31 January. Year Book Statistical Summary.

Table IV. Calculation of Non-Farm Weekly Wages. Wage statistics are presented for each occupational group and for all groups. "All groups", being an aggregate, can be corrected so as to eliminate the influence of "farm occupations" on the average. Since the weights of the groups are fixed it is possible to calculate a constant factor for this purpose If x is the difference between the non-farm average and the all groups average, and y is the difference between the farm and the all groups average, then $x = 0.304y$, since the weight of "farm" is 48/206.

Table XIII. (a) Total Sheep on Farms as at April 30. Since 1949-50, this has been shifted to June 30. Found in Year Book Statistical Summary.
(b) Wethers slaughtered on farms, as at January 31. Found in early Agricultural and Pastoral Statistics. Later definition has been "adult sheep slaughtered for home use."

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MONTHLY RAINFALL - SELECTED LOCALITIES.

| YEAR | RUAKURA | | HASTINGS | ASHBURTON | TOTAL |
|---|---|---|---|---|---|
| | JAN-FEB. | JAN-FEB-MAR. | JAN-FEB. | JAN-FEB. | JAN-FEB. |
| 1928 | 3.99" | 6.55" | 1.63" | 2.75" | 8.35" |
| 1929 | 2.00 | 6.60 | 0.95 | 3.05 | 6.00 |
| 1930 | 8.65 | 9.66 | 4.70 | 6.35 | 19.70 |
| 1931 | 6.27 | 7.55 | 1.18 | 5.24 | 12.79 |
| 1932 | 4.35 | 6.29 | 6.82 | 3.44 | 14.61 |
| 1933 | 9.66 | 11.58 | 3.25 | 3.38 | 16.29 |
| 1934 | 5.64 | 7.04 | 7.85 | 9.52 | 23.01 |
| 1935 | 5.47 | 7.93 | 4.77 | 4.10 | 14.34 |
| 1936 | 14.68 | 18.26 | 16.07 | 10.49 | 41.24 |
| 1937 | 6.93 | 9.83 | 3.12 | 7.36 | 17.41 |

Monthly Rainfall (contd.)

| YEAR | RUAKURA JAN-FEB. | RUAKURA JAN-FEB-MAR. | HASTINGS JAN-FEB. | ASHBURTON JAN-FEB. | TOTAL JAN-FEB. |
|---|---|---|---|---|---|
| 1938 | 8.66" | 8.96" | 18.74" | 5.84" | 33.23" |
| 1939 | 6.80 | 7.34 | 1.35 | 1.03 | 9.18 |
| 1940 | 10.45 | 11.17 | 5.05 | 4.91 | 20.41 |
| 1941 | 7.53 | 15.90 | 4.72 | 2.63 | 14.88 |
| 1942 | 3.30 | 5.89 | 8.36 | 4.58 | 16.24 |
| 1943 | 3.93 | 4.79 | 5.30 | 4.76 | 13.99 |
| 1944 | 7.30 | 13.15 | 6.76 | 6.07 | 20.13 |
| 1945 | 11.30 | 13.75 | 7.32 | 12.66 | 31.38 |
| 1946 | 1.68 | 3.79 | 0.14 | 3.14 | 4.96 |
| 1947 | 3.28 | 6.47 | 5.99 | 8.84 | 18.11 |
| 1948 | 5.68 | 7.27 | 2.72 | 4.65 | 13.05 |
| 1949 | 4.90 | 9.16 | 9.57 | 3.74 | 18.21 |
| 1950 | 6.53 | 7.54 | 6.37 | 7.56 | 20.46 |
| 1951 | 6.12 | 6.94 | 7.10 | 9.79 | 23.01 |

Source: New Zealand Gazette, Monthly Climatological Tables.

DEFLATION OF EXPORT PRICES.

| YEAR | EXPORT PRICES JUNE YEARS 1909-13 = 1000 | FARM EXPENDITURE 1914 = 100 | RATIO |
|---|---|---|---|
| 1924-25 | 1927 | 157 | 12274 |
| 1925-26 | 1648 | 157 | 10497 |
| 1926-27 | 1514 | 153 | 990 |
| 1927-28 | 1647 | 153 | 10765 |
| 1928-29 | 1668 | 162 | 10296 |
| 1929-30 | 1397 | 162 | 862 |
| 1930-31 | 1052 | 162 | 649 |
| 1931-32 | 934 | 145 | 644 |
| 1932-33 | 861 | 123 | 700 |
| 1933-34 | 1089 | 118 | 923 |
| 1934-35 | 1046 | 119 | 879 |
| 1935-36 | 1205 | 123 | 980 |
| 1936-37 | 1397 | 132 | 10583 |
| 1937-38 | 1386 | 156 | 888 |
| 1938-39 | 1320 | 161 | 820 |
| 1939-40 | 1479 | 166 | 891 |
| 1940-41 | 1524 | 175 | 871 |

Deflation of Export Prices (contd.)

| YEAR | EXPORT PRICES JUNE YEARS 1909-13 = 1000 | FARM EXPENDITURE 1914 = 100 | RATIO |
|---|---|---|---|
| 1941-42 | 1577 | 179 | 881 |
| 1942-43 | 1613 | 187 | 863 |
| 1943-44 | 1681 | 199 | 845 |
| 1944-45 | 1817 | 232 | 783 |
| 1945-46 | 1907 | 248 | 769 |
| 1946-47 | 2336 | 281 | 831 |
| 1947-48 | 2803 | 334 | 839 |
| 1948-49 | 2696 | 348 | 775 |
| 1949-50 | 3122 | 355 | 879 |
| 1950-51 | 4952 | 384 | 12896 |
| 1951-52 | | 422 | |

The values of the farm expenditure index since 1944 were calculated from the structure of the guaranteed price for butterfat. This calculation is presented in the next table. From the 1932 YB., wages are found to have a weight of 25% in the farm expenditure index and rent and interest 33%. Thus the weight of the remainder, working costs, must be 42%. To obtain an equivalent index from the guaranteed price structure, the fraction $25/_{42}$ of "labour reward" has been added to "working costs".
Source: New Zealand Year Books, 1947-49, p.891; 1951-52, p.400.

| YEAR | WORKING COSTS | LABOUR REWARD | FRACTION | TOTAL | INDEX |
|---|---|---|---|---|---|
| 1939-40 | 5.340d | 8.840d | 3.180d | 8.520d | 186 |
| 1940-41 | 5.340 | 8.840 | 3.180 | 8.520 | 186 |
| 1941-42 | 5.340 | 8.840 | 3.180 | 8.520 | 186 |
| 1942-43 | 5.510 | 9.280 | 3.340 | 8.850 | 192 |
| 1943-44 | 6.107 | 9.450 | 3.399 | 9.506 | 206 |
| 1944-45 | 6.757 | 10.920 | 3.928 | 10.685 | 232 |
| 1945-46 | 7.254 | 11.440 | 4.115 | 11.369 | 248 |
| 1946-47 | 8.015 | 13.676 | 4.919 | 12.934 | 281 |
| 1947-48 | 10.011 | 14.196 | 5.348 | 15.359 | 334 |
| 1948-49 | 10.179 | 16.267 | 5.852 | 16.031 | 348 |
| 1949-50 | 10.199 | 17.073 | 6.142 | 16.341 | 355 |
| 1950-51 | 10.905 | 18.802 | 6.764 | 17.669 | 384 |
| 1951-52 | 12.342 | 19.613 | 7.055 | 19.397 | 422 |

APPENDIX B. FARM LABOUR FORCE ESTIMATES.

| YEAR | MALES AT CENSUS | AGRICULTURAL & PASTORAL MALES AND FEMALES | A. & P. MALES | A.& P. FEMALES | DEPART-MENTAL ESTIMATE | OWN ESTIMATE |
|---|---|---|---|---|---|---|
| 1901 | 85300 | | | | | |
| 1906 | 93500 | | | | | |
| 1911 | 102600 | | | | | |
| 1916 | 107700 | | | | | |
| 1921 | 122600 | 133260 | 101355 | 31905 | | |
| 1926 | 116953 | 137451 | 102771 | 34680 | | |
| 1928 | | 129481 | 106649 | 22832 | 148000 | 109000 |
| 1929 | | 138609 | 112885(a) | 25724 | 148 | 112 |
| 1930 | | 138121 | 119321 | 18800(b) | 151 | 119 |
| 1931 | | | | | 155x | 128x |
| 1932 | | | | | 159x | 135x |
| 1933 | | | | | 161x | 138x |
| 1934 | | | | | 162x | 141x |
| 1935 | | | | | 163x | 143x |
| 1936 | 144456 | 150813* | | 6357* | 163 | 144 |
| 1937 | | | | | 161x | 143x |
| 1938 | | | | | 159x | 140x |
| 1939 | | | | | 157x | 135x |
| 1940 | | | | | 154x | 128x |
| 1941 | | | | | 140x | 120x |
| 1942 | | | | | 125x | 112x |
| 1943 | | | | | 125x | 109x |
| 1944 | | | | | 127x | 107x |
| 1945 | 107787 | 118543* | | 10754* | 130 | 107 |
| 1946 | | | | | 149 | 108 |
| 1947 | | 124386 | 112921(c) | 11465 | 147 | 108 |
| 1948 | | 121304 | 109431 | 11873 | 146 | 109 |
| 1949 | | 121386 | 109246 | 12140 | | 109 |
| 1950 | 109461 | 125689* | 109461* | 16228* | | 110 |

x Extrapolated.
* Census estimates which have found their way into Agricultural and Pastoral Statistics.

(a) Change in instructions to farmers - working proprietors had tended to be excluded.

(b) Females wholly engaged on domestic work eliminated.

(c) An over-estimate according to Agricultural and Pastoral Statistics 1947-48, p.11.

Sources: Census Reports 1901 - 50.
Annual Agricultural and Pastoral Statistics.
New Zealand Year Book 1932, p.370.
" " " " 1950, p.778.
Labour and Employment Gazette, February 1951, p.44.
Half-Yearly Survey of Employment, January, 1950.

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The Census definition of full-time male workers is all those over 15 years, working more than 14 hours a week on holdings of one acre or more. The Agricultural & Pastoral definition has the additional condition of holdings outside borough boundaries only. Seasonal workers, Maoris, domestic servants and wives and daughters (unless the 14 hour qualification is met) are all excluded. In the case of 1936, 1945 and 1950, the Census figure has been corrected to follow the Agricultural and Pastoral definition. Since the labour question was left off the Agricultural and Pastoral schedules from 1930 to 1947, the trend of farm labour movements has been shrouded in mystery only to temporarily emerge from the census data of 1936 and 1945. The generally accepted estimates found in most official publications are the result of some work carried out by the Department of Labour and Employment in 1948.

In consultation with the Census and Statistics Department and the Agriculture Department, their objective was to derive a "true" estimate of the farm labour position between 1928 and 1948. Their estimate allows for workers coming under the "Not Specified" category, for Maoris on farms, for those employed within borough boundaries and for casual, seasonal, contracting and part-time workers. The general trend of their estimate seems reasonable, except for the post-war period. To my mind, there is no satisfactory evidence that the number of workers jumped by 19,000 in one year. The number of holdings changing hands (transfers) averages two to three thousand since the war, while the rate of settlement of returned soldiers has never exceeded two thousand in any one year. It seems reasonable to suggest that many older people, who had held on during the war, took the return of the servicemen as an opportunity to retire to the city and hand over the management of their farms. The Agricultural and Pastoral schedule question has been included since 1947 while the Census estimate is available for 1945. Although the Census was taken while war conditions still prevailed, subsequent Agricultural and Pastoral figures have shown no marked change. A final note from this source adds that the years 1931-35 and 1937-44 (exclusive) were partly interpolated. It seems to me that the years since 1946 were also interpolated on the pre-war line of trend!

The mixed definition of these Labour and Employment estimates and the free use of trend in the latter years, makes the series somewhat unsuitable for statistical purposes. The available figures on which to base a new estimate are presented on the first page of this appendix. Males and females employed full-time on properties over one acre outside borough boundaries appears at first sight to be satisfactory. But a detailed inspection of the female figures shows a tremendous variation not in accordance with the known facts, and which can only be explained by difficulties of interpretation of the schedules by the farmers or the local police constable as to how many hours a female must work in a week, and as to how much reward constitutes a full-time female worker. The low figures for 1936, compared with pre-depression figures suggests that lack of payment removed many wives and daughters from the category of full-time workers.

We are thus left with the series of full-time male workers in farming. It is argued that this definition would cause least difficulty to the farmers as they fill in their schedules. It is these figures which have been used as a basis of my own interpolation. They are no more than estimates, but they are based on the most accurate figures available.

## APPENDIX C. TESTING FOR SERIAL CORRELATION IN RESIDUALS.

### (1) Testing First Differences.

where $\hat{Y} = -16.867 + 0.499X_1 + 0.221X_6$

| YEAR | Y | $\hat{Y}$ | $-z$ | $+z$ | $z^2$ | $-\Delta z$ | $+\Delta z$ | $\Delta z^2$ |
|---|---|---|---|---|---|---|---|---|
| 1929-30 | 54 | 65.3 | 11.3 | | 127.7 | | | |
| 1930-31 | 31 | 45.2 | 14.2 | | 201.6 | 2.9 | | 8.4 |
| 1931-32 | 30 | 38.0 | 8.0 | | 64.0 | | 6.2 | 38.4 |
| 1932-33 | 89 | 53.1 | | 35.9 | 1288.8 | | 43.9 | 1927.2 |
| 1933-34 | 43 | 42.5 | | 0.5 | 0.3 | 34.4 | | 1183.4 |
| 1934-35 | 15 | 27.7 | 12.7 | | 161.3 | 13.2 | | 174.2 |
| 1935-36 | 54 | 56.4 | 2.4 | | 5.8 | | 10.3 | 106.1 |
| 1936-37 | 43 | 31.0 | | 12.0 | 144.0 | | 14.4 | 207.4 |
| 1937-38 | 28 | 27.4 | | 0.6 | 0.4 | 11.4 | | 130.0 |
| 1938-39 | 15 | 19.4 | 4.4 | | 19.4 | 5.0 | | 25.0 |
| 1939-40 | 39 | 57.9 | 18.9 | | 357.2 | 14.5 | | 210.3 |
| 1940-41 | 85 | 49.1 | | 35.9 | 1288.8 | | 54.8 | 3003.0 |
| 1941-42 | 13 | 10.6 | | 2.4 | 5.8 | 33.5 | | 1122.3 |
| 1942-43 | 16 | 27.4 | 11.4 | | 130.0 | 13.8 | | 190.4 |
| 1943-44 | 16 | 45.0 | 29.0 | | 841.0 | 17.6 | | 309.8 |
| 1944-45 | 66 | 51.6 | | 14.4 | 207.4 | | 43.4 | 1883.6 |
| 1945-46 | 6 | 11.6 | 5.6 | | 31.4 | 20.0 | | 400.0 |
| 1946-47 | 41 | 25.6 | | 15.4 | 237.2 | | 21.0 | 441.0 |
| 1947-48 | 42 | 55.6 | 13.6 | | 185.0 | 29.0 | | 841.0 |
| 1948-49 | 45 | 43.9 | | 1.1 | 1.2 | | 14.7 | 216.1 |
| 1949-50 | 51 | 37.6 | | 13.4 | 179.6 | | 12.3 | 151.3 |
| | $\Sigma Y$ = 822.0 | 821.9 | | | $\Sigma z^2$ = 5477.9 | | | $\Sigma \Delta z^2$ = 12568.9 |

Testing first differences we use the statistic 4-d, where d is the ratio of the square of the mean successive difference to the variance. Thus d - 2.2946 and 4-d = 1.7054 (as in Ch. VI). From the regression calculation we have

$$\hat{Sy}^2_{16} = (b_{y1.6} \times Sx_1y) + (b_{y6.1} \times Sx_6 y) = 4784,$$ that is,

the sum of squares of deviations of Y predicted by $X_1$ and $X_6$. Since the total square of deviations of Y from its mean is 10261, the difference between these figures should give us the "unexplained" or error sums of squares. This is so, as 10261 - 4784 = 5477. The variance of regression is, of course, 5477/18 = 304.27, which in turn gives us the standard error of regression, 17.44.

(2) Testing in Original Values of Variables.

where $\hat{Y} = 33.847 + 0.0163X_1 + 0.5422X_6$

| YEAR | Y | $\hat{Y}$ | +z | −z | $z^2$ | −Δz | +Δz | $\Delta z^2$ |
|---|---|---|---|---|---|---|---|---|
| 1928–29 | 98 | 65.1 | 32.9 | | 1082 | | | |
| 1929–30 | 121 | 120.4 | 0.6 | | | | 32.3 | 1043 |
| 1930–31 | 122 | 156.6 | | 34.6 | 1197 | | 35.2 | 1239 |
| 1931–32 | 122 | 172.6 | | 50.6 | 2560 | | 16.0 | 256 |
| 1932–33 | 181 | 187.8 | | 6.8 | 46 | 43.8 | | 1918 |
| 1933–34 | 195 | 229.3 | | 34.3 | 1176 | | 27.5 | 756 |
| 1934–35 | 180 | 205.2 | | 25.2 | 635 | 9.1 | | 83 |
| 1935–36 | 203 | 219.2 | | 16,2 | 262 | 9.0 | | 81 |
| 1936–37 | 217 | 237.6 | | 20.6 | 424 | | 4.4 | 19 |
| 1937–38 | 215 | 222.9 | | 7.9 | 62 | 12.7 | | 161 |
| 1938–39 | 200 | 193.3 | 6.7 | | 45 | 14.6 | | 213 |
| 1939–40 | 209 | 229.8 | | 20.8 | 433 | | 27.5 | 756 |
| 1940–41 | 264 | 248.1 | 15.9 | | 253 | 36.7 | | 1347 |
| 1941–42 | 246 | 233.4 | 12.6 | | 158 | | 3.3 | 11 |
| 1942–43 | 233 | 223.3 | 9.7 | | 94 | | 2.9 | 8 |
| 1943–44 | 219 | 200.6 | 18.4 | | 339 | 8.7 | | 76 |
| 1944–45 | 255 | 238.9 | 16.1 | | 259 | | 2.3 | 5 |
| 1945–46 | 231 | 240.6 | | 8.6 | 74 | | 24.7 | 610 |
| 1946–47 | 243 | 192.9 | 50.1 | | 2510 | 58.7 | | 3446 |
| 1947–48 | 254 | 237.7 | 16.3 | | 266 | | 33.8 | 1142 |
| 1948–49 | 269 | 249.0 | 20.0 | | 400 | 3.7 | | 14 |
| 1949–50 | 290 | 263.4 | 26.6 | | 707 | 6.6 | | 44 |
| | $\Sigma Y =$ 4567 | 4567.6 | | | $\Sigma z^2 =$ 12982 | | | $\Sigma \Delta z^2 =$ 13228 |

The distribution of the yearly values of these residuals has already been presented in Graph II. The marked influence of related successive values is clearly seen in this data. The value of the "d" statistic is 1.020 (see Ch.VI). An alternative test for finding whether or not such residuals are successively related, is to calculate the ordinary correlation between coded successive errors. This gives a value r = 0.5467.** The exact relationship of these two methods is not clear.

## APPENDIX D. SUMS OF SQUARES OF DEVIATIONS PREDICTED BY VARIOUS COMBINATIONS OF INDEPENDENT VARIABLES.

| VARIABLES | S.S. | VARIABLES | S.S. |
|---|---|---|---|
| $Y$ | 10261.0 | $X_6 X_7$ | 2195.8 |
| $X_1$ | 2053.1 | $X_3 X_5$ | 1794.6 |
| $X_3$ | 123.4 | $X_5 X_6$ | 2746.4 |
| $X_4$ | 751.4 | $X_1 X_3 X_5$ | 2914.9 |
| $X_5$ | 838.2 | $X_1 X_5 X_6$ | 4171.8 |
| $X_6$ | 1834.2 | $X_4 X_5 X_6$ | 3636.3 |
| $X_7$ | 80.8 | $X_3 X_5 X_6$ | 3177.2 |
| $X_9$ | 1020.0 | $X_1 X_7 X_6$ | 3801.5 |
| $X_1 X_3$ | 2130.9 | $X_1 X_4 X_6$ | 4392.4 |
| $X_1 X_4$ | 3137.4 | $X_1 X_6 X_9$ | 3841.6 |
| $X_1 X_5$ | 2391.1 | $X_1 X_4 X_5$ | 3984.5 |
| $X_1 X_6$ | 3774.4 | $X_1 X_4 X_5 X_6$ | 5191.8 |
| $X_1 X_9$ | 2054.3 | $X_1 X_4 X_6 X_7$ | 4477.8 |
| $X_1 X_3 X_6$ | 3783.9 | | |

$$r^2_{y1.56} = \frac{S\hat{y}^2_{156} - S\hat{y}^2_{56}}{S_y^2 - S^2_{\hat{y}56}}$$

$$= \frac{4171.8 - 2746.4}{10261 - 2746.4}$$

$$= 0.18968$$

$$r_{y1.56} = 0.4356$$