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**TOTAL FACTOR PRODUCTIVITY
AND SOURCES OF GROWTH IN THE SHEEP
AND BEEF FARM IN NEW ZEALAND
1973-74 TO 1990-91**



**A Thesis
Submitted in Partial Fulfilment
of the Requirements
for the Degree of**

Master in Agricultural Economics



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ABSTRACT

This study examined the productivity of the average sheep and beef farm in New Zealand during the period from 1973-1974 to 1990-1991. The Tornqvist quantity index method was used to construct the aggregate indices for inputs utilized and outputs produced on the farm. Total factor productivity was calculated as the ratio of the total output index to the total input index.

Results of the study indicated an annual rate of growth of 1.6 percent in the productivity of the average sheep and beef farm in New Zealand. This originated from the combined effect of a 1.4 percent annual increase in total output and a 0.21 percent annual decrease in input usage. Farmer terms of trade during the study period has declined by 4.7 percent per year. Returns to costs ratio has, likewise, declined by 3.1 percent annually.

An attempt was made to determine the sources of growth in the output of the farm using regression analysis. The explanatory variables considered included a climate factor, fertilizer subsidy, output assistance and a trend variable. It was determined that the trend variable was the only significant explanatory variable for the growth in TFP of the average sheep and beef farm. It was, thus, concluded that the growth in output of the average sheep and beef farm during the period from 1973-1974 to 1990-1991 has been caused by factors other than the climate, fertilizer subsidy and output assistance.

CHAPTER ONE

INTRODUCTION TO THE STUDY

1.1 Introduction

Improving productivity in the utilization of resources lies at the heart of economic growth, no less so in agriculture than in other economic sectors or in the national economy. Productivity growth enhances standards of living and the quality of life. Specifically, it improves production efficiency which can translate to increases in incomes that potentially can be reallocated toward improving conditions of social concern such as environmental pollution or poverty. Advances in productivity also help abate inflation and conserve scarce resources. It stimulates market competition within an economy and between economies, thus improving resource allocation in general (Link, 1987).

As stated by Barker (1987), growth in productivity of resources is a fact generally accepted as being essential to the development of modern industrial economies. The most important uses of productivity statistics, as determined by the United States Department of Agriculture (USDA Technical Bulletin, 1980) are: 1) identifying the sources of economic growth; 2) justifying the appropriation of agricultural research funds; 3) estimating production relationships; 4) serving as an indicator of technical change; 5) comparing inter-sectoral economic performance; and 6) justifying price changes. More

specifically, the USDA report indicated that productivity statistics are used to compare agricultural inputs to outputs in order to measure the performance of the sector.

This study is concerned with examining the productivity of the average sheep and beef farm in New Zealand, being a major component of the country's pastoral industry in particular and the agriculture sector in general. Traditionally, sheep and beef farming has centered on producing sheepmeat, beef, wool and hides. In recent years new types of livestock have been introduced which include deer and goats.

The significance of the sheep and beef industry to the New Zealand economy may be measured in terms of its contribution to the gross output in agriculture. In 1993 the industry contributed an estimated four billion dollars worth of output which comprised about 42 percent of total agricultural output. Table 1.1 shows in detail the various outputs contributed by the sheep and beef industry to the output in agriculture from 1988 to 1993. Over this period, the industry's contribution increased at an average of 2.4 percent per year.

The sheep and beef industry also contributes significantly to the country's export earnings. In 1992 exports of meat and meat products

Table 1.1 Gross Agricultural Production

Year ended 31 March	1988	1989r	1990r	1991r	1992p	1993e
(in NZ \$ million)						
Wool*	1385	1508	1252	832	783	820
Sheep and Lambs**	690	610	865	885	833	949
Cattle**	951	1173	1187	1376	1442	1521
Dairy Products	1431	1902	2166	1641	2203	2496
Pigs**	110	101	125	126	125	130
Poultry and Eggs	186	192	215	208	193	200
Crops and Seeds	260	262	338	313	317	338
Fruit and Nuts	578	549	623	694	821	717
Vegetables	297	373	412	420	430	447
Other Horticulture	122	145	166	160	175	175
Other Farming	211	243	259	255	272	336
Agricultural Services	498	556	620	648	665	709
Value of Livestock Change	45	-67	131	-14	88	113
Sales of Live Animals	601	585	721	671	701	774
Total Output	7365	8132	9080	8216	9027	9725
Less Intermediate Consumption	3851	4255	4800	4657	4867	5101
Agriculture's Contribution to Gross Domestic Product***	3515	3877	4280	3559	4160	4624
Gross Domestic Product	61867	66403	71505	73343	73213	76800
Agriculture as a Percentage of Gross Domestic Product	5.7	5.8	6	4.9	5.7	6

* Excludes slipe wool and sheepskins

** Sales for slaughter, including on-farm kill

*** "Agriculture's contribution to Gross Domestic Product" is gross agricultural output measured at the point of first sale including agricultural contracting, less off-farm non-factor inputs. These items (for example, wire, which comes from the metal manufacturing sector) are called "intermediate consumption" items.

**** Includes sales of live animals

r revised

p preliminary

e estimate

Source: Situation and Outlook for New Zealand Agriculture, 1993
Ministry of Agriculture and Fisheries

earned the country some three billion dollars while wool exports earned about 1.2 billion dollars (Table 1.2). Overall, wool and meat and meat products comprise about 29 percent of total agricultural-based exports or 17 percent of New Zealand's total exports of goods.

In terms of livestock numbers, inventories of sheep were observed to have generally declined while stocks of beef cattle rose. Table 1.3 shows the inventory levels of sheep and beef cattle during the past twenty years. It is noticeable from the statistics that the movements in livestock numbers over this period have been in changing proportions. Specifically, during the early 1970's beef cattle numbers increased to over six million while sheep numbers declined. Over the period 1975 to 1983 the pattern switched with beef cattle numbers decreasing and sheep numbers consistently increasing to reach a peak at around 70 million. Since 1983, there has been a steady running-down of the sheep stock while beef cattle numbers have again increased.

The period from 1973 to 1991 covered in this study was characterized by the combined effects of various factors including inflation, product price variability, weather variability and government policies, which have influenced the environment in which sheep and beef farmers made their production decisions. Specifically, the random effects of these factors have either encouraged or made farmers pessimistic about

Table 1.2 Value of Exports

Year ended 30 June	1989	1990	1991	1992
	(in NZ \$ million, FOB)			
Live Animals	212.1	193.7	178.9	186.1
Beef and Veal	1279.7	1091.6	1283.8	145.1
Lamb	720.7	957.7	977.8	1177.0
Mutton	130.4	135.8	171.8	170.9
Total Meat and Meat Products*	2424.9	2335.1	2612.1	3031.9
Butter	609.2	710.5	542.1	701.6
Cheese	319.8	341.0	358.0	412.1
Wholemilk Powder	487.1	443.8	668.4	784.0
Skimmilk and Buttermilk Powder	416.9	534.4	415.5	444.1
Casein and Caseinates	343.7	448.7	450.1	490.4
Total Dairy Products*	2234.1	2534.2	2485.0	2897.1
Meat Meal and Pet Food	73.0	69.0	68.8	53.1
Crude Animal Materials	191.1	201.5	217.1	307.6
Animal Oils and Fats	75.0	65.6	67.3	79.9
Greasy Wool	651.7	418.3	261.3	307.9
Slip Wool	159.2	125.4	87.4	101.8
Scoured Wool	984.7	772.1	613.8	671.7
Tops and Yarns	113.4	98.2	78.7	90.5
Total Wool*	1909.0	1424.1	1043.7	1172.7
Hides and Skins	556.2	494.8	391.0	355.2
Total Pastoral Based Exports	7675.4	7318.0	7063.9	8083.6
Fresh Kiwifruit	455.1	539.1	519.7	501.6
Apples and Pears, Nashi	161.5	218.3	305.2	335.1
Total Fruits and Vegetables*	824.2	998.6	1069.4	1166.6
Cereals and Cereal Products	27.3	15.1	13.9	23.5
Seeds, Other Vegetable Products	205.5	178.8	275.2	336.0
Eggs and Honey	4.8	4.3	6.5	7.1
Carpets	75.2	88.3	70.6	70.3
Leather	177.6	167.1	172.9	201.1
Dressed Skins	13.3	14.0	19.1	25.6
Total Agricultural Based Exports*	9003.3	8784.1	8751.5	9992.9
Fish	819.0	734.9	791.3	1141.6
Total New Zealand Exports of Goods*	14905.4	15163.5	15768.4	17890.6

* Includes items not listed

Source: Situation and Outlook for New Zealand Agriculture, 1993
Ministry of Agriculture and Fisheries

Table 1.3 Sheep and Beef Cattle Inventory

Year ended 30 June	Sheep	Beef Cattle
(in '000 Head)		
1973	56959	5694
1974	56147	6171
1975	55562	6238
1976	56643	6034
1977	59363	5809
1978	62478	5487
1979	64166	5105
1980	68772	5142
1981	69884	5094
1982	70301	4906
1983	70263	4497
1984	69739	4531
1985	67854	4613
1986	67470	4881
1987	64244	4804
1988	64600	4858
1989	60569	4526
1990	57852	4593
1991	55162	4671
1992	52568	4676

Source: Annual Review of the New Zealand
Sheep and Beef Industry 1992-1993
NZ Meat and Wool Boards' Economic Service

pursuing investments or expenditures on factor and non-factor inputs used in the sheep and beef farm.

The market environment over the study period was an exacting one for farmers as indicated by the terms of trade indices for sheep and beef products shown in Table 1.4. It is apparent from the indices shown that real sheep and beef product prices have fluctuated considerably during the period from 1973 to 1989, around a long-term declining trend.

There has also been significant variation in the relative terms of exchange between commodities over the period. This has been caused either by the cost of a commodity rising faster, or returns increasing more slowly, than those of the other products. In this case, shifts in the relative terms of exchange indicate changes in the enterprise mix. The change in enterprise mix, however, need not necessarily involve a change in livestock. For example, as beef becomes more profitable relative to dairy, more dairy calves will be raised for beef production. Likewise, as real wool returns rise relative to sheepmeat, more "dry" sheep will be kept, producing wool only. This occurred in the late 80s, with the turnaround in wool returns relative to those from lamb. Prior to 1985, real lamb returns had generally been superior (Sandrey and Reynolds, 1990).

Table 1.4 Terms of Exchange Indices for the Pastoral Industries

June Year	Wool	Lamb	Mutton	Beef	Dairy	Pastoral
(1976=100)						
1973	130	134	136	186	115	137
1974	111	121	111	130	113	122
1975	65	71	49	71	100	86
1976	100	100	100	100	100	100
1977	110	113	154	91	92	102
1978	88	92	110	83	88	88
1979	93	100	103	130	84	103
1980	92	89	95	113	83	96
1981	70	76	75	91	84	88
1982	79	88	65	95	85	94
1983	70	80	59	97	90	90
1984	70	84	68	106	87	98
1985	74	81	75	121	87	105
1986	60	40	24	80	79	77
1987	67	58	37	78	65	76
1988	69	41	47	65	70	71
1989	73	46	39	65	87	79

Source: Farming Without Subsidies: The New Zealand Experience
 Edited by Sandrey R. and R. Reynolds (1990)

Because of the critical linkages among export receipts from the pastoral sector, employment and economic growth in New Zealand, the government was compelled to make efforts to encourage output from the pastoral sector. This was undertaken through the institutionalization of policy instruments designed to provide assistance to the pastoral sector. The major emphasis of the assistance was to stabilise farmers' incomes.

The assistance measures were broadly categorized as¹:

- 1) Assistance to outputs - effects of those policies which increase the gross returns by influencing output prices (e.g., price supplementation);
- 2) Assistance to inputs - effects of those policies that reduce costs (e.g., fertilizer subsidies); and
- 3) Assistance to value adding factors - effects of those policies which increase the returns to, or subsidise the use of, the primary factors of production - land, capital and labour (e.g., taxation concessions).

Specifically, the major policy instruments directed at providing assistance to outputs came in the form of an income stabilization scheme and supplementary minimum payments (SMPs). The former scheme, which aimed to encourage farmers to commit sums to an income stabilization fund, was introduced in response to the boom years of 1972-1973 and 1973-1974. As it happened, such a deposit

¹Source: Farming Without Subsidies: New Zealand's Recent Experience (1990)

proved beneficial to many farmers in the 1974-1975 season when product prices fell. In 1976, a permanent income stabilization scheme was put up by sheep and beef farmers through the Meat and Wool Boards. This scheme guaranteed a minimum price for meat and wool products and set a trigger price at which level receipts were to be deposited in the stabilization fund. In 1978, the government superimposed on this permanent scheme its own supplementary minimum price (SMP) scheme guaranteeing a minimum price for sheepmeat, wool and beef at the beginning of each season. When international market determined payouts fell below the set minimum, the government made up the difference. The SMPs worked in tandem with the producer board stabilization scheme. The floor price set by the boards was generally lower than that for SMPs. If market prices fell below both set floor prices, government would meet the difference between the SMP and the producer board set minimum, while the producer boards would make up the remainder. The SMP scheme was ended at the close of the 1983-1984 season (although payments were recorded until 1986) while the producer board stabilization scheme, operated through the Meat Industry Stabilization Account (MISA) with the Reserve Bank, ended in 1986. By this time the MISA had accumulated a huge debt as world sheepmeat prices had plunged.

The major forms of policy assistance to inputs were the Livestock Incentive Scheme (LIS), the Land Development Encouragement Loan

(LDEL) scheme and subsidies for the purchase and transport of fertilizer.

The LIS which was introduced in 1978 offered a combination of low interest loans, and/or reductions of loan principal and tax rebates if certain livestock expansion targets were met. The LDEL was introduced in 1978. This scheme included interest free loans and reductions in principal for farmers if certain land development targets were met. The LIS and LDEL schemes were operational during the entire study period although the level of assistance has been substantially reduced since 1986. Fertilizer subsidies, which were paid until 1986, existed mainly to encourage expenditure on this input when farm income was low. Noticeably, fertilizer subsidies were increased during periods when farmers' incomes were low, and reduced when farmers' incomes improved.

The level of assistance extended to the pastoral sector of New Zealand is shown in Table 1.5. This is further presented in detail by commodities in Table 1.6.

As shown in Table 1.6, sheepmeat received the most assistance. The level provided via the SMPs and producer board stabilization in the early and mid 1980s vastly exceeded that for other commodities. This

Table 1.5 Assistance to Pastoral Agriculture

Year Ended March	1970	1975	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
	(Millions of NZ\$)												
ASSISTANCE ON OUTPUTS													
Dairy Board Stabilization	-16	102	116	-23	49	81	0	0	0	0	0	0	0
Meat Industry Stabilization Account	0	0	-44	26	99	270	274	337	176	2	0	0	0
Supplementary Minimum Prices (SMPs)*	0	28	17	1	245	438	346	215	65	0	0	0	0
Inspection, Grading and Hygiene	1	4	34	39	52	60	59	59	63	59	34	35	35
Town Milk Subsidy	3	6	13	10	13	14	15	19	19	23	8	0	0
TOTAL ASSISTANCE ON OUTPUT	-13	141	136	53	457	863	694	630	323	84	42	35	35
ASSISTANCE ON INPUTS													
Fertilizer Subsidies	5	30	62	52	48	44	41	35	12	6	0	0	0
LIS/LDEL	0	0	3	7	14	14	18	10	4	6	7	9	13
Agricultural Pest Control	2	2	5	6	5	5	6	5	4	4	3	3	3
Other	3	1	9	7	7	8	8	7	3	3	4	2	2
TOTAL ASSISTANCE ON INPUTS	9	33	79	72	74	71	73	57	23	19	14	14	18
ASSISTANCE TO VALUE-ADDING FACTORS													
Advisory Services	2	4	7	9	10	12	12	13	14	16	15	13	11
Labour	0	0	9	7	10	11	12	7	6	2	0	0	0
Research/extension (MAF/DSIR)	4	8	27	34	39	44	48	48	51	58	61	46	46
Animal Health and Quarantine	2	8	19	25	30	30	29	29	32	32	32	31	27
Interest Concessions	5	14	45	63	75	92	119	152	242	207	226	92	26
Taxation Concessions	13	25	78	76	79	67	104	96	168	22	17	13	10
Agricultural organizations	***	1	4	2	2	2	2	3	4	3	3	3	3
Rural Bank Debt Write-Off	0	0	0	0	0	0	0	0	0	76	133	0	0
Climatic Relief Grants**	***	***	0	0	0	0	0	0	0	0	0	37	30
TOTAL ASSISTANCE TO VALUE-ADDING FACTORS	27	59	189	216	245	258	326	348	517	416	487	235	153
TOTAL ASSISTANCE	23	233	405	341	776	1192	1093	1035	863	519	543	284	206

* Includes government grant for meat and wool stabilization in 1975

** In most years, climatic relief was in the form of interest concessions, and is included in that category

*** less than one million

Source: Farming Without Subsidies: The New Zealand Experience

Edited by Sandrey R. and R. Reynolds (1990)

Table 1.6 Assistance to Pastoral Agriculture, by Commodity

Year Ended March	1970	1975	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
SHEEPMEAT													
Stabilization	0	0	0	0	72	269	278	346	176	0	0	0	0
SMP	0	26	0	0	53	183	264	201	65	0	0	0	0
Other	*	1	21	22	31	35	34	34	37	35	20	21	21
Total Assistance to output	*	27	21	22	156	486	576	582	278	35	20	21	21
Apportioned Factor**	9	18	49	56	60	61	81	72	64	71	76	28	24
Total Assistance	10	45	70	80	216	548	657	654	342	106	96	49	45
WOOL													
SMP	0	2	0	0	148	197	82	14	0	0	0	0	0
Total Assistance to Output	0	2	0	0	148	197	82	14	0	0	0	0	0
Apportioned Factor**	7	22	84	84	96	88	108	111	151	134	157	75	42
Total Assistance	7	24	84	84	244	285	190	125	151	134	157	75	42
BEEF													
Stabilization (MISA)	0	0	-44	26	27	1	-3	-9	0	2	0	0	0
SMP	0	0	0	1	43	58	0	0	0	0	0	0	0
Other	*	1	9	10	14	16	15	15	16	15	9	9	9
Total Assistance to Output	*	1	-35	37	84	75	12	6	16	17	9	9	9
Apportioned Factor**	9	18	64	57	60	70	79	94	110	107	107	57	36
Total Assistance	9	19	29	94	144	145	91	100	126	124	116	66	45
DAIRY													
Stabilization	-16	102	116	-23	49	81	0	0	0	0	0	0	0
SMP	0	0	17	0	0	0	0	0	0	0	0	0	0
Town Milk Subsidy	3	6	13	10	13	14	15	19	19	23	8	0	0
Other	*	2	5	7	8	9	9	9	9	9	5	5	5
Total Assistance to Output	-13	111	151	-6	69	104	24	28	29	32	13	5	5
Apportioned Factor**	11	35	71	89	103	110	131	127	216	124	160	89	69
Total Assistance	-2	146	222	83	172	214	155	155	244	156	173	94	74

* Less than one million

** Apportioned factor includes assistance to inputs and assistance to value-adding factors

Source: Farming Without Subsidies: The New Zealand Experience
Edited by Sandrey R. and R. Reynolds (1990)

reflected the relatively poor international prices and high SMP and producer board stabilization levels for sheepmeat during this period.

Assistance to wool, mostly in the form of SMPs, peaked in 1983. Assistance to beef remained at moderate levels over the period. In 1984 and 1985, when support to sheepmeat production was exceedingly high, beef producers were actually paying levies into the board stabilization fund as a consequence of strong international beef prices.

Given these myriad of market forces and institutional changes that have occurred during the period covered in the study, it is interesting to know how the average sheep and beef farm in New Zealand fared in terms of changes in the productivity of the enterprise. In addition, the dearth of information on the changes in the productivity of New Zealand's sheep and beef farms gave impetus to this study.

1.2 Objectives of the Study

The general objective of the study is to determine productivity growth of the sheep and beef industry of New Zealand for the period covering 1973-1974 to 1990-1991. Specifically, the study aims to:

- i) measure total factor productivity on the average sheep and beef farm in New Zealand from 1973-1974 to 1990-1991;
- ii) identify the sources of growth in the productivity of the average sheep and beef farm;
- iii) determine the effect of changes in productivity to the sheep and beef farmer in terms of implicit prices received and prices paid; and
- iv) examine the effect of assistance to inputs and outputs on the performance of the sheep and beef farm.

CHAPTER TWO

CONCEPTUAL FRAMEWORK

2.1 Introduction

This chapter describes the framework on which the analysis and the results of this study are based. The first part focuses on the concept of productivity growth. The succeeding sections discuss the various approaches to productivity measurement as well as their attendant problems. The latter sections are devoted to a discussion of the index number procedure and its theoretical linkage with production economics.

2.2 Productivity Growth

Productivity growth may be defined as the rate of change in the efficiency of the production process. It measures the impact of technological improvements upon the ratio of the physical output to physical inputs. Thus the term productivity growth, which has been used synonymously with total factor productivity, is often associated with technological change or technical progress. More descriptively, productivity growth or technological change represents the percentage change in output that is not explained by the percentage growth in factor inputs. In this sense, productivity growth is referred to as a

residual measure since "it absorbs like a sponge, all increases in output not accounted for by the growth of explicitly recognized inputs" (Domar, 1961 *in* Link, 1987). The residual could, therefore, contain the effects of changing input quality, changes in capacity utilization, economies of scale, or management and entrepreneurial capacity. Productivity increases, as measured by the residual, can also be induced by research, extension, human capital, infrastructure and climatic factors (Kumar and Mruthyunjaya, 1992).

Productivity growth is often conveniently considered as a function of time. Although, why the passage of time should of itself improve productivity is very difficult to explain. Thus time must be a proxy for something which actually does explain productivity growth.

In Nadiri's study (1971), two major sets of factors have been suggested as the determinants of productivity. These are: 1) the technical characteristics of the production process; and 2) the movement of the relative factor prices. The first factor was described by Nadiri as referring to the following technical characteristics:

- (a) the efficiency of production, i.e., reducing the unit cost of all factors of production equally by applying better techniques;
- (b) the bias in technical change, i.e., the nature of the new technique is such that it leads to a greater saving in one input than in the other;

- (c) the elasticity of substitution, which measures the ease of exchanging factors of production in the course of the production process;
- (d) the scale of operation of the production process, i.e., economies (diseconomies) that arise due to changes in the scale of operation of the economy; and
- (e) the homotheticity of the production function, i.e., whether the returns to scale are evenly distributed among all factors of production.

As regards movements in relative factor prices, their influence on productivity is seen in terms of their effect on the rate of factor substitution. Rate of factor substitution is further determined by the factors' elasticity of substitution.

Productivity growth may take several different forms including new processes of production, new goods and new methods of industrial organization especially in the fields of management and marketing. Productivity growth, in all its aspects, is impossible to measure precisely but its essential quantitative characteristic is to shift the production function (embodying all previously known techniques) enabling greater output to be produced with the same amount of inputs, or the same output with lesser inputs. In this sense the introduction of an unused but known technique is not, strictly speaking, a technological change, nor is the alteration of an existing technique unless by chance it shifts the production function. Similarly,

technical progress is not to be confused with the diffusion of existing technical knowledge which does nothing to change production possibilities, or with scientific research that fails to produce new knowledge and which may not always be a prerequisite to technical change (Griliches, 1963).

The shift in the production function associated with productivity growth or technical progress may be illustrated using the Cobb-Douglas production function written in terms of labour (L) and capital (K) as

$$Q = A(t)K^aL^b$$

where Q is output, $A(t)$ is a time-related shift factor, and (assuming perfect competition) a and b are the shares of income distributed to capital and labour respectively ($a+b = 1$). From the expression given above, it is possible to approximate productivity change by estimating a residual growth rate. This follows from first, taking the natural logarithm of both sides of the equation which yields

$$\ln Q = \ln A(t) + a \ln(K) + b \ln(L).$$

Then taking the time derivatives of both sides of the equation and rearranging terms, productivity change ($\Delta TFP/TFP$) in terms of the residual measure ($\Delta A/A$) can be estimated as

$$\Delta TFP/TFP = \Delta A/A = \Delta Q/Q - a \Delta K/K - b \Delta L/L.$$

Diagrammatically, for a single-input production function, technical change may be demonstrated by the shift in the production function from period 0 to period 1 via A_0 to A_1 as shown by movement from point D to point A in Figure 2.1. The residual $\Delta A/A$ is approximated in terms of the line segment DE , while the change in capital intensity is approximated by the segment EA (Link, 1987).

Productivity change can also be conveniently demonstrated with the use of the isoquant map. Figure 2.2 illustrates the case for a two-input production function, showing one isoquant at two different points of time, t_0 and t_1 . If technological progress has occurred between t_0 and t_1 this means that more can be produced at t_1 with the same amounts of inputs (v_1 and v_2) than at t_0 . This is the same as saying that fewer inputs are needed to produce the same amount of output, i.e., the isoquants have moved towards the origin.

So far, what has been illustrated is a case where the isoquant has moved uniformly towards the origin. It should be noted, though, that this uniform movement is not always the case. Technical progress can, for instance, imply that factor saving only occurs for one factor of production, say labour. In this case, the isoquant would still move downwards but not in a uniform fashion (i.e., no parallel shift),

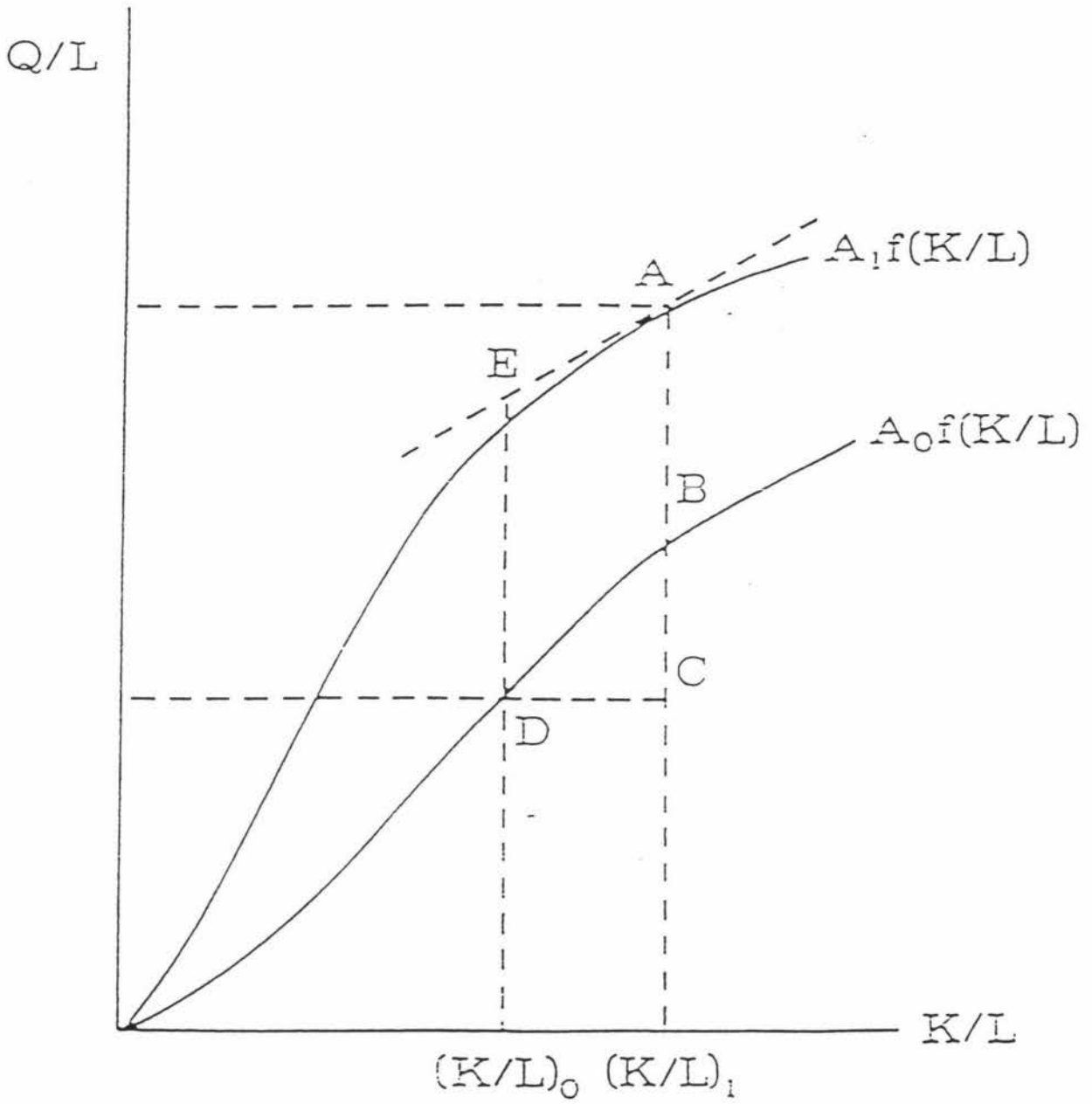


Figure 2.1 Discrete Approximation of Technological Change as a Shift in the Production Function

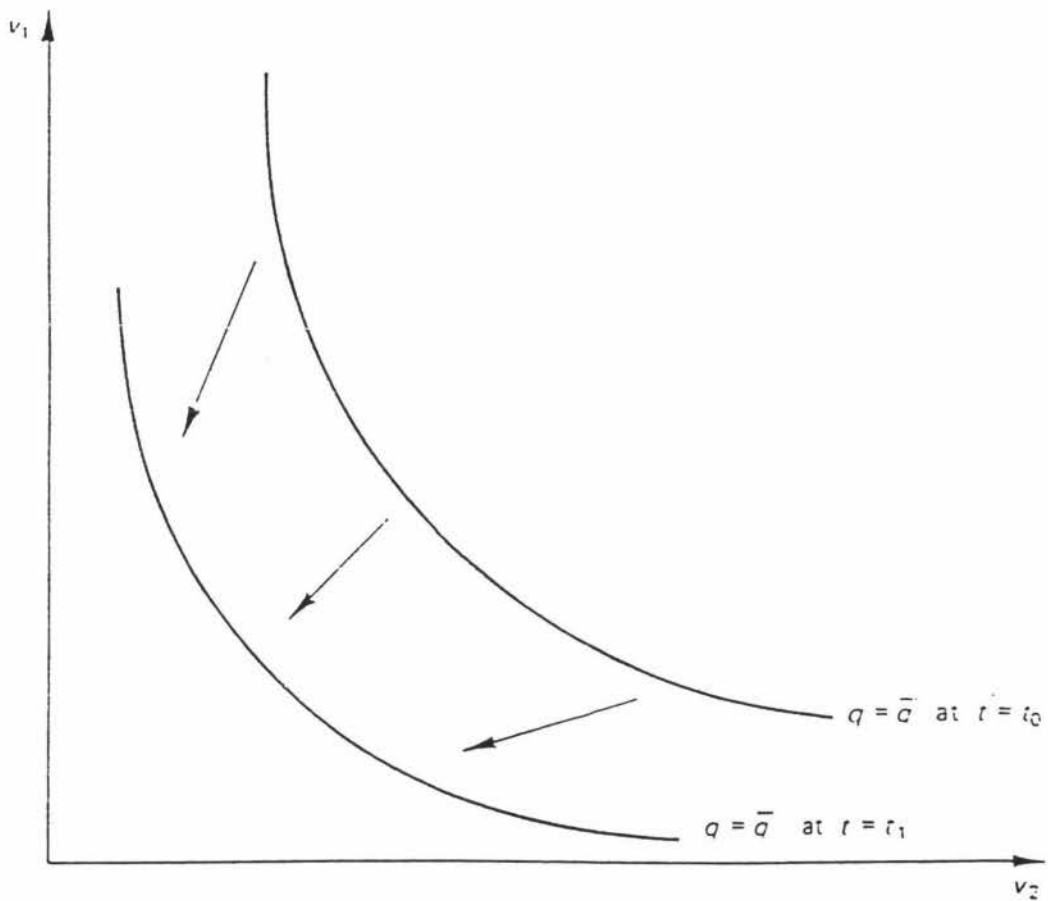


Figure 2.2 Illustrating Technological Change With the Isoquant

indicating biased or non-neutral technical progress (Heathfield and Wibe, 1987). This will be discussed in more detail in Section 2.2.3.

2.2.1 Limitations of Productivity Growth Measurements

The residual measure of productivity suffers from a number of limitations. Specifically, to attribute the residual wholly to changes in efficiency, restrictive assumptions have to be made about the behaviour of the other technical characteristics of the production process. It is commonly assumed, for example, that constant returns to scale, unitary elasticity of substitution between inputs and neutral technological change operate. This procedure, however, cannot be viewed as totally satisfactory as evidently, there is a high degree of inter-relationship between the technical characteristics and consequently, it becomes difficult to be able to identify conclusively the change in output that is the result of a change in any one of the these characteristics (Young, 1971).

Other problems associated with the residual measure of productivity growth are the inaccuracies in the data used and in the specification of the underlying production function. According to Griliches (1963), conventionally derived residual measures of productivity growth are not measures of technical change but are rather the result of errors in measurement procedure. He identified the sources of these errors as:

1) the list of variables affecting output may be misspecified, excluding some relevant factors from the calculations; 2) changes in included variables may be mismeasured, particularly if changes in their qualities are disregarded; and 3) wrong weights may be used in estimating the contribution of changes in individual inputs to the growth in output. Correcting such errors is expected to lead to a reduction of the residual, thereby reducing the proportion of growth previously attributed to the "unexplained" category. Such an approach, however, does not remove technical change from the explanation of productivity growth. Rather, the procedure aims to transform what has been known as a catch-all residual into identifiable changes in the qualities of the inputs.

The subject of errors in measurement and consequently the explanation of productivity growth was further explored in Jorgenson and Griliches (1967) where the authors advanced the hypothesis that if quantities of output and input are measured accurately, growth in total output is largely explained by growth in total input. In their study, attempt was made to eliminate the following measurement errors: 1) errors of aggregation in combining investment and consumption goods, and labour and capital services; 2) errors of measurement in prices of investment goods arising from the use of prices for inputs into the investment goods sector rather than outputs from this sector; and 3) errors arising from the assumption that the flow of services is proportional to stocks of labour and capital by introducing direct

observations on the rates of utilization of labour and capital stock. Their findings, which confirmed their hypothesis, showed that after elimination of aggregation errors and correction for changes in rates of utilization of labour and capital stock, the rate of growth of input explained 96.7 percent of the rate of growth of output. This was an improvement over the initially determined (i.e., not corrected) 52.4 percent rate of output growth attributed to the growth in inputs.

2.2.2 Embodied and Disembodied Technological Change

The role of inputs in conveying new technology into the production activity may be examined in terms of the embodiment hypothesis. In particular, an important distinction is drawn between embodied and disembodied technical improvements. An embodied technical change is one which is incorporated into the latest version of an input: for example, design improvements into the latest version of an equipment². As such, the embodiment hypothesis implies that improvements in technology affect output only to the extent that they are carried into practice either by net capital formation or by the replacement of old-fashioned equipment by the latest models (Lingard and Rayner, 1975). In other words, the possibility of embodied technological change means that the efficiency of production will

²Embodiment is not necessarily limited to capital and material inputs. Technical change may also be transmitted through changes in the characteristics of the labour force, such as its skill and level of education.

depend not only on the current state of knowledge, but also upon the rate of investment in new machines. The latest set of efficient input combinations, though available to all, can be had only at a price - the cost of replacing old stock with new. Those firms which do choose from the latest production possibility frontier are said to be using "best-practice techniques". Firms which bought their capital last year would be using slightly less efficient equipment and those which bought capital some years ago will be using (by current standard) rather inefficient equipment.

Disembodied technical change is defined as technical change which does not require new inputs to be introduced into the production process. It can be identified with a shift in the production function; in particular, with a shift in the efficiency factor. To illustrate, capital may be assumed to be homogeneous such that any one piece of capital is exactly like any other and is equally well suited to any task - more capital simply means more of the same. If this really is a true picture of capital then technological progress must affect all existing processes. If, for example, a new way of making candles was discovered, then all existing candle makers would increase their sets of efficient input combinations immediately, costlessly and equally, making use of existing labour and existing capital to produce more of the same product.

Closely related to the concept of embodiment is the notion of quality change in resources. A resource is said to improve in quality if the average unit of the resource provides an increased flow of services to the production function. The service flow from a current resource is always provided by new purchases and, as a result, the rate of quality change is equal to the rate of embodiment for such a resource. However, the service flow from a durable resource is provided by both the old and the new purchase of resource stock. As such, a gap exists between the average technology employed and the latest technology available. Consequently, in this case, quality change can arise not only from embodiment in current investment but also from a change in the average age of the stock (Lingard and Rayner, 1975).

Jorgenson and Griliches (1967) have referred to "quality change" as a special type of aggregation error. Specifically, they referred to it as the error that arises in aggregating investment goods of different vintages by simply adding together quantities of investment goods of each vintage. If the quality of investment goods, as measured by the marginal productivity of capital, is not constant over all vintages, this procedure results in aggregation errors. An appropriate index of capital services, according to the authors, may be constructed by treating each vintage of investment good as a separate commodity.

But whether inputs are adjusted for quality changes before total factor productivity is calculated must depend on the purpose of the study. If the purpose is simply to measure the increase in the productivity of factors of production over time, it makes no sense to adjust the factors for quality changes. Similarly, if the interest is in advances in knowledge, the effect of these changes somehow need to be isolated. If, on the other hand, the purpose of the study is to lay down the conditions for growth there is a case for adjusting the input series for quality changes to avoid misunderstanding of the growth process; in particular to avoid the impression that growth is costless (Kennedy and Thirlwall, 1972).

2.2.3 Neutrality of Productivity Growth

Interest in productivity growth springs not only from the improved efficiency made possible but also from the implications it has for factor demands and factor rewards. In other words, will technological progress reduce the demand for labour rather more than it reduces the demand for capital (all other things constant) and will it increase wage earnings more than interest rates or vice versa? In short, will technological progress be biased or neutral?

Technological change is biased (or non-neutral) if it alters the production function such that marginal rates of substitution are

affected. Or, technological progress is said to be neutral if it changes the production relationship without affecting the set of partial marginal rates of substitution for relevant input bundles. In other words, a neutral technological change is assumed to affect all inputs equally. Neutral technological changes are represented by a change in the efficiency of technology and/or a change in the economies of scale relationship while non-neutral technological changes affect the substitution relationship between inputs. For example, in the two-factor Cobb-Douglas production function:

$$Q = A(t)L^aK^b$$

an increase in the efficiency parameter, $A(t)$, represents a neutral technological improvement while changes in the elasticity parameters a and b , which affect the ratio a/b , change the marginal rate of substitution of labour for capital (Lingard and Rayner, 1975).

The difference between biased and neutral technological change is illustrated diagrammatically in Figure 2.3. Using the diagram, the effect of technological change is evaluated in terms of changes in the amount of capital and labour (assuming only two factors of production) used in production, assuming that technological change alters the input mix for a fixed level of output. For a given level of output and input price ratio, a labour-saving technological change results in a

higher capital-to-labour ratio; a capital-saving technological change in a lower capital-to-labour ratio; and a neutral technological change in an unchanged capital-to-labour ratio. In terms of Figure 2.3, a labour-saving technological change results in *Isoquant I* (with output level Q^*) shifting inward to point *A*, whereas a capital-saving change results in a shift to point *B*. A neutral technological change is shown by a parallel shift in *Isoquant I* inward to point *C*. At point *C*, Q^* is produced with proportionally less capital and less labour.

Related to the concept of neutrality that has been discussed so far are three other types of neutrality of technological progress most commonly discussed. These are: 1) Hicks neutrality; 2) Harrod neutrality; and 3) Solow neutrality³.

2.2.3.1 Hicks Neutrality

Hicks neutrality is associated with that kind of technological progress which leaves factor ratios unchanged if factor prices remain constant. That is such that:

$$K/L = H_1 (P_K/P_L)$$

³Definitions drawn from Heathfield and Wibe (1987).

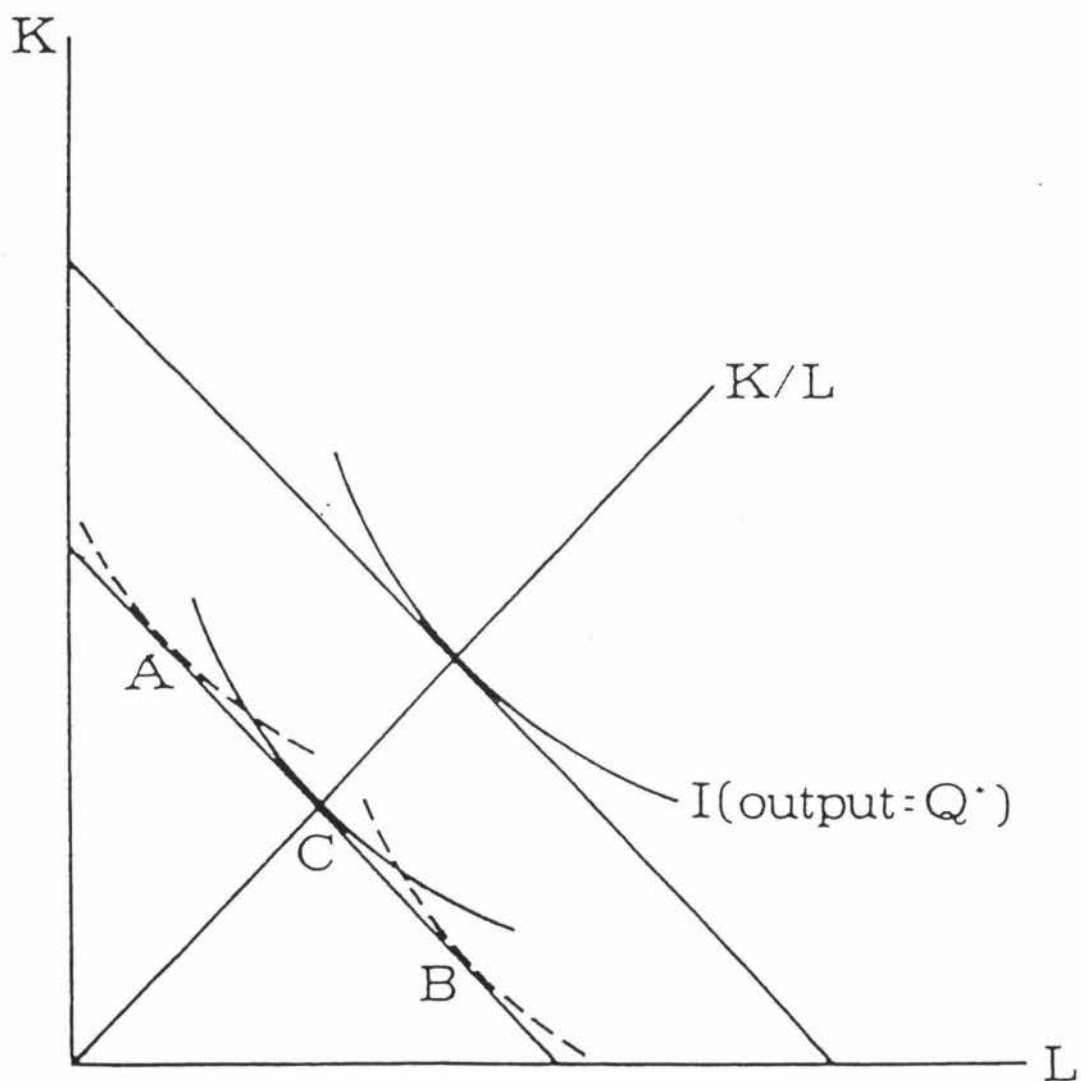


Figure 2.3 Labour-Saving, Capital Saving and Neutral Technological Change: Output Held Constant

where H_1 is any function and K and L stand for capital and labour, respectively. Hicksian technological change is thus labour-saving, capital-saving or neutral if it raises, lowers or leaves unchanged the marginal product of capital relative to the marginal product of labour for a given capital-to-labour ratio. As shown in Figure 2.4, *Isoquant I* represents the initial state of production. The labour-saving effect of technological change is illustrated in *Isoquant II* while *Isoquant III* reflects a capital-saving technological change. *Isoquant IV* characterizes a neutral technological change.

2.2.3.2 Harrod Neutrality

Harrod neutrality is associated with technological progress which leaves capital-output ratios unchanged if the price of capital (i.e., interest rate) is held constant. Symbolically,

$$K/q = H_2 (P_K)$$

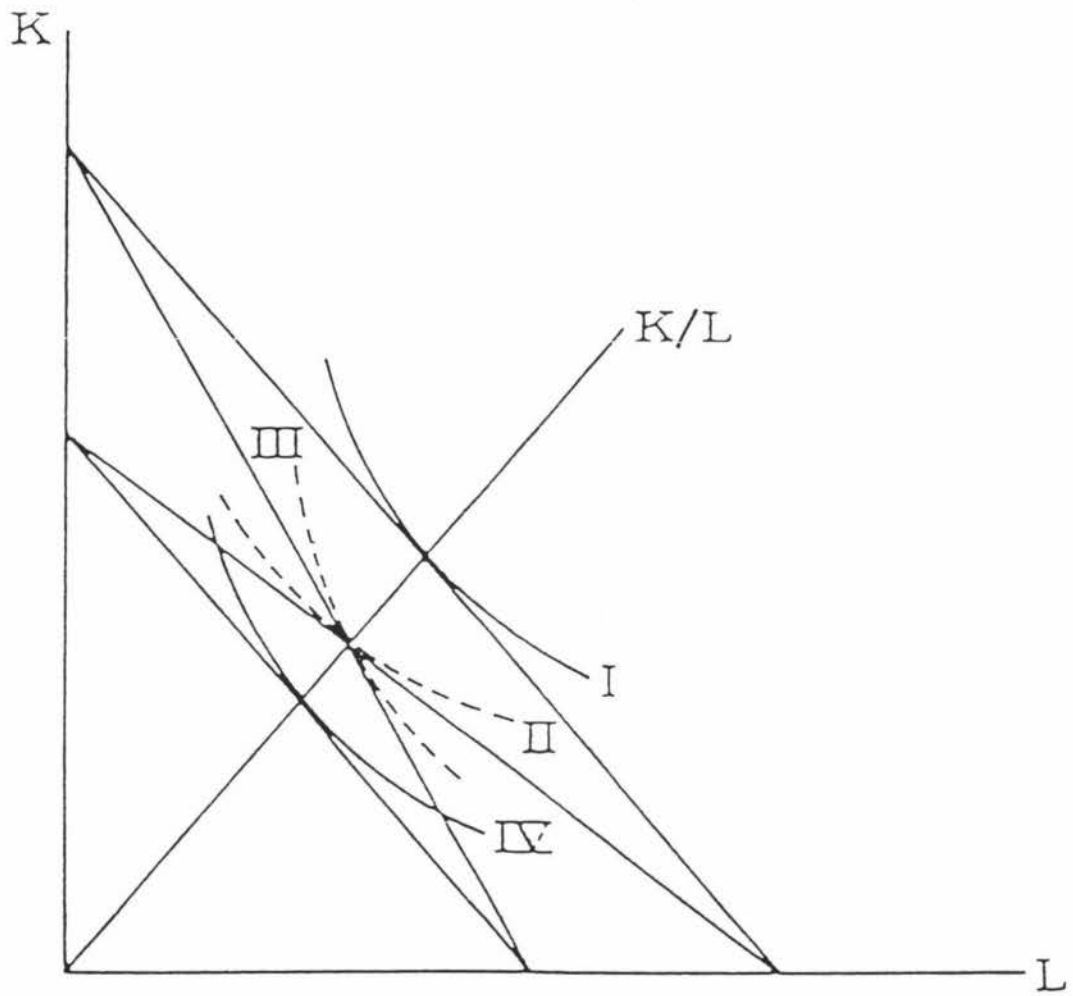


Figure 2.4 Labour-Saving, Capital Saving and Neutral Technological Change: Capital-to-Labour Ratio Held Constant

where K is capital, q is output and H_2 is any function. Thus, Harrod neutral technological progress implies that if P_K is constant, then so is the capital-output ratio.

2.2.3.3 Solow Neutrality

Solow neutrality requires that if the wage rate remains unchanged then so will the labour-output ratio. Mathematically,

$$L/q = H_3 (P_L)$$

where again, L stands for labour, q is output and H_3 is any function.

2.3 Methods of Measurement of Productivity

Productivity measurements are classified as either representing partial factor or total factor productivity (TFP). Partial factor productivity measures output per unit of a single input used. Total factor productivity measures output in relation to the combination of all inputs used.

According to Thirtle and Bottomley (1991), partial factor productivity measures are useful for indicating factor-saving biases of technical change. However, they cautioned that partial indices assign over-riding

significance to the average physical productivity of a single factor as a measure of the overall productivity of the entire process. For instance, in the use of the average product of labour as a measure of productivity, labour-saving improvements resulting from other factors of production are improperly attributed as improvements in labour productivity (Link, 1987).

A useful and meaningful productivity framework is one which identifies the sources of the productivity improvements and their interaction with other factors, such as capital and materials, in the overall production process. Along this line, it is noted that partial factor productivity measures do not quantify the impact of technical substitution. If, for example, a new technology is embodied in capital, Q/L (or the average product of labour) could rise as a result of capital for labour substitution, other things held constant. But if the cost of the new capital-embodied technology equals the cost saving from fewer workers, then total production costs are unchanged and the initial movement in Q/L is misleading with regard to real productivity gains (Link, 1987).

Similarly, Lawrence and McKay (1980) in their study of the Australian sheep industry cautioned about the use of partial productivity measures. They contended that as with any multi-output, multi-input industry it is important to analyze movement in the sheep industry's total output in relation to the movements in total input to measure

productivity change. Partial productivity measures are very sensitive to both the composition of output and the relative intensity of various inputs. For instance, if capital were being substituted for labour, the partial productivity of labour would be increasing faster than that of capital. Likewise, if the importance of wool were declining relative to beef, the quantity of beef produced per unit of any farm input would have increased faster than the quantity of wool per unit of the same input. Thus, while partial productivity measures may indicate changes in the relationship between particular inputs and outputs, they must always be interpreted with caution.

As regards, therefore, the appropriate measure of productivity, it is suggested that as a general rule, it is better not to limit productivity indices that purport to measure change in efficiency to a comparison of output with a single resource (Fabricant, 1959 *in* Christensen, 1975). The broader the coverage of resources, generally, the better is the productivity measure. In this sense, the best measure is one that compares output with the combined use of all resources, thus indicating total factor productivity.

For the purposes of the present study, total factor productivity was the relevant measure considered in examining the performance of the average sheep and beef farm in New Zealand.

2.4 Approaches to Productivity Measurement

The two basic approaches in measuring productivity are known as the parametric or production function approach and the accounting or index number approach.

2.4.1 The Production Function Approach

The production function approach to productivity measurement involves an accurate modelling of changes in the relationship between the quantities of the firm's inputs and outputs over time. In general form, the production function can be specified as

$$Y = f(L, K, R, S, O, v, y)$$

where Y is output, L is labour input, K is capital input, R is raw materials, S is land input, O is other exogenous factors which impinge on the production process, v is a scale factor, and y is an efficiency factor (ABARE, 1990). Increases in output due to changes in the efficiency factor, y , are regarded as a result of growth in productivity.

Productivity growth, which is characterized by improvements in the production technology, is demonstrated by a shift in the production function. For example, productivity growth occurs when there are

improvements in the production technique which reduces the amount of inputs required to produce a given quantity of output. Such a change is illustrated in Figure 2.5 which shows a shift of the isoquant from I_1 to I_2 . This is distinguished from a change in the combination of inputs that is just represented by a movement along the isoquant, I_1 , from A to B . This movement would not change the estimated coefficients of the input variables in the production function, and hence would not be measured as a change in productivity (ABARE, 1990).

In the estimated production function, the shift is measured as an increase in the efficiency parameter. If the form of the production function is fully specified and this function can be observed at different times, productivity changes may be measured as the change in the shift or efficiency parameter in the production function over time (ABARE, 1990 and USDA Technical Bulletin, 1980).

However, it is recognized that there is generally insufficient quantitative information to accurately estimate a fully specified production function. Moreover, it is difficult to obtain sufficient data to be able to identify changes in the relationships among inputs and between inputs and outputs as well as on the other factors that impinge on the production process. Such difficulty in obtaining the required data limits the application to research of the production function approach.

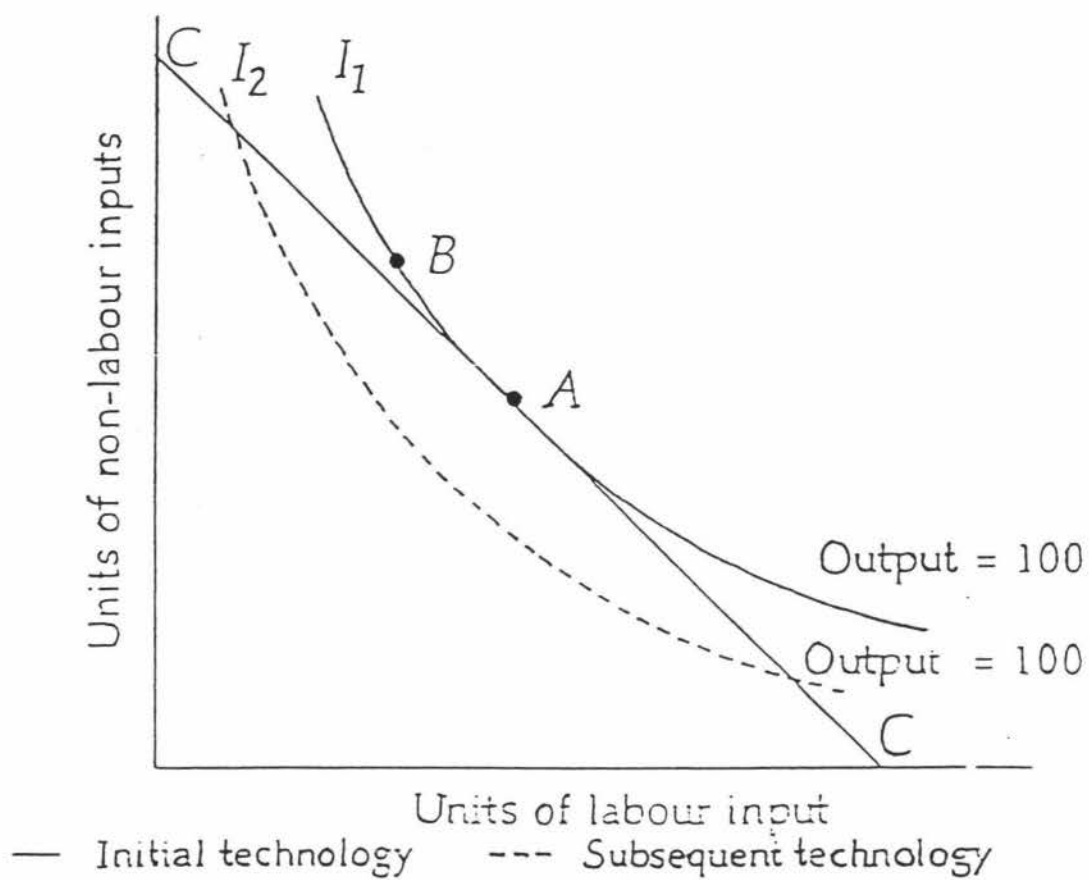


Figure 2.5 Combinations of Input Quantities for a Given Output

Also in relation to problems with the use of the production function approach, Nadiri (1971) pointed out the need to be cautious in interpreting the results that depend on the existence and specification of an aggregate production function. That the use of the aggregate production function gives reasonably good estimates of factor productivity is, according to Nadiri, due mainly to the narrow range of movement of aggregate data, rather than the solid foundation of the function. He stated further that the aggregate production function does not have a conceptual reality of its own; it emerges as a consequence of the growth processes at various microeconomic levels and is not a causal determinant of the growth path of an economy.

2.4.2 Index Number Approach

The alternative procedure, which is adopted in the present study, is to make use of the index number approach. This involves the computation of an index of total output and an index of all factor inputs. The total output index represents the aggregate of all outputs produced while the total input index represents the aggregate of the various inputs utilized in the production process over time. Total factor productivity is then computed as the ratio of the output index to the input index (Rayner, Whittaker and Ingersent, 1986).

The index number approach in the measurement of total factor productivity (TFP) is based on the economic theory of production (Jorgenson and Griliches, 1967). As such, total factor productivity estimates derived from an index number formula are based on the implicit assumption of an underlying production function that accurately describes the maximum output attainable from a given set of factor inputs (Link, 1987). To illustrate: If output, Q , and a vector of n inputs (x_1, \dots, x_n), denoted by X are related as

$$Q = A(t)f(X)$$

where $A(t)$ is a time related shift factor, then total factor productivity can be approximated as

$$TFP = A(t) = Q/f(X) = Q / \sum \omega_i x_i$$

where the ω_i ($0 \leq \omega_i \leq 1$) represents the individual input weight. The percentage rate of growth over time of TFP is denoted as

$$\dot{TFP}/TFP = \dot{A}(t)/A(t) = \dot{A}/A$$

where the dot notation refers to a time derivative and where the time notation for $A(t)$ is frequently dropped for simplicity (Link, 1987).

The advantage of using the index method is that productivity can be measured using only information on prices and quantities, without the need to estimate the coefficients of a production function. As such, numerical estimation is simpler than for a production function. Further, an appropriately selected indexing procedure will give a productivity measure as robust as, and of similar magnitude to, those which would be obtained from a production function (ABARE, 1990).

2.4.2.1 Index Number Problems

The index number approach, according to Capalbo, Ball and Denny (1990), is designed to approximate the spatial and/or time derivatives of the production technology using only information on prices and quantities, thus some limitations should be expected. The limitations were pointed out by the authors as originating from the underlying assumptions, particularly the assumption of competitive markets. Conceptually, government policies are distorting the productivity measures if they are resulting in inefficiencies in production. If the producers are simply operating at a different location on the production possibility surface, then according to the authors, there is no inefficiency in resource use, although social welfare implications are likely. If the government programs constrain producers to be inside the frontier, then the authors stated that inefficiencies in resource use are introduced.

A disadvantage in the use of the aggregate index numbers, cited in ABARE (1990), is that it is not possible to determine whether changes in measured productivity are due to technical advances or to other exogenous factors impinging on the production process. The USDA (1980) pointed to the weighting procedure involved in combining the heterogeneous inputs and outputs into an aggregate index as another problem with the index number approach. For example, it was found that simply by changing the (price) weights used in the aggregation of inputs in a hypothetical case, the measured productivity growth rate was significantly changed.

2.4.2.2 Justification for Use of the Divisia or Tornqvist Index

Despite the popularity of the index number method among research practitioners, a major area of disagreement exists regarding the choice of a particular index number procedure for aggregating inputs and outputs. For instance, Christensen (1975) noted in the case of the USDA's total factor productivity index that its use of Laspeyres⁴ indices for total output and total input appears to bear a serious problem. In particular, Christensen pointed out that it is difficult to justify keeping the base period for the Laspeyres index fixed for long periods of time.

⁴The Laspeyres index method makes use of base year quantities in the computation of each index number using the formula: $(P_1Q_0 / P_0Q_0) \times 100$, where P_1 stands for prices in the current year, P_0 is price in the base year, and Q_0 stands for quantity in the base year (Levin, 1987).

He suggested that the USDA institute a 'superlative' index number procedure, such as Fisher's⁵ ideal index or the Tornqvist index, which can closely approximate the underlying production process. Such concern may be attributed to the discovery in recent decades that properties of index numbers can be directly related to the properties of the underlying aggregator functions (e.g., production functions, utility functions, etc.), that they represent (Caves, Christensen and Diewert, 1982). This relationship between aggregator functions and index number formulas has been referred to as the economic theory of index numbers. From this theory, it has been demonstrated that index number formulas can be explicitly derived from particular production functions. For instance, it has been found that the Laspeyres index implies a linear production function, the geometric index implies a Cobb-Douglas production technology and the Tornqvist index implies a homogeneous translog production function (Capalbo, et. al., 1990).

As regards, therefore, the appropriate index number procedure with which to aggregate heterogeneous components of output and inputs, economic theory suggests that the relevant index formula should be one which has the ability to adequately represent the production choices of a profit-maximising producer (Boyle, 1988). An index formula that

⁵Fisher's ideal index number is a combination of the Laspeyres and Paasche indices and is computed using the formula: $(\text{Laspeyres Index} \times \text{Paasche Index})^{0.5}$. The Paasche index method, in contrast to the Laspeyres method, uses current year quantities in computing each index number. The formula for the Paasche method is given as: $(P_1Q_1 / P_0Q_1) \times 100$ (Boyle, 1988).

imposes unappealing *a priori* restrictions on, for instance, substitution possibilities between outputs or inputs would not be considered suitable in summarising the production technology. For example, linear functions which are implied by the Laspeyres index impose the restriction of infinite substitution possibilities while Cobb-Douglas functions imply a unitary elasticity of substitution. These conditions, according to Boyle (1988) appear too stringent to impose *a priori*. It is preferable to employ indices which allow a less restrictive producer response. This condition is satisfied by the Divisia or the Tornqvist index. For this reason the Tornqvist index was employed in the present study in aggregating the inputs and outputs of the sheep and beef farm in New Zealand.

2.4.2.3 Properties of the Tornqvist Index

The Tornqvist index is an approximation to the Divisia index⁶. Like other index numbers, it is based on price and quantity data. It is calculated using the chain principle rather than a fixed base as in the Laspeyres index. The main advantage of a chain index is in the reduction of errors of approximation as the production process moves from one configuration to another (Jorgenson and Griliches, 1971). If

⁶The Tornqvist index is referred to in other literatures as the Divisia index but in a strict sense it is a discrete approximation to the Divisia index. The Tornqvist index is expected to carry the properties of the Divisia index (Christensen, 1975).

weights are changed continuously, errors of approximation are reduced to a minimum.

Expressed in log-change form, the Tornqvist index is written as:

$$\log \left(\frac{Q_t}{Q_{t-1}} \right) = \sum_{i=1}^N v_{it} \log \left(\frac{q_{it}}{q_{it-1}} \right)$$

where:

$$v_{it} = (P_{it}q_{it} / \sum_{j=1}^N P_{jt}q_{jt} + P_{it-1}q_{it-1} / \sum_{j=1}^N P_{jt-1}q_{jt-1}) / 2$$

- and where Q_t = total output (or input) at time t
 q_{it} = quantity of output (or input) i at time t
 p_{it} = price of output (or input) i at time t
 $p_{jt}q_{jt}$ = value of all outputs (or inputs) at time t

As indicated in the formula, the relative importance of the component input items in the aggregate Tornqvist index for total factor inputs is indicated by the weights of the component inputs. The weights are derived as the ratio of the cost of a particular input to total costs. The same principle applies in the construction of the index of total outputs. The Tornqvist index between adjacent periods is then calculated as the antilog of the sum of log proportional changes in the components

(inputs and outputs) weighted by the arithmetic mean of their shares in the total value for the two periods (ABARE, 1990).

The Tornqvist index implies a homogeneous translog production function. According to Christensen (1975), the homogeneous translog production function can provide a second-order approximation to an arbitrary twice differentiable homogeneous production function. Having this approximation feature, the Tornqvist index is considered a "superlative" index. It is also characterized as being "flexible" as it can reflect an arbitrary set of substitution possibilities at any given feasible point.

The Tornqvist index can be shown to satisfy most of the standard Fisher tests⁷, in particular, the commodity reversal test, the identity test, the commensurability, the strong proportionality test and the time reversal test. It does not satisfy the factor reversal test and is only approximately consistent in aggregation⁸, i.e., an overall Tornqvist index of Tornqvist indices of subaggregate groups is only approximately

⁷Fisher outlined eight requirements which he considered desirable for a given index number. These include commodity reversal, identity test, commensurability, determinateness, proportionality, time or point reversal test, circularity test and factor reversal. These are discussed in Boyle (1988).

⁸'Consistency in aggregation' is also known as Vartia's property. It states that an index is consistent in aggregation if the value of the index calculated in two stages necessarily coincides with the value of the index as calculated in a single stage (Boyle, 1988).

equal to a Tornqvist index of all the basic components within these subaggregate groups (ABARE, 1990).

An important implicit assumption underlying the use of the Tornqvist index is the existence of a competitive market environment. This is necessary to eliminate the first order derivatives of the underlying function. Elasticity of scale of the translog function changes with factor proportions and with the level of production; elasticity of substitution also depends on the level of output and the level of inputs (Heathfield and Wibe, 1987).

CHAPTER THREE

REVIEW OF RELATED LITERATURE

3.1 Introduction

This chapter is devoted to examining empirical studies on productivity measurement. Section 1 presents a selection of studies on productivity written by various authors overseas. Section 2 reviews selected studies related to productivity measurement done on the New Zealand and the Australian economies.

3.2 Review of Selected Studies from Overseas

3.2.1 Chen's Study (1971)

The study was done for the Manchurian agriculture covering the period 1914 to 1957 to show that the concept about agricultural productivity becoming stagnant over time in traditional societies was also plausible for a newly settled region, such as Manchuria, if production is based on traditional factors. The procedure employed in the construction of the productivity index followed the Solow ratio method.

As found in the study, stagnation of agricultural productivity occurred in Manchuria during the 43-year study period as indicated by the 0.2

percent trend rate of growth in productivity. Based on this, it was concluded that no matter how abundant the land, so long as the state of art in agriculture remained unchanged, the expansion of labour input through immigration and other means could only push agricultural productivity of the newly-settled region from a lower level to a higher level of stagnation.

3.2.2 Ball's Study (1985)

Tornqvist indexes of outputs and inputs were used by Ball to construct indexes of productivity growth in the US agriculture over the postwar period from 1948 to 1979.

The results obtained indicated that total factor productivity in US agriculture grew at an annual rate of 1.75 percent, compared with the 1.70 reported by the USDA for the same period. Aggregate output grew at an average annual rate of 1.99 percent from 1948 to 1979, while aggregate input grew at 0.24 percent. Hence, growth in aggregate input accounted for about 12 percent of the growth in output; increases in productivity accounted for about 88 percent. Sources of the growth of productivity in US agriculture during the period were not identified in the study.

3.2.3 Rayner, Whittaker and Ingersent's Study (1986)

The empirical portion of this study was concerned with measurement of productivity growth in the UK agriculture from 1964-1965 to 1978-1979. Estimates of total factor productivity were made using the Tornqvist index procedure.

The results obtained showed an average rate of growth of productivity originating in the UK agriculture of about 1 percent per annum for the period covered in the study. No further investigation of the sources of productivity growth was made. A caveat was given by the authors, however, regarding measurement errors arising from their inattention to quality change, omission of inputs, and biases resulting from the assumption of competitive equilibrium, which could diminish the reliability of the productivity growth measure obtained.

3.2.4 Shoemaker and Somwaru's Study (1986)

Total factor productivity was estimated by Shoemaker and Somwaru for seven dairy States in different regions in the United States from 1978 to 1982. The Tornqvist index was used in the construction of the TFP index. Results of the study are presented in Table 3.1.

Table 3.1 Sources of Growth, 1978-1982

Item	Pennsylvania	Vermont	Florida	Wisconsin	California	New York	Texas
				(Percent)			
AVERAGE ANNUAL GROWTH RATE							
Output	4.41	5.75	8.04	3.71	8.14	3.83	5.38
Total Input	2.83	2.91	2.64	4.26	5.29	2.22	1.45
Capital	3.02	3.24	3.80	2.17	4.14	2.17	2.56
Labour	0.48	0.67	0.22	0.84	0.32	0.74	0.07
Materials	-0.67	-1.00	-1.38	1.25	0.83	-0.69	-1.19
Total Factor Productivity (TFP)	1.58	2.84	5.40	-0.55	2.85	1.60	3.93
GROWTH IN INPUTS AND TFP*							
Total Input	64.13	50.64	32.82	114.78	65.01	58.09	26.92
Capital	68.44	56.48	47.25	58.34	50.91	56.82	47.66
Labour	10.85	11.64	2.76	22.73	3.95	19.35	1.34
Materials	-15.16	-17.48	-17.19	33.70	10.16	-18.09	-22.08
TFP	35.87	49.36	67.18	-14.78	34.99	41.91	73.08

* As a percentage of the growth of output

Source: Shoemaker and Somwaru (1986)

The average TFP growth for the seven States from 1978 to 1982 was estimated at 2.5 percent per year. The growth in dairy output was distinguished in the study between the part originating from the growth in inputs and the part due to total factor productivity. This is shown in detail in Table 3.1. It was observed that capital was an important source of output growth in all regions, and materials were less important. The contribution of labour was more important in the traditional regions and less important in the more capital-intensive regions. Productivity growth was significant in all regions.

Based on these findings, it was concluded that structure (in terms of relative factor intensity and growth) was important in explaining output growth and productivity differences among the regions included in the study. Also, it was concluded that TFP growth and technological change were important contributors to the output differentials among the regions. Nonetheless, it was recognized that TFP is a residual based on measured items that can have measurement errors; hence, part of the residual is TFP and part is measurement error.

3.2.5 Boyle's Study (1987)

The study concerned measurement of total factor productivity of Irish agriculture from 1960 to 1982. The Fisher-Ideal aggregator index was used in the estimation of the productivity index.

The findings of the study indicated an average annual growth rate in aggregate output of 2.74 percent and in aggregate input use of 1.67 percent resulting in a TFP estimate of over 1 percent for the period 1960 to 1982. Explanation of the TFP growth was not explored in detail in the study although factors such as agricultural research, farmer training, education and technical advice which are publicly funded, were mentioned as potentially related with the evolution of TFP.

3.2.6 Thirtle and Bottomley's Study (1991)

New estimates of total factor productivity in UK agriculture were derived in this study by Thirtle and Bottomley which covered the period 1967 to 1990. The Tornqvist approximation of the Divisia index was used in the calculation of the TFP index.

As indicated in the study, the UK aggregate agricultural accounts have been adjusted and used to produce a TFP index. Policy interventions such as subsidies have been allocated to the appropriate enterprises or inputs, and all categories of farm labour have been included. Farm-produced capital items have been allocated to the appropriate input categories. For all capital items, running costs and depreciation have been taken unaltered from the aggregate agricultural accounts. Rent has been imputed to owner-occupied land and interest has been attributed to all capital items. Quality adjustments, however, were not

attempted for either primary factors of production or intermediate inputs.

The TFP index derived in the study indicated an overall growth of productivity in UK agriculture of 1.9 percent per annum for the period 1967 to 1990. Noticeably, TFP growth increased after the UK joined the European Community (EC) in 1973 but has fallen considerably since 1985. As explained in the study, this trend appeared to be a case of price response on the output side, i.e., output growth was rapid following rising prices and then became slow when prices ceased to rise. At the aggregate level, it was indicated that the change in productivity seemed to be explained by increased aggregate output and decreased aggregate input in about equal proportions.

3.2.7 Jorgenson and Gollop's Study (1992)

This study provides updated estimates of TFP in US agriculture during the postwar period. Compared with the previously cited work by Ball (1985), this study covers the period 1947 to 1985. The measured rates of productivity growth were obtained using Tornqvist indexes of outputs and inputs.

The results indicated an average annual rate of TFP growth in agriculture of 1.58 percent. Inputs were categorized as labour, capital,

energy and materials. Except for labour which declined by 1.8 percent per year, the rest of the input groups have all increased annually by 0.8 percent for capital, 2.1 percent for energy and 1.2 percent for materials. Output growth was estimated at 1.9 percent per year. Source decomposition of the growth in output showed 80 percent originating from total factor productivity and 20 percent from the collective contribution of all inputs. No further attempt was made to identify sources of productivity growth in the US agriculture.

3.2.8 Kumar and Mruthyunjaya's Study (1992)

This more recent study extends the measurement of TFP in the wheat region of India to the period from 1970-71 to 1988-89. The Divisia-Tornqvist index was used to derive the TFP indices for wheat grown in the major states of India. In assessing the determinants of TFP, the TFP index was estimated as a function of the following variables:

- a. number of regulated markets per thousand hectares of wheat area;
- b. proportion of rural males who are literate;
- c. four years lagged cumulative publications on Indian wheat abstracted from *Indian Science Abstracts, 1965-1988*;
- d. share of machine labour in total labour;
- e. January, February and march rainfall; and
- f. trend variables

Results of TFP decomposition by regression indicated market infrastructure, research and mechanization as the most important sources of growth in TFP for the wheat region in India. Rain from January to March, the critical stage of wheat plant growth, was of crucial importance for growth in productivity. The estimated effect of literacy on TFP was found to be negative and insignificant. This was seen as a result of the moving-away of the educated rural youth to non-agriculture.

3.2.9 Wong's Study (1992)

This study examined the trends and differences in agricultural productivity growth in China and India from 1960 to 1983. The Solow geometric index method was used to measure total factor productivity. In identifying the sources of growth, the study looked at the relationship between land reform and productivity changes between the two nations. It compared the rate of change in productivities and ascertained the contributions of land, labour, livestock, machinery, fertilizer, technology and productivity growth.

The results indicated strong upward trends in labour and land productivity in the two countries during 1960 to 1983 but a downward trend in total factor productivity in the 1960s and 1970s. Further, the results suggested that both China and India exhibited no net gain from

technical change, which implied that most of the agricultural growth came from increased use of factor inputs and not from technical change. According to the author, this meant that the benefit of technology in this case was outweighed by the cost of the technology, namely the cost of the additional input used. He explained that the production function in the two countries may have shifted upward over the twenty years considered in the study but the production point moved away from the expansion path in a manner that may have counteracted the benefit of technical changes; thus resources were misallocated. The analysis of productivity trends between China and India also suggested that land reform alone did not necessarily generate positive effect on production efficiency and thus, should not be treated as the panacea for agrarian problems in developing countries.

3.2.10 Rosegrant and Evenson's Study (1992)

This study was done to assess total factor productivity in the Indian agriculture and the results compared with TFP estimates for Pakistan and Bangladesh. The Tornqvist index method was used in deriving the TFP indexes for the period 1957 to 1985.

The results showed that in India, TFP grew steadily over time at 1.01 percent annually. TFP in the Pakistani crops sector grew at 1.07 percent a year, nearly the same rate of growth achieved in India.

Growth in TFP had been slower in the Bangladesh crops sector at 0.78 percent per annum.

As indicated in the study, TFP growth in India explained about one-third of the total output growth in the crops sector from 1957 to 1985. The main sources of productivity growth were identified as public research and extension and private research. Specifically, the stock of research, extension expenditures, domestic and foreign inventions, and adoption of modern varieties were determined to have had positive impact on total factor productivity in the Indian crops sector. The number of markets, used as a proxy for the level of infrastructure development also significantly explained TFP growth in India. Noticeably, these sources of TFP growth are consistent with the results of the previously cited work by Kumar and Mruthyunjaya (1992) done on the Indian agriculture.

The estimated effects of public research in India were found to be consistent with the findings for Bangladesh and Pakistan, where public research was estimated to have the largest impact on TFP.

3.3 Review of Selected New Zealand and Australian Studies

Studies of productivity measurement in New Zealand are varied in scope ranging from research that has focused on specific sectors of the economy in particular, to work that has tried to assess the productivity of the economy in general. These studies also vary in their approaches to productivity measurement. Some works have concentrated on single factor analyses (e.g., labour productivity) while other studies have used multi-factor productivity measurements (e.g., labour and capital productivity). The inclusion of policy variable as a factor influencing output growth has also been considered in one of the studies reported here.

Some selected Australian studies on productivity are reviewed here basically to provide an insight into the performance of some sectors of the Australian agriculture. In particular, it is recognized that the New Zealand and Australian farm sectors are similar in respect to the high proportion of farm output derived from livestock activities and high dependence on export markets.

The review of the studies presented in this section focuses on the methodologies employed and the empirical results obtained.

3.3.1 Philpott's Study (1966)

This pioneering work by Philpott was basically a survey of knowledge regarding long term changes in the productivity of New Zealand and its relation to economic growth. It covered the pre-war period represented by the years 1926 to 1939 and the post-war period from 1946 to 1964. Two approaches to productivity measurement were used: the first involved the measurement of trends in total national product per worker; and the second, the measurement of productivity changes (based on net product per person employed) in each sector of the economy.

The first approach is plainly measurement of labour productivity. This was calculated based on the net product of the sector divided by the number of persons employed. The net product of a sector was calculated as the gross value of output less the payments to other sectors (including imports) for goods and services used in production. The residual net product represents the amount available to reward the factors of production - land, labour and capital - employed in the sector.

Philpott noted in his study that the growth in real per capita national product is a result of the separate rates of real productivity growth in

each sector, together with the changes in the relative size of each sector.

In the second approach, which used productivity changes by sectors, measurement was looked at from the viewpoint of the total product of the economy and its component sectors. Specifically, sector productivity rates (which basically represented net product per person employed in the sector) were combined into a weighted average for the whole economy, using the sector's proportionate contribution to national net product as weights.

The results obtained indicated a 2.1 percent per annum rate of growth in the productivity of the New Zealand economy during the pre-war period. This was evidently higher than the 1.7 percent per annum rate achieved during the post-war period. It was observed, nonetheless, that the productivity growth rate seemed to be rising during the later years of the post-war era. For the primary industry (composed of farming, forestry and logging, hunting and fishing, and mining), productivity growth during the pre-war period was estimated at 3.6 percent per annum. This growth slightly declined to 3.4 percent per annum during the post-war years.

The overall low post-war productivity growth rate in New Zealand was attributed to the reverse trends in sectoral importance during the post-

war as compared to the pre-war period. Specifically, the sector with the highest productivity growth rate during the pre-war period, viz, agriculture (or primary production), had contributed a much smaller proportion of post-war national product. On the other hand, the pre-war low productivity growth sector, viz, tertiary production, had risen markedly in importance. As such, it was noted in Philpott's study that it was perhaps inevitable that, as the economy grows, and a greater proportion of its activity is devoted to tertiary production where productivity growth rates are low, the overall national productivity rate will decline. It was stated further that there was clear evidence of consistently higher productivity growth rates for the primary sector, particularly the agriculture sector, compared with most other sectors. Any increase in the relative size of the primary sector will therefore contribute to an increase in the aggregate national productivity rate. Furthermore, it was pointed out that the rise in aggregate productivity in New Zealand observed in the last five years covered in the study has coincided with the renewed interest in the need for increased agricultural production and the introduction of economic policies towards this end.

In identifying the determinants of productivity growth, Philpott's study used the Solow growth equation and distinguished two factors to which changes in productivity can be attributed. The first factor was related to the "growth in stock of capital per worker". The second factor has

been called "efficiency". This includes the effect of technical progress, improvements in managerial skill, more intensive labour effort and increasing returns to scale. The results indicate that in the nine years (1955-64) considered during the post-war period, about 1.1 percent of the annual increase in product per worker was due to increased capital per worker and about 0.8 percent due to increased efficiency. The growth in productivity during the pre-war years was all attributed to increased efficiency since, as stated in the study, growth in capital per worker during this period was virtually non-existent.

The conclusion reached in the study suggested that in the effort to increase productivity, it is desirable to ensure that there is optimal allocation of capital and to maintain a high rate of efficiency. The latter objective was based on the assumption that raising efficiency reduces capital requirement. The reduction in capital requirement also has the effect of reducing the required annual investment and relieving some of the pressure on the overseas balance of payments as long as the major proportion of capital equipment comes from overseas.

3.3.2 Philpott, et. al.'s Study (1967)

The study aimed at providing estimates of farm income and productivity in New Zealand's agriculture during the period 1921 to 1965.

The productivity ratio derived for the agriculture sector was calculated as the rate of output per unit of aggregate input. In the study, the total output series was represented by the volume index of gross farm production which included agricultural, pastoral and dairy produce. This was calculated by combining individual output indexes using weights in the same proportion as in the Official volume of farm production figures. The aggregate or total farm inputs index was calculated by combining land, capital, labour and real working expenses (in Official figures) using weights according to the quantities of inputs used.

The resulting trend in output per unit of aggregate input, as determined in the study, indicated an average rate of increase in overall productivity in New Zealand agriculture of 0.7 per cent per annum. But it was also shown that there have been fluctuations in productivity over the period under study. These fluctuations appeared to be related to changes in the level of investment. In the 1920's, early 1950's and early 1960's inputs were high in relation to outputs achieved. As indicated in the study, these were periods characterized by high business confidence and satisfactory liquidity. On the other hand, the early 1930's, early 1940's and late 1950's were referred to as periods wherein confidence had declined and re-investment had slackened. Nonetheless, the investments made on improvements during the better

years continued to raise output in the periods of economic slowdown. As a result, output per unit of aggregate input increased rapidly.

3.3.3 Young's Study (1971)

The objective of the study by Young was to measure the productivity growth in the Australian rural industries for the period 1948-1949 to 1967-1968 as well as to identify some of the factors which have possibly influenced the rate of productivity growth. Using the ratio method based on the Solow approach, Young was able to calculate an average productivity index that had an annual compound rate of growth of 1.9 percent. It was determined that 52 percent of this growth was due to changes in the quantity of capital, labour and intermediate inputs. The remaining 48 percent was the residual measure. In trying to break down this residual into component factors which may have been responsible for the growth in productivity, Young initially considered climate and the level of government's bounties and subsidies as potential explanatory variables. A trend variable was also designated to represent the effect of other factors not identified in the regression model. The results indicate that bounties and subsidies did not have any significant influence on productivity, while the climate and trend variables were able to explain 89 percent of the variation in the productivity index. When examined on its own, the trend variable was found to account for 78 percent of the growth in productivity. This

meant that a very large proportion of the variation in productivity was left unexplained.

A further attempt at investigating the 'residual' measure obtained was made by adjusting the quality of the labour input. In this sense, education was introduced as a potential source of productivity growth. This was based on the hypothesis that more education raises the marginal productivity of labour. Appropriate adjustment to the labour input was done by weighting the labour input using expenditure on education. TFP was recalculated and the results indicated a 1.16 percent compound annual rate of growth. Further, it was determined that in this case the residual was reduced from 48 percent to 29 percent of the growth in output. Regression was re-run using the labour-adjusted TFP index and with rainfall and a trend variable as explanatory variables. The results showed that of the 29 percent change in output unexplained by the changes in the quantity of inputs and in the quality of labour, some 72 percent can be attributed to changes in rainfall and the trend variable. On its own, the trend variable was able to account for 57 percent of the unexplained 29 percent growth in output.

The reduction of the residual in this particular study was viewed by Young as still not entirely satisfactory because of the recognized weaknesses in the data used and the remaining problem of not being

able to totally identify the sources of productivity growth. These, the author noted, detracts from the statistical significance of the results obtained.

The conclusion reached in the study stated that the effects of the cost-price squeeze on farm income are unlikely to be solved solely by raising productivity. As Young observed, increases in productivity have tended to be translated as increases in output. In the context of the relatively inelastic demand for rural products, Young believed that the higher output will not necessarily earn sufficient revenue to offset the high cost of inputs.

3.3.4 Johnson's Study (1972)

This study extended the previously cited work by Philpott (1966) by analyzing the role of efficiency in the growth of New Zealand agriculture. Johnson's approach made use of productivity measures based on gross product/gross input ratios, net product/factor input ratios, neutral technology production functions and production functions based on biased factor efficiency growth.

Two distinct types of efficiency were distinguished by Johnson. The first was related to new equipment as being more productive, other things unchanged, than the equipment replaced. In this sense,

Johnson also related this type of efficiency to other inputs used in agriculture such as new weedicides and pesticides, new crop varieties and genetically better livestock. The second type of efficiency distinguished by Johnson was in the area of management. According to him, better management is synonymous with the "education" of the entrepreneur and his employees in that new skills of farming are learnt that enable new technology to be incorporated in the day to day running of the farm enterprise. He cited, for instance, that increased labour productivity could be achieved largely by adapting management to the labour saving opportunities available.

In measuring efficiency growth for the post-war period of 1946-1967, Johnson estimated neutral technology growth rates for a gross output and a net output production function of the Cobb-Douglas type. The results obtained showed an estimated technological growth of 1.89 percent per annum and 1.47 percent per annum in terms of net output and gross output, respectively. These results, however, were described by Johnson as being statistically not acceptable. He pointed out that Cobb-Douglas production functions explain very little in a steady growth industry. Further, he stated that the assumption of neutral technology is quite restricting on the forms of productivity that can be tested. He said that a closer examination of the nature of technological advance is possible by assuming factor augmenting technical change. By employing production functions with elasticities of substitution not

equal to unity, Johnson said that the assumption of neutral technological change can finally be abandoned.

As such, Johnson tested for factor efficiency growth by using a constant elasticity of substitution (CES) production function, where the elasticity of substitution is not equal to one. The main result of his analysis indicated that for agriculture, the growth of factor efficiency was concentrated almost completely on the labour input. It was determined that efficiency of the labour input increased at 2.8 percent per annum. Growth in efficiency of capital and materials was estimated at 2.4 percent per annum and 2.3 percent per annum, respectively. Further, Johnson estimated that the growth in labour efficiency was equivalent to an overall growth in productive efficiency of 0.95 percent per annum.

Overall, it was concluded that post-war efficiency growth had been labour augmenting, i.e., technical change during the period had been relatively labour saving and capital using. In fact, the whole survey of efficiency growth in New Zealand agriculture, according to Johnson, showed that technology was utilized in farming through better and more improved farming systems and not so much through better quality inputs themselves. In the post-war period for New Zealand agriculture, this, he said, has meant that labour efficiency had increased rapidly through better management techniques, which in

turn had incorporated better inputs when and where they were available.

3.3.5 Johnson and Taylor's Study (1976)

The study examined productivity in New Zealand agriculture and related industries for the 1960-1973 period. With the available data, they measured productivity change at three levels of aggregation of inputs, i.e., output per unit of labour input, output per unit of labour and capital input combined and output per unit of total input, including all non-factor inputs. Aggregate output index was based on the Official index of production series. Productivity index was derived using the formula

$$I_t = P_0Q_t / (W_0L_t + R_0K_t + S_0M_t)$$

where

P_0Q_t = value of output at base year prices

W_0L = labour share at base year wage

R_0K = capital share at base year return

S_0M = non-factor inputs at base year prices

The results for agriculture indicated an annual rate of growth of 2.3 percent in the productivity of labour, 1.6 percent in the combined

productivity of labour and capital, and 1 percent in productivity of all inputs.

In their discussion of the results obtained, the authors explained that the study had concentrated upon a conventional analysis of productivity and had made no allowance for further disaggregation of "the residual" over and above the use of non-factor inputs. It was recognized, however, that better machinery is introduced with new plant, better plant layouts are introduced at the same time that management and labour are under a continuous learning process, and that some improvements are also introduced via non-factor inputs such as improved seeds and fertilizers in farming. Further, they recognized that increased productivity is a fairly broad concept incorporating all elements which do not yield to normal measurement methods that incorporate "labour" and "capital".

The main conclusion reached was that higher productivity growth was highly dependent on high rates of capital investment. However, it was pointed out that a high rate of growth of capital investment of itself is not synonymous with good productivity growth performance. A detailed analysis of the capital investment process in each industry had not been undertaken but, as stated by the authors, it was evident that those industries which have made greatest contribution to growth of GNP have been able to exploit an opportunity to transform their

productive structure. Some of these opportunities mentioned were changes in relative prices, the introduction of new technology, the cost of labour relative to capital, the shortage of labour, and the size of the market.

It was notable that among the industries included in the study, farming had remained the largest sector in a "price-taking" situation, and traditionally had found the greatest part of its capital needs from "plough back" of its own revenue. The authors stated that farming also had little control over its input prices and had met the relevant "cost-price squeeze" by sustained increases in productivity.

As cited in the study, the authors supported the conclusions and recommendations contained in the 1971 Report of the Targets Advisory Group to the National Development Council. Said Report stated that higher productivity growth will require changes in attitudes and policies by all groups in the economy and must include not only farming and manufacturing but also the servicing sectors, i.e., distribution, transport, financial and other services. The Report, as cited further by Johnson and Taylor, also identified the key factors for productivity growth as: 1) control of inflation; 2) improved industrial relations; 3) greater skills on the part of management and labour; 4) increased investment in labour saving plant; 5) increased domestic savings in

order to finance the investment; and 6) better all-round use of resources and speedy application of the latest technology.

3.3.6 Lawrence and McKay's Study (1980)

The study was done to assess the trends in the inputs, outputs and the productivity of the Australian sheep industry for the period from 1952-1953 to 1976-1977. The method employed in the construction of the inputs, outputs and productivity indexes was the Tornqvist quantity index. Among other reasons, the authors' preference for the Tornqvist index over the Laspeyres index was based on the relative flexibility of the Tornqvist index particularly where factor substitution is concerned. The authors indicated that employing the Laspeyres indexing method may yield incorrect measurements of productivity changes since the Laspeyres index imposes a perfect substitutability criterion of inputs and outputs which does not accurately describe the nature of the relevant production process.

As regards the findings in the study, the results showed that total factor productivity in the Australian sheep industry increased at a compound annual rate of 2.9 percent during the period covered in the study. This growth rate resulted from compound annual growth rates of 4.4 percent and 1.5 percent in total outputs and total inputs, respectively. As stated in the study, the advancement and deferment

of inputs and the seasonal conditions affecting outputs have been important causes of short-run fluctuations in productivity around the underlying trend increase in productivity.

3.3.7 Powell and Bushnell's Study (1981)

A comparison of technological change between New Zealand and the Australian rural sectors over the period 1945-46 to 1977-78 was the main feature in this study. The authors made use of Solow's residual growth method rather than other methods particularly due to its relative ease of calculation. It was recognized by the authors that the residual, as determined in their study, included errors in data and the effects of disturbances such as droughts and commodity booms.

Over the study period, it was found that gross output in the Australian rural sector increased by 142 percent. Capital inputs increased by 58 percent, with the largest proportionate increase of 223 percent in plant and machinery. The smallest increase of 26 percent was recorded for land. Non-factor inputs increased by 85 percent while labour input decreased by 18 percent.

The estimated technical change index for the Australian rural sector, which was shown diagrammatically, indicated an accelerated growth for

the late 1960s and early 1970s reaching a peak in 1973. This growth was associated with reduced input levels.

In the case of New Zealand's agriculture, gross output during the study period increased by 72 percent. Labour input declined until the early 1960s and rose sharply from 1970 onwards. Capital stock increased steadily at 64 percent throughout the period. Non-factor inputs fluctuated during the 1950s then increased rapidly levelling off in the mid 1970s.

The index of technical change in New Zealand agriculture increased by 2.6 percent per annum during the 1950s, by 1.8 percent per annum in the 1960s, and then declined by 3.4 percent per annum during the 1970s.

Based on these findings, it was found that overall, the Australian rural sector showed a better performance in terms of output and technical change. The reason for this was seen as having been due to the ability of Australian farmers to adjust input levels more readily than their New Zealand counterparts. Such adjustment had been facilitated by a number of factors identified as including the buoyant economy associated with the mining boom and the introduction of the Rural Adjustment Scheme.

The relatively better performance of the Australian rural sector in the 1970s was also partly attributed to differences in product mix between the two countries. In Australia, the large contributor to productivity was cereal production which had expanded during the 1970s and had achieved rapid advances in the use of high capacity machinery, while industries with low productivity (such as dairying and some horticulture) had contracted. In contrast, New Zealand was seen as not having had such favourable product mix as the Australians.

The study also indicated the absence in both countries of new technological developments to be implemented during the 1970s. It was noted that gains had come mostly from management advances, i.e., improvements in the way industries were operated. Based on this, it was suggested for management to seek means to reduce inputs in the absence of strong growth in outputs. Among the variety of means identified were farm amalgamation, realisation of economies of size, better feed management systems and better machinery management and operating systems.

3.3.8 Evans's Study (1983)

A concept related to productivity was explored by Evans in his study of technical progress in agriculture. The primary purpose of his study, which covered the 1960-1976 period, was to identify the rate and

direction of biased factor augmenting technical change. Knowledge of factor augmenting biases, according to him, can be useful to the investigation of induced innovation. His analysis which provided a picture of the nature of change enabled identification of sources of productivity growth.

The methodology employed by Evans in this study made use of aggregation of the 44 sector input/output framework for New Zealand. This method facilitated the investigation of the nature of agricultural industry production relationships as they relate to primary inputs as well as to current inputs such as imports.

The results of Evans's analysis portrayed changing production relationships in the agricultural industry. The possibility that these changes could have been due to "induced innovation" was investigated using the results of the study shown in Table 3.2. In the theory of induced innovation, Evans explained that technical progress will take place most rapidly in areas where the returns to new techniques and practices are high. Assuming that costs of innovations are similar, the theory suggests that more technical progress will take place with respect to an input whose price is rising rapidly and/or has a larger cost share. The return to innovation, according to Evans, will depend upon the effect of these innovations on the use of inputs whose prices are increasing rapidly and upon inputs which demand a large share of

costs. As presented in Table 3.2, factor saving Hick's bias was characterized by the two inputs with the largest shares in total cost. Evans indicated that although imports and labour had high price growth rates they each have a small share in the total cost and had exhibited factor using biases. He also stated that although plant and equipment had a larger cost share than imports or labour its price growth rate was low and possessed a correspondingly low factor-using bias.

Table 3.2 Results of Evans's Study (1983)

	Ave. Ann. % Change in Expected Prices	Hicks Biases	Factor Augmentation rates	Ave. Cost Share
Domestic Materials	4.5 %	-0.0013	0.000	.126
Imports	6.9%	0.0006	0.000	.010
Labour	7.1%	0.0011	0.069	.042
Plant and Equipment	3.8%	0.0007	0.000	.096
Land and Buildings	6.1%	-0.0012	0.018	.726

The Hick's biases and cost shares together with the rates of price increase were used to examine induced innovation. In the interpretation of the results, Evans emphasized that the induced

innovation hypothesis has to be viewed from the decision maker's perspective. He mentioned that it may be that management changes and the other innovations which led to a high labour augmentation rate were able to be effected by farmers and other research workers in agriculture whereas factor augmentation affecting imports, for example, may be difficult to influence by firms in agriculture. He stated that it is the farmer who has the strongest incentive to develop and implement cost saving ideas, and that input suppliers do not have the same incentive.

In conclusion, Evans stated that if the induced innovation argument is correct, then prices will not only influence input intensities for a given technology but will also contribute to determining the shape of this technology.

3.3.9 Laing and Zwart's Study (1983)

An econometric model was used by Laing and Zwart to describe the structure and behaviour of the pastoral sector of New Zealand. The objective was to understand the economic inter-relationships in the livestock sectors as well as have an instrument to monitor developments and aid policy making in that sector. The focus of the model was the supply dynamics in the livestock industry which depended on the decision making of the individual farmers involved.

The reliability of the model used in describing the structure and behaviour of the pastoral sector was tested by the authors through historical simulation analysis and through generation of elasticities reflecting the model's responsiveness to changes in major exogenous variables such as farm-gate prices, fertilizer prices and interest rates. From the results obtained, Laing and Zwart concluded that perhaps the most clear-cut implications of the elasticity analysis for agricultural policy is the recognition that the effects of policy are ubiquitous throughout the pastoral sector. As determined by their model, policy instruments targeted on particular variables in the system indirectly affect every other variable. An example cited was the effect of changes in farm-gate prices, which may be supported in order to maintain farm incomes. The authors expressed that since it is difficult not to alter market-determined relativities between farm enterprises when income support is achieved through price policy, the impact of such policy is also seen in the composition of livestock held on pastoral farms and, therefore in the longer run, the production from these livestock. Further, they stated that the elasticities determined in their study also revealed strong competition between the sheep and beef and the dairy components of the pastoral sector. As such, policies directed specifically at either component will certainly affect the competitive enterprise.

It was also found in the study that although the effects of agricultural policies on livestock numbers and farm production were inherently spread over the longer term, the effects of these policies on farm income and expenditure were more immediate. They determined that current expenditure, specially on fertilizer and repairs and maintenance, was sensitive to changes in gross income. As a consequence, net income has tended to be more sensitive than gross income to price changes.

Further in the results of the study, the authors also cited the effects of agricultural policy-induced changes in farm-gate prices and interest rates on the composition of capital assets held on pastoral farms. In the short-run, the effect of higher prices on capital investment was largely income related so that more easily acquired assets such as plant and machinery were bought. In the long-run, more productive assets (in terms of output) were acquired due to their higher profitability and the fact that initial investment decisions often determine subsequent investment in these assets. The strong effect of farm purchase on land development expenditure was cited as an example. These inter-relationships between various categories of asset were viewed as an important contribution to understanding the long-run effects of changes in farm incomes and profitability, whether originating from the market or from policy instruments.

3.3.10 Burke and Naughtin's Study (1984)

This study was undertaken to assess the productivity of the meat processing industry in Queensland (Australia). Compared with all the other studies reviewed here, this study had employed a different method in the measurement of productivity growth. Specifically, the study used the Deakin-Seward formulation which measures productivity in terms of the capital and labour inputs. As explained by the authors, the approach adopted in their study looks at total factor productivity and the trends in the individual factor productivity, and at the causes contributing to the increases in what was termed "applied technical and organizational knowledge and external factors (ATOKE)". ATOKE was referred to as the residual causes producing increased efficiency after allowance has been made for increases in the inputs of labour and capital. This residual factor (ATOKE) was further referred to as representing a refinement of the efficiency term A_t in the Cobb-Douglas function. As explained in the study, the appeal of the method is in its being less demanding on the accuracy of the absolute values of the factors since the method is dependent on the measurement of changes rather than absolute amounts.

The overall finding in the study was that there was no discernible improvement in productivity of the meat processing industry over the period from 1968-1969 to 1980-1981. This was despite a decade of

new investments during which the real value of the capital stock almost doubled. The conclusion derived from this result is that the meat processing industry had very poorly utilized its resources.

3.3.11 Scobie and Eveleens's Study (1987)

The primary purpose of the study was to examine the contribution of agricultural research in New Zealand over the period 1926- 1927 to 1983-1984. This was undertaken through the specification of a model for measurement of productivity in agriculture where research is specified as an explanatory variable for changes in productivity.

Other explanatory variables included in the model were the weather conditions, the level of spending on extension services, the number of graduates and diplomats trained in the agricultural sciences, and the economic conditions of the agriculture sector (as measured by the annual deviation of net farm income from its long-term trend).

The results of the study showed that the return on research comes over an extended period, i.e., 23 years as estimated in the study. Nonetheless, the study noted that the size of benefits from research is such that the annual rate of return to research investments is around 30 percent. As such, it may be considered a socially profitable form of

investment. As determined further in the study, any cuts in research expenditure will lead to lower future productivity growth in agriculture.

3.3.12 Studies by the Australian Bureau of Agricultural and Resource Economics (ABARE, 1990)

The primary purpose of the studies done on various industries of the Australian rural and resources sectors was to provide up-to-date estimates of productivity in Australia's primary industries to serve as a basis for assessing the productivity growth experience of each of these industries.

The studies used the Tornqvist index in the aggregation of inputs and outputs. Two different measures of industry production were used to calculate productivity, namely gross output and gross product. Using gross output as the measure of industry production, productivity was calculated as the change in the ratio of the quantity indexes of gross output and of total input (i.e., labour, capital and intermediate goods and services). On the other hand, using gross product, the ratio was between gross product and labour and capital inputs only. The gross product measure was used particularly for industries in which data on prices and quantities of intermediate inputs were not available. It was noted in the study that estimates of productivity based on gross product were affected by changes in the intensity of use of intermediate inputs within an industry. For example, it was cited that a decrease in prices for intermediate inputs which led to their increased use were

reflected in a rise in the gross product measure of productivity even if no actual growth in underlying productivity occurred.

Using gross output, productivity in the rural industries was estimated to have grown by 2.0 percent per year over the period 1971-72 to 1988-89. For the resources sector, productivity growth measured by gross output was estimated to have been in excess of 1.4 percent a year over the period 1971-72 to 1985-86.

As explained in the study, the differences in measures of productivity among the industries within the same sector (for example, cropping industry versus the broadacre industries) were due to a range of factors and did not solely reflect differences in rates of technical progress. Specifically, differences among industries in timing of the purchases of inputs have accounted for much of the variation in measured productivity growth across the rural sector. It was also observed that since expenditure on inputs such as fertilizers and repairs and maintenance was included as an input in the year of purchase, inputs tend to be overstated (relative to the associated outputs) in the year of purchase and understated in the other years. This followed from the recognition of such inputs as partly capital inputs since the resulting "service flows" derived from them are obtained over several years.

In the case of the resources sector, the wide fluctuations in the productivity measures were explained as being caused by investment cycles and the long lags between expenditure and the ensuing production in the industries within the sector. As such, productivity growth was considered to be an understatement of the technical progress occurring in the sector.

3.3.13 Philpott's Study (1994)

This more recent work by Philpott presents estimates of productivity growth for the whole of the New Zealand economy as well as its various component sectors for the period 1950 to 1993. For the farming sector, productivity trends were estimated in terms of growth rates over two decades, 1973-1983 and 1983-1993. The results are shown in Table 3.3.

As indicated by Philpott, the turn around in productivity growth in New Zealand agriculture during the last two decades from -0.2 percent to 4.4 percent has less to do with changes in traditional sheep and dairy industries than it has with horticulture. As was found, TFP in sheep and dairying hardly changed at all over the last twenty years. In the case of sheep farming, Philpott attributed the rise in productivity growth from 1.7 percent to 1.9 percent over the two decades as partly the result of lower factor use possibly reflecting wasteful over-

expenditure in the subsidised years of the first decade. Horticulture exhibited the most dramatic turn around in productivity growth from -4.4 percent during the first decade to 7.9 percent in the next. This was seen as possibly the result of the massive expansion in plantings in horticultural holdings and orchard areas during the first decade (which meant heavy expenditures) with the benefits (in terms of growth in output) being reaped in the second decade.

One important implication of the study's findings indicated by Philpott was that the 4.4 percent annual acceleration of productivity in total agriculture since 1983 has little to do with restructuring but much to do with the lagged effect of horticultural investment in the pre-1983 period.

Table 3.3 Productivity Growth by Type of Farming

	Sheep, Beef and Cropping		Dairy Farming		Horticulture		Sheep & Dairy and Horticulture		Total Agriculture Including Others	
	1973-83	1983-93	1973-83	1983-93	1973-83	1983-93	1973-83	1983-93	1973-83	1983-93
Average of 3 Years* (ending years shown)										
	Percent Per Year									
Real Growth Output	1.4	-0.8	0.7	1.8	5.4	9.5	1.6	2.1	1.5	2.1
Real Non Factor Inputs	0.3	-2.2	2.2	1.9	9.0	3.9	1.4	0.0	2.8	0.6
Real Net Output	3.3	1.0	0.3	1.8	2.9	13.2	1.8	4.0	0.2	3.8
Real Non Factor Inputs/ Real Gross Output	-1.1	-1.4	0.6	0.0	3.4	-5.1	-0.2	-2.1	1.3	-1.7
Real Capital Stock	0.3	-0.9	0.8	0.4	1.0	1.2	0.5	-0.3	0.5	-0.3
Employment	2.6	-0.9	-0.8	1.0	9.5	5.3	2.0	0.6	0.4	-0.7
Land in Use	0.8	-0.9	-1.4	1.7	2.1	8.2	0.6	-0.6	0.6	-0.6
Total Factor Use	1.6	0.9	-0.5	1.0	7.6	5.0	1.4	0.2	0.4	-0.6
Real Net Output/Capital	2.9	1.9	-0.5	1.4	1.9	11.9	1.3	4.3	-0.4	4.1
Real Net Output/Labour	0.7	1.9	1.0	0.8	-6.1	7.5	-0.2	3.3	-0.2	4.5
Real Net Output/Land	2.5	2.0	1.6	0.1	0.8	4.6	1.2	4.6	-0.4	4.4
Total Factor Productivity	1.7	1.9	0.8	0.8	-4.4	7.9	0.4	3.8	-0.2	4.4

* Thus 1973 is measured as average of three years 1971, 1972 and 1973 and similarly for 1983 and 1993.

Source: Philpott (1994)

3.4 Conclusion

The review of literature has shown that productivity studies have been regularly conducted in a variety of countries. The studies reviewed have also demonstrated the difficult task of trying to explain the meaning of the 'residual' obtained. Only a few studies were able to explain a significant amount of the measured productivity growth. On one hand this may not be a serious shortcoming since in the main we are interested in knowing that R&D and education is continuing to lead to further productivity growth. On the other hand however, given the sensitivity of productivity measures to measurement errors which can have serious implications for the interpretation of the results obtained, this inability is far from satisfactory. This also in the light of the usefulness of the results for purposes of guiding investment.

With regard to the methodology, nearly all the empirical studies of the last decade reported here, have advocated the use of the ratio method (index number approach) for the measurement of productivity growth. Noticeably also is the use of the Tornqvist index in the more recent studies completed during the 1980s and 1990s. The theoretical underpinning of this index (flexible production function) has made this approach more acceptable for longer term productivity studies. The Solow growth equation and ratios using other aggregators are still being used as some of the studies reported here showed.

Productivity measurement is mainly concerned with total factor productivity. Although some of the studies measured partial or single factor productivity as well, the limited use of such indicators was made clear. In some situations, where data on all factors is not available, partial productivity measures can still provide some useful information.

In relation to the topic of this thesis, the calculated results for productivity growth in agriculture are of relevance. For instance, it has been shown that the trend in productivity in the New Zealand agriculture was increasing from 0.7 percent per annum between 1921-1965 (Philpott, et. al., 1967) to 1.0 percent per annum between 1960-1973 (Johnson and Taylor, 1976). From 1973 to 1983, however, productivity growth was determined to have declined at 0.2 percent per annum before achieving a 4.4 percent per annum turn around in the years from 1983 to 1993 (Philpott, 1994). In the UK, productivity in agriculture increased from 1.0 percent per annum between 1965 to 1975 (Rayner, et. al., 1986) to 1.9 percent per annum for the period extended to 1990 (Thirtle and Bottomley (1991). In the US, agricultural productivity growth was estimated at 1.75 percent per annum between 1948 to 1979 (Ball, 1985). This growth declined to 1.58 percent per annum when the period was extended to 1985 (Jorgenson and Gollop, 1992).

Although productivity growth was significant in many cases (between 1 percent to 4.4 percent per annum) little success has been had in trying to explain the main causes of this growth. If most of it would be due to weather, then the results give little of significance to guidance of future investment in R&D or education and policy.

CHAPTER FOUR

DATA AND ANALYSIS

4.1 Introduction

The first sections in this chapter describe the sources of data, the study's data requirement and the alternative procedures used to derive other data which could not be directly obtained from the sources. These sections also discuss the methods used to process the data collected in the study.

The later sections of this chapter present the findings of the study. The analyses of the results are largely focused on the general trends exhibited during the period from 1973-1974 to 1990-1991, rather than on the year-to-year variations. Marked departures from the long-term trends are, however, noted.

4.2 Sources of Data

The main source of the physical and price data used in the study was the New Zealand Meat and Wool Boards' Economic Service (MWBES). The MWBES conducts an annual survey of sheep and beef farms and keeps a historical record of accounts of the industry. The Economic Service's survey is based on a random sample of sheep and beef farms

which are selected and stratified by geographical regions and by sheep numbers. A detailed description of the survey farms in each strata is given in Appendix 1.

The sampling unit in the MWBES's survey is the farm. Only those farms which winter at least 750 sheep or their equivalent sheep plus cattle stock units are included in the sample. In addition, the farm must be privately owned and must not be run in conjunction with another property. Also, at least 80 percent of the farm's revenue must be derived from sheep or from sheep plus beef cattle and the farm is to be run as an ordinary commercial sheep and beef farm.

In the survey, physical and financial data are presented on an average per farm basis to reflect the structure of sheep and beef farming in New Zealand. In the present study, use of the average per farm data was adopted to reflect productivity of the sheep and beef sector of New Zealand.

Other data sources were publications by the Statistics Department and the Ministry of Agriculture and Fisheries.

4.3 Data Requirement

This section presents the specific types of data used in the calculation of the input and output indices. In addition to these physical and price data, information on various policy instruments designed to provide assistance to the sheep and beef industry is also presented (see Chapter 1).

4.3.1. Input Index

There are five major categories of farm inputs included in the study: land, capital, livestock, labour and materials and services. In constructing a total quantity of input index, a Tornqvist index procedure was used. This procedure requires information on physical quantities (q) as well as values (price \times quantity, pq) for every input used (see Section 2.3.2.3).

In the case of the durable inputs such as land, capital and livestock, their annual input values were derived from the cost of the service flows that they provide to the production process on the farm each year⁹. This in contrast to labour and the materials and services inputs the values of which were entirely attributed to the purchase period. Generally, the value of the service flow from durable inputs can be

⁹Methodology drawn from Lawrence and McKay (1980).

measured in terms of the depreciation, maintenance and opportunity costs of the asset. The calculation of the annual input quantity for each input is discussed below.

Land

The quantity of the land input, as used in the study, is defined as the effective farm area. This includes areas occupied by agro-forestry, buildings, yards and shelter belts as these contribute to the overall operation of a farm.

In deriving the value of the land input, the relevant cost considered was its opportunity cost. This was calculated by taking the current market value of the land multiplied by the weighted average overdraft rate related to the year being examined. While there are various rates of return on different types of investment, the overdraft interest rate used to calculate the opportunity cost of all durable inputs considered in the study was taken as being representative of the rate of return that could be expected from an alternative form of investment.

The land input was assumed to have a zero depreciation cost since it is basically an inexhaustible asset. However, in order to preserve its value, some maintenance of the land in the form of fertilizer and management, among other things, is required. These maintenance

costs were included under the materials and services and the labour input groups.

Capital

For the capital group of inputs (consisting of farm buildings, trucks and tractors and plant and machinery) for which direct physical quantity measurements were not available, a quantity index was derived by dividing the current market value of capital by the Statistics Department's relevant farming capital price index. In the absence of an aggregate capital price index for the components mentioned, the farm building price index was used as farm buildings made up an average of 66 percent of the total capital inputs considered in this study.

The value of the service flow of the capital input is the sum of the depreciation and opportunity costs of the asset. In this study, the depreciation cost of capital was taken directly from the calculations of the MWBES as indicated in the Beef and Sheep Farm Survey. The opportunity cost of capital was calculated by multiplying the current market value of the asset by the relevant weighted average overdraft rate.

Maintenance cost of capital was included in the materials and services category.

Livestock

The livestock input group represents a special case in that livestock can be considered as capital in a "living form". As such, it is conceptually treated in the same manner as other durable inputs. The quantity of livestock input consisted of the opening livestock number. Unlike other durable inputs, though, it is assumed that livestock does not depreciate. In order to maintain zero depreciation, however, some form of maintenance inputs such as medicaments and labour are required. These were included in the other input groups. Another form of maintenance is the replacement of stocks which die or are disposed of as output. To account for this, livestock purchases plus the absolute value of a negative change in inventory (also called a negative operating gain) were also considered as inputs. Change in inventory refers to the difference between the closing and the opening stock numbers.

The relevant value weight of the opening stock numbers is its opportunity cost. This was calculated by multiplying the current market value of the opening livestock number by the weighted average overdraft rate. Actual purchase expenditure was used to value livestock purchases. Negative operating gains were valued by multiplying the absolute value of the negative change in livestock inventory by the closing price of the livestock. The total value of livestock inputs was then calculated as the sum of the value weight of the opening stock

numbers, the value of livestock purchases and the value of the negative operating gain.

Labour

Direct measurements of the quantity as well as the value of the labour input were taken from the MWBES's survey data.

Materials and Services

A quantity index for the materials and services group was derived, in the absence of direct physical quantity measurements for this particular input group, by dividing the value of materials and services by the MWBES's farming inputs price index.

The value of materials and services was taken directly from the MWBES's survey data. The value of fertilizer included in this input group was adjusted by adding the amount of the government's fertilizer price subsidy for the relevant years in the study period. This was done to reflect the true cost of fertilizer.

4.3.2 Output Index

There are six categories of output considered in the study: wool, sheep, cattle, deer, goats, and other outputs. Cash crop was incorporated under the "other outputs" group. A Tornqvist index procedure was, likewise, used in constructing the total quantity of output index.

Quantities

The quantities of wool and livestock outputs were taken directly from the MWBES's survey data. Wool output quantities represent the volume of sales made during the year as well as physical quantity balances after accounting for opening and closing stocks. Livestock output quantities represent total meat production.

The MWBES's calculation of total meat production takes into account changes between opening and closing stock numbers, sales and purchases of stock "on the hoof" as well as the carcass weight of slaughtered stock. Where stock were purchased for finishing, the carcass weight of stock purchased was deducted from their meat production. Likewise, the carcass weight of store stock sold "on the hoof" was included as part of meat production on the selling farm.

The quantities of the "other outputs" were derived, in the absence of direct quantity measurements of these outputs, by dividing the gross revenue from these outputs by their prices received index.

Values

Generally, gross revenue is taken to represent the value of outputs produced by the farm. Output assistance in terms of SMP and stabilization payments to farmers were deducted from the gross value of wool, sheep and beef output on relevant years to reflect the true value of the farm's output.

Gross revenue from wool consisted of receipts from wool sales and the trading balance after accounting for opening and closing stocks.

Gross revenue from livestock also consisted of receipts from sales and the balance after accounting for changes between opening and closing stock numbers at standard values. Gross revenue from livestock is net of expenditures for purchasing livestock.

The gross revenue from "other outputs" comes from other farming activities such as sale of hay and grazing. The gross revenue from cash crop, included under other outputs, consisted of receipts from the sales

of small seeds, grain and other crops after accounting for opening and closing stocks on hand.

4.4 Characteristics of the Data Derived

4.4.1 Input Indexes

Data on quantities and values of the various inputs are given in Table 4.1a and Table 4.1b, respectively. An indexing procedure was applied to these various categories of inputs and the resulting quantity indexes are shown in Table 4.1c, with 1973-1974 as base year¹⁰. The total input index derived using the Tornqvist quantity index method is also shown in the same table.

The results obtained indicate that in general, total input usage by the sheep and beef farm has declined over the period from 1973-1974 to 1990-1991. The only departure from this trend is the livestock input group which shows an increase of 1.1 percent per year during the period. A logarithmic trend line fitted by regression to the total input index for the 18-year period shows a decline in the rate of growth of total input of -0.21 percent per year.

¹⁰It is recognized that 1973-1974 was a particularly good year. The designation of this year as base period was made to correspond to the start of the 18-year period covered in the present study. It is noted, however, that the choice of any other base year invariably yields the same compound annual growth rate for the 18-year study period.

Table 4.1a Input Quantities
Average Per Farm

YEAR	LAND (ha)	LVSTK (no)	CAPITAL (index)	LABOUR (units)	MATERIALS/ SERVICES (index)
1973-1974	538	2959	115	2.17	103
1974-1975	475	2826	103	1.99	79
1975-1976	484	2837	91	1.83	95
1976-1977	487	2910	102	1.83	98
1977-1978	493	3029	99	1.81	98
1978-1979	504	3068	105	1.83	99
1979-1980	507	3255	116	1.85	103
1980-1981	508	3350	131	1.83	98
1981-1982	498	3447	132	1.83	102
1982-1983	495	3444	121	1.80	104
1983-1984	487	3353	117	1.77	110
1984-1985	487	3486	90	1.74	115
1985-1986	487	3276	70	1.67	94
1986-1987	492	3420	67	1.61	88
1987-1988	502	3294	62	1.59	88
1988-1989	485	3563	66	1.55	88
1989-1990	487	3375	74	1.59	92
1990-1991	514	3312	74	1.57	88

Table 4.1b Input Values
Average Per Farm

YEAR	LAND	LVSTK	CAPITAL	LABOUR	MATERIALS/ SERVICES
(in NZ \$)					
1973-1974	9018	11070	3549	3203	18455
1974-1975	9053	6541	3428	2995	16198
1975-1976	10291	8505	5049	3134	21830
1976-1977	15163	12276	5224	3628	26575
1977-1978	20928	13884	6361	3971	30853
1978-1979	25942	19177	7984	4566	33882
1979-1980	43428	27032	11449	5687	43197
1980-1981	66241	26019	14773	6413	50647
1981-1982	77761	28177	17017	7395	61554
1982-1983	73663	31473	16639	7487	69105
1983-1984	65690	30506	15914	7029	73639
1984-1985	69269	44602	18548	7312	84596
1985-1986	80152	51551	20458	6879	78329
1986-1987	76560	40475	19581	6802	78603
1987-1988	76415	46875	19527	7302	84046
1988-1989	77177	48802	18868	7704	86328
1989-1990	90811	54071	21562	8360	90661
1990-1991	87971	63412	22016	8859	88254

Table 4.1c Input Quantity Indexes
Average Per Farm

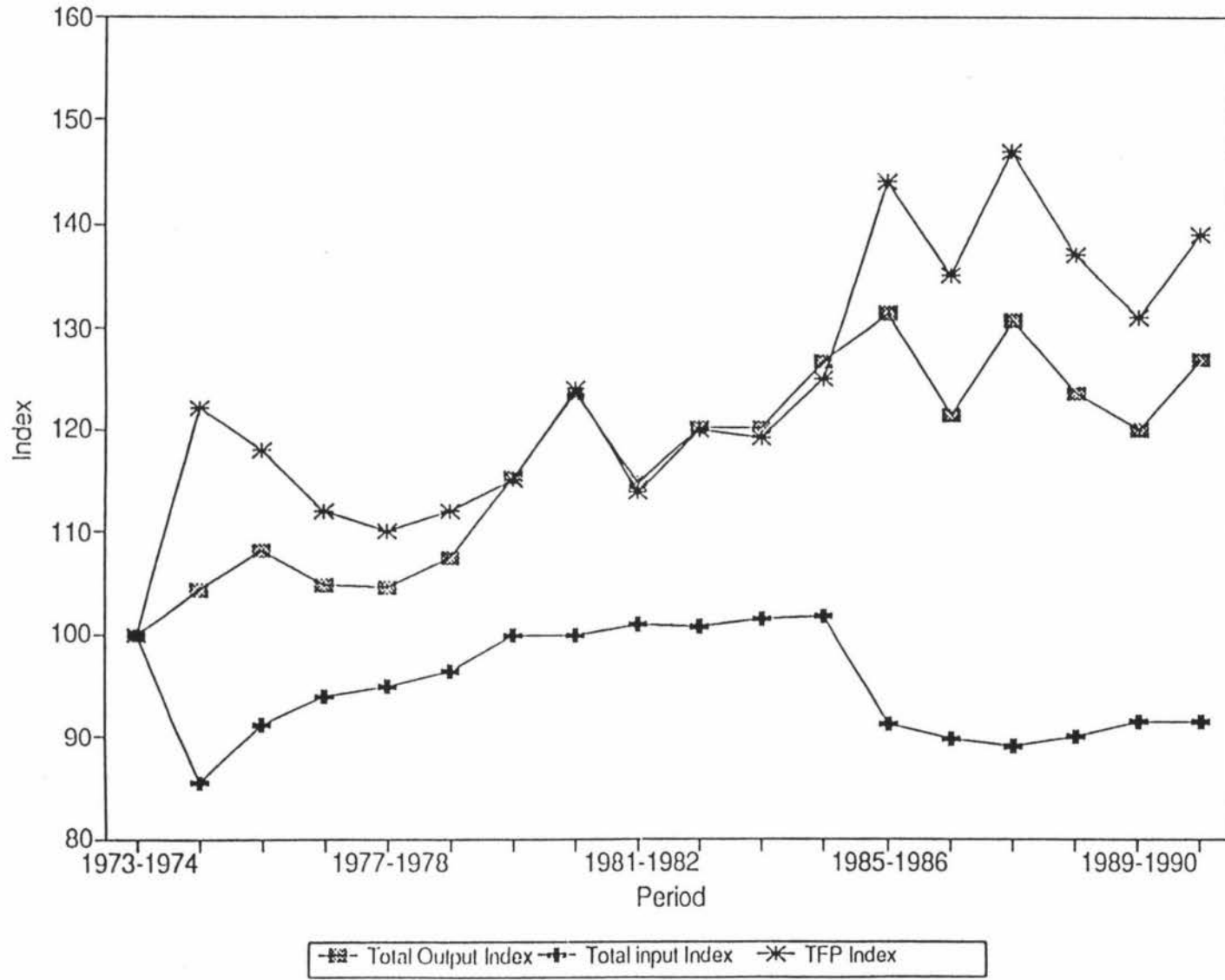
YEAR	LAND	LVSTK	CAPITAL	LABOUR	MATLS/ SVICES	TOTAL INPUTS
1973-1974	100	100	100	100	100	100
1974-1975	88	96	90	92	77	85
1975-1976	90	96	79	84	93	91
1976-1977	91	98	89	84	95	94
1977-1978	92	102	86	83	96	95
1978-1979	94	104	91	84	96	96
1979-1980	94	110	101	85	100	100
1980-1981	94	113	114	84	96	100
1981-1982	93	116	115	84	99	101
1982-1983	92	116	106	83	101	101
1983-1984	91	113	102	82	108	101
1984-1985	91	118	79	80	112	102
1985-1986	91	111	61	77	92	91
1986-1987	91	116	58	74	86	90
1987-1988	93	111	54	73	85	89
1988-1989	90:	120	57	71	86	90
1989-1990	91	114	65	73	90	91
1990-1991	96	112	65	72	86	91

Figure 4.1 shows the total input curve. A sharp decline in input usage in the sheep and beef farm occurred in 1985-1986 and was sustained until 1987-1988. These years coincided with the post-deregulation period. The sharp decline in the volume of inputs purchased in 1985-1986, which has come about as a result of the relative increases in the prices paid for these inputs, reflects the fall in expenditure per stock unit which was not compensated by the small decrease in stock units held per farm¹¹. The higher rate of increase in the overall index of prices paid for farm inputs (Appendix 2) reflects the impact of the higher interest rates as compared with those of the previous year. The increase in interest rates was seen as a result of the lifting of interest rate controls in July 1984 which was part of the broad program towards deregulation of the agriculture sector. The low usage of inputs such as fertilizer, lime and seeds, and repairs and maintenance continued through 1986-1987 and 1987-1988. Most expenditure on these items, being discretionary, were deferred until the last quarter of the year when farm incomes became known with certainty¹².

¹¹Source: Annual Review of the New Zealand Sheep and Beef Industry: 1985-1986 (NZ Meat and Wool Boards' Economic Service)

¹²Source: Annual Review of the New Zealand Sheep and Beef Industry: 1987-1988 (NZ Meat and Wool Boards' Economic Service)

Figure 4.1
Total Output, Total Input & TFP Indexes



4.4.2 Output Indexes

Table 4.2a and Table 4.2b present data on the quantities and values of the outputs produced in the average sheep and beef farm. Individual quantity indexes for these various outputs as well as the total output index are shown in Table 4.2c.

The total output index shows a 1.4 percent compound annual increase during the period from 1973-1974 to 1990-1991. The rate of growth in component output groups during the 18 year period was highest in the "other outputs" produced in the sheep and beef farm which included cash crop. The volume of these other outputs increased by about 2 percent per year during the period. The major products of the sheep and beef farm, consisting of wool, sheepmeat and beef, recorded compound annual growth rates of 1.2 percent, 1.0 percent and 0.6 percent, respectively.

Deer and goats were relatively new "products" that have been integrated into the sheep and beef farm. Considered a very volatile activity (Philpott, 1994), deer and goat farming had only been recognized for their commercial significance during the last decade when these types of livestock were first recorded in the sheep and beef farm survey of 1983-1984. In 1991, deer and goats comprised one percent of the

Table 4.2a Output Quantities
Average Per Farm

YEAR	WOOL (kg)	SHEEP (kg)	CATTLE (kg)	DEER (kg)	GOAT (kg)	OTHER OUTPUT (index)
1973-1974	10763	22930	11884	0	0	12.49
1974-1975	10874	22657	12109	0	0	16.94
1975-1976	11183	24200	12764	0	0	16.31
1976-1977	11302	24821	12202	0	0	12.13
1977-1978	11379	23813	10629	0	0	15.40
1978-1979	11568	25682	9786	0	0	16.46
1979-1980	13374	29413	10783	0	0	10.67
1980-1981	14082	30255	11277	0	0	14.93
1981-1982	13282	28151	10196	0	0	13.63
1982-1983	13214	28864	9777	0	0	18.90
1983-1984	13018	29027	9095	57	10	21.04
1984-1985	13747	29241	10552	88	18	21.11
1985-1986	13456	28600	11127	116	35	26.26
1986-1987	12823	25592	11931	156	58	19.31
1987-1988	13996	29856	12539	190	88	17.71
1988-1989	13037	26461	13003	200	90	17.07
1989-1990	12398	25054	12460	252	44	18.27
1990-1991	12668	28318	14543	310	33	15.15

Table 4.2b Output Values
Average Per Farm

YEAR	WOOL	SHEEP	CATTLE	DEER*	GOAT*	OTHER OUTPUT	TOTAL VALUE
(in NZ \$)							
1973-1974	14384	13424	6282	0	0	4108	38198
1974-1975	9376	9384	3984	0	0	3946	26690
1975-1976	16013	12888	6253	0	0	5596	40750
1976-1977	21446	18368	6729	0	0	5482	52025
1977-1978	20627	16877	7296	0	0	6128	50928
1978-1979	22815	20346	9533	0	0	8296	60990
1979-1980	32619	25658	12804	0	0	6551	77632
1980-1981	32040	28317	12625	0	0	8959	81941
1981-1982	30446	25386	13050	0	0	9843	78725
1982-1983	30684	16571	17261	0	0	13573	78089
1983-1984	35148	19354	14023	-447	16	16581	84675
1984-1985	46954	24661	21745	83	280	19150	112873
1985-1986	41600	24957	18774	835	134	19168	105468
1986-1987	47657	30793	20999	1131	234	16313	117127
1987-1988	57112	30856	20877	1536	211	15586	126178
1988-1989	59974	26684	24385	1211	-20	16302	128536
1989-1990	51284	39894	29585	1534	-30	21089	143356
1990-1991	39938	42548	34606	1414	1	15146	133653

* Negative values are accounted for by "standard values" used to assess changes between opening and closing stock numbers.

Table 4.2c Output Quantity Indexes
Average Per Farm

YEAR	WOOL	SHEEP	CATTLE	DEER	GOAT	OTHER OUTPUT	TOTAL OUTPUT
1973-1974	100	100	100	0	0	100	100
1974-1975	101	99	102	0	0	136	104
1975-1976	104	106	107	0	0	131	108
1976-1977	105	108	103	0	0	97	105
1977-1978	106	104	89	0	0	123	104
1978-1979	107	112	82	0	0	132	107
1979-1980	124	128	91	0	0	85	115
1980-1981	131	132	95	0	0	120	124
1981-1982	123	123	86	0	0	109	115
1982-1983	123	126	82	0	0	151	120
1983-1984	121	127	77	100	100	169	120
1984-1985	128	128	89	154	180	169	127
1985-1986	125	125	94	204	350	210	131
1986-1987	119	112	100	274	580	155	121
1987-1988	130	130	106	333	880	142	131
1988-1989	121	115	109	351	900	137	124
1989-1990	115	109	105	442	440	146	120
1990-1991	118	123	122	544	330	121	127

value of the total output of sheep and beef farm farms in New Zealand (Table 4.2b).

Deviations from the general trend of an increasing total output in the sheep and beef farm occurred during four distinct stages over the period (Refer to Figure 4.1). In 1976-1977, total output declined as a consequence of a fall in total meat production. Specifically, beef and lamb production declined by 13 percent and 5 percent, respectively over the previous year. The decline in beef production was due to lower cattle numbers (Table 1.3). Lamb meat production declined largely as a result of a higher retention of ewe lambs¹³. This relatively lower production performance was carried over the 1977-1978 season where meat production further declined due to the summer and autumn drought conditions that prevailed over New Zealand. The direct effect of the drought was seen in terms of lower average slaughter weights for lamb, mutton and beef.

The decrease in total output of the sheep and beef farm in the 1981-1982 production period mostly reflects the "difficult season" encountered by sheep and beef farmers. Both meat and wool production fell from their record levels of the previous two years (Table 4.2c). This was attributed to the relatively "only fair condition"

¹³Source: Annual Review of the New Zealand Sheep and Beef Industry: 1976-1977 (NZ Meat and Wool Boards' Economic Service)

managed by the stocks when they came out of the 1981 winter which in turn had affected per head production during the 1981-1982 season¹⁴.

The 1988 to 1990 periods also showed marked declines in total sheep and beef farm output. This was generally attributed to the severe drought conditions which affected the east coast regions of the North and South islands of New Zealand. In particular, the drought forced a run-down in livestock numbers. Consequently, fewer stock coupled with low stock performance particularly in the drought affected areas resulted in low meat and wool production.

Traditionally, wool is considered the most important product from sheep and beef farms. During the last three years of the study period, however, the relative importance of wool in the sheep and beef farm's product mix gradually dropped from 46 percent to 33 percent of the value of the farm's gross output (Table 4.2b). In contrast, the share of beef increased from 18 percent to 23 percent of gross output during the same period. The share of sheepmeat increased from 23 percent to 30 percent in the same three years. These shifts in weights among the three major components of the sheep and beef farm's product mix may

¹⁴Source: Annual Review of the New Zealand Sheep and Beef Industry: 1981-1982 (NZ Meat and Wool Boards' Economic Service)

be seen as a response to the more favourable price signals for beef and sheepmeat as compared to declining wool prices.

4.5 Terms of Trade

The ratio of output prices to input prices, called the "terms of trade", represents the incentive faced by farmers, which in turn determines changes in farm production. The terms of trade ratio measures the relative profitability of producing particular products and thus determines the overall output mix on the farm. For instance, given relative fixed costs, resources tend to get shifted from activities for which returns are lower to those which pay higher returns.

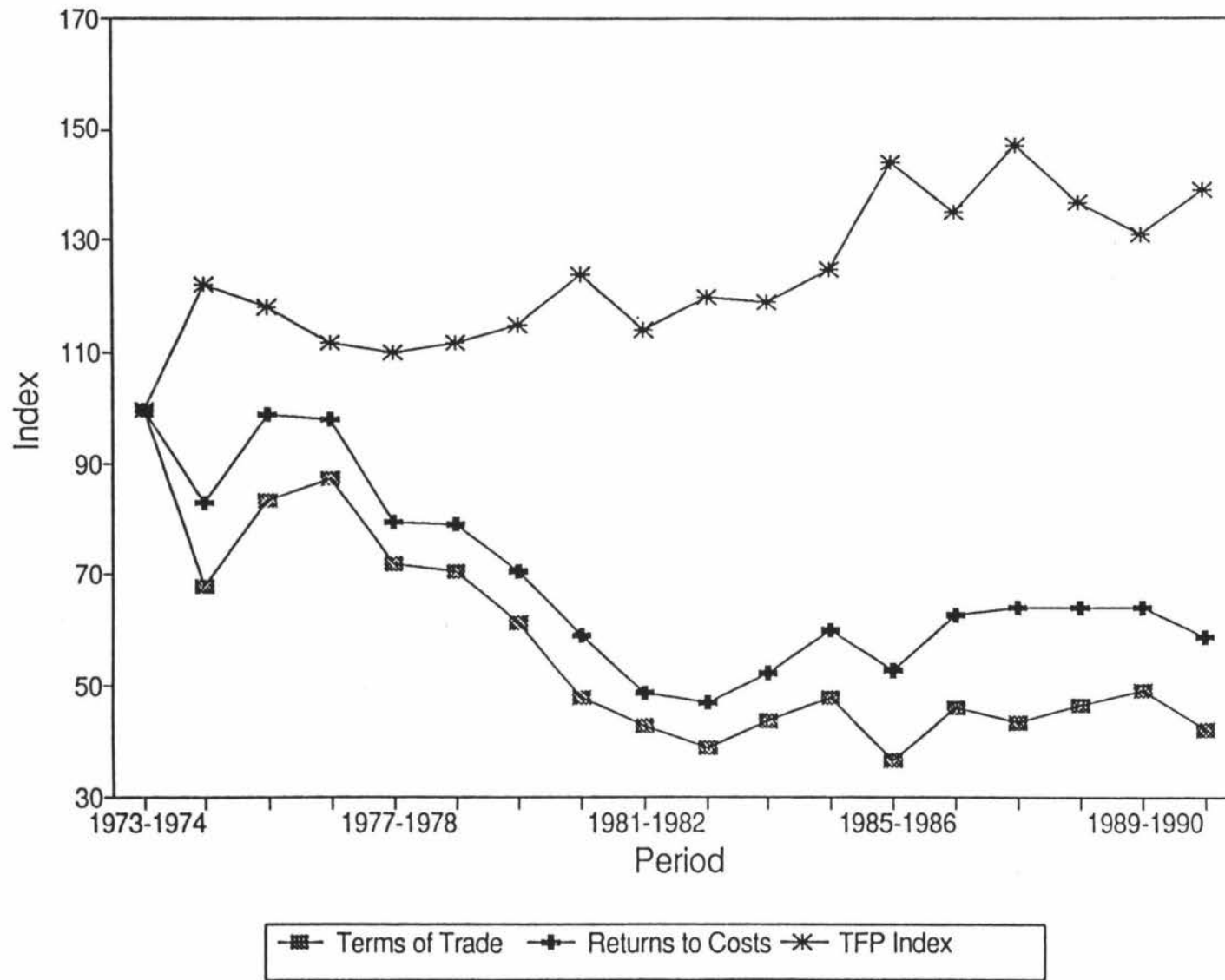
In this study, the terms of trade index for the sheep and beef farm was calculated by taking the ratio of the implicit prices received index to the implicit prices paid index over the period from 1973-1974 to 1990-1991. Implicit prices received were calculated by dividing the total value of the output by the total output index. Implicit prices paid were, likewise, calculated from the ratio of the total value of inputs and the total input index. The resulting terms of trade index is shown in Table 4.3 and illustrated in Figure 4.2.

As determined in the study, terms of trade in the sheep and beef farm decreased at 4.7 percent per year during the period. This was brought

Table 4.3 Terms of Trade and Returns to Costs Indexes

YEAR	IMPLICIT PRICES PAID INDEX	IMPLICIT PRICES REC'D INDEX	TERMS OF TRADE INDEX	RETURNS TO COSTS INDEX
1973-1974	100	100	100	100
1974-1975	99	67	68	83
1975-1976	118	99	84	99
1976-1977	148	130	88	98
1977-1978	177	128	72	79
1978-1979	210	149	71	79
1979-1980	289	176	61	70
1980-1981	362	174	48	59
1981-1982	420	179	43	49
1982-1983	436	170	39	47
1983-1984	420	184	44	52
1984-1985	488	233	48	60
1985-1986	574	210	37	53
1986-1987	546	253	46	63
1987-1988	581	252	43	64
1988-1989	586	272	46	64
1989-1990	641	313	49	64
1990-1991	654	276	42	59

Figure 4.2 Terms of Trade,
Returns to Costs & TFP Indexes



about by input prices which grew faster than the rate of increase in farm revenues. On their own, implicit prices received increased at 7.3 percent per year while implicit prices paid rose even higher at 12 percent per year.

Without a more detailed examination, it is difficult to attribute the characteristics exhibited by the terms of trade index as being due to the influence of any specific factor or product because of the aggregate index. It is instructive to note, nonetheless, that there may be significant variations in the relative terms of trade between commodities comprising the output index over the period covered in the study. When the terms of trade for one commodity or product falls relative to another, the first commodity has experienced a loss in relative profitability. This can be caused either by the commodity's costs increasing faster or its returns increasing more slowly than those of the alternative commodities. In this case, shifts in the relative terms of trade indicate changes in the farm's product mix.

4.6 Returns to Costs

The returns to costs index shown in Table 4.3 and in Figure 4.2 was derived by taking the ratio of the total value of output to the total value of input. The relationship among changes in productivity, terms of trade and the returns to costs ratio is illustrated in the following

identity (Lawrence and McKay, 1980), which states that at any given moment,

$$\begin{array}{l} \text{The} \\ \text{proportional} \\ \text{rate of} \\ \text{change in the} \\ \text{returns/costs} \\ \text{ratio} \end{array} = \begin{array}{l} \text{The} \\ \text{proportional} \\ \text{rate of} \\ \text{change in the} \\ \text{output/input} \\ \text{ratio} \end{array} + \begin{array}{l} \text{The} \\ \text{proportional} \\ \text{rate of} \\ \text{change in} \\ \text{farmer terms} \\ \text{of trade} \end{array}$$

This relationship is calculated in this study and showed a -3.1 percent rate of growth in returns to costs. This figure is equivalent to the sum of the trend rates of change in output/input ratio and the terms of trade computed as 1.6 percent and -4.7 percent respectively.

4.7 Productivity

4.7.1 Partial Factor Productivity

Productivity indexes for each of the factor and non-factor inputs utilized in the sheep and beef farm were calculated by taking the ratio of the total output index and the individual quantity index for each category of input. As a measure of the average product of a factor used, partial factor productivity should indicate the relative efficiency of each type of input used. Results of these calculations are shown in Table 4.4. The compound rate of change in the relative efficiencies of the inputs over

Table 4.4 Partial Factor Productivity Indexes
Average Per Farm

YEAR	LAND	LVSTK	CAPITAL	LABOUR	MATERIALS/ SERVICES
1973-1974	100	100	100	100	100
1974-1975	118	109	116	114	135
1975-1976	120	113	136	128	116
1976-1977	116	107	118	124	110
1977-1978	114	102	121	125	109
1978-1979	115	104	118	127	111
1979-1980	122	105	114	135	115
1980-1981	131	109	108	147	129
1981-1982	124	99	100	136	116
1982-1983	131	103	114	145	119
1983-1984	133	106	118	147	112
1984-1985	140	107	161	158	113
1985-1986	145	119	215	171	143
1986-1987	133	105	209	163	141
1987-1988	140	118	241	179	153
1988-1989	137	103	216	173	143
1989-1990	132	105	186	164	134
1990-1991	133	113	196	175	147

the 18 years covered in the study period were also determined and are presented in Table 4.5 below.

Table 4.5 Trend Rates of Growth of Partial Productivities of Inputs

Input	Compound Annual Growth Rate (%)
Land	1.5
Livestock	0.3
Capital	4.5
Labour	2.9
Materials and Services	0.017

Overall, both factor and non-factor inputs exhibited increases in efficiency over the 18-year period. Productivity growth was highest for capital which recorded a 4.5 percent increase per year. This result coincided with a declining trend in the employment of capital in the sheep and beef farm during the period. The lower productivity growth rates for the other factors were consequences of the also smaller magnitudes of declines in their rates of usage (as indicated by the growth rates of the input indexes) as compared with the capital factor. In contrast, productivity of the livestock input grew marginally by 0.03

percent while it alone indicated an increase in usage among all other inputs during the period.

As suggested by Link (1986), however, caution must be exercised in interpreting partial productivity measures so as not to attribute efficiency as being due to a single factor alone. A more useful and meaningful interpretation is to consider the productivity of a single factor as resulting from its interaction with the rest of the other inputs used in the production process. As such, productivity of the capital factor, as determined in the study, may have been achieved in relation to the intensities of use of the land, labour and the non-factor inputs employed in the sheep and beef farm at every point in time during the period covered in the study.

4.7.2 Total Factor Productivity (TFP)

The relationship between total output and the combination of all inputs used on the sheep and beef farm was determined by taking the ratio of the total output index and the total input index. This measure, given in index terms, indicates total factor productivity in the sheep and beef farm (Table 4.6).

The TFP curve, presented in Figure 4.1, closely follows the trends demonstrated by the total output index curve. Specifically, TFP rose

Table 4.6 Total Output, Total Input and
Total Factor Productivity (TFP) Indexes
(Average Per Farm)

YEAR	TOTAL OUTPUT INDEX	TOTAL INPUT INDEX	TFP INDEX
1973-1974	100	100	100
1974-1975	104	85	122
1975-1976	108	91	118
1976-1977	105	94	112
1977-1978	104	95	110
1978-1979	107	96	112
1979-1980	115	100	115
1980-1981	124	100	124
1981-1982	115	101	114
1982-1983	120	101	120
1983-1984	120	101	119
1984-1985	127	102	125
1985-1986	131	91	144
1986-1987	121	90	135
1987-1988	131	89	147
1988-1989	124	90	137
1989-1990	120	91	131
1990-1991	127	91	139

sharply during stages in the 18-year period when total input usage was markedly low. As shown in the figure these rises in TFP occurred in 1974-1975, 1980-1981, 1986-1987 and 1987-1988. Also noticeably, the TFP curve coincided with the total output curve during the six-year period from 1979-1980 to 1984-1985 when the volume of total input usage remained relatively unchanged.

A logarithmic trend line fitted to the productivity index by regression shows a compound rate of growth of the TFP index equivalent to 1.6 percent per annum. This figure also represents the difference between the rate of growth of the total output index and the rate of growth of the total input index which were previously determined as 1.4 percent and -0.21 percent, respectively. Based on this derivation, the change in TFP which has been referred to as a residual measure (Solow, 1957) reflects the influence on the production process of all factors other than the changes in the explicitly recognized inputs. The task of breaking down the residual measure obtained in this study into its component parts is the focus of the next section.

4.8 Sources of Growth

The interpretation of the residual is a problem fundamental to productivity research. As such, it has often been labelled as "a measure of our ignorance" to describe the change in output

unexplained by changes in specified inputs (Young, 1971). The change in total factor productivity is also ascribed to "technical progress" and thus simply defines TFP growth as a measure of the efficiency achieved in the production process (Griliches and Jorgenson, 1967).

In the present study, an attempt was made to identify factors to which changes in total factor productivity in the sheep and beef farm in New Zealand could be attributed. While there is potentially a large number of factors which may explain the changes in total factor productivity, the choice of the factors considered in this study was limited to those for which data was readily available.

The factors examined included policy variables in the form of output assistance and fertilizer subsidies, a climatic factor in the form of soil moisture deficit, and a trend variable.

4.8.1 Government Policy

The allusion to government policy as a source of growth is based on the assumption that policy, such as assistance to inputs and outputs, affects farmers' decisions, and hence influences productivity. In theory, a change in the level of assistance will lead to a change in output. However, if the resulting change in output is accompanied by a change in the quantity of inputs used, then productivity cannot be said to rise.

On the other hand, if with the increases in subsidy the farmer is able to increase output by more fully utilising inputs which were previously unemployed or under-employed, then productivity can be said to rise.

For the present study, output assistance and fertilizer subsidy were used to represent the government policy variable. The significance of these policy instruments is stated in the purpose for which they were instituted. Specifically, assistance to outputs such as price supplementation, was aimed to increase gross returns to the farm by influencing output prices. On sheep and beef farms, assistance to outputs was carried out through the "supplementary minimum prices" (SMP) scheme and the producer board stabilisation scheme¹⁵. Under the former scheme, guaranteed prices were set by the government for sheepmeat, beef and wool at the beginning of each season, and if international market determined payouts fell below the set minimum, government made up the difference. As regards the producer board stabilisation scheme, a floor price which is generally lower than that for SMP is set by the board. If market prices fell below both set floor prices, government would meet the difference between the SMP and the producer board minimum while the producer board would make up the remainder. SMPs and stabilisation payments were made to sheep and beef farmers from 1980-1981 season to 1986-1987.

¹⁵Source: *Farming Without Subsidies: The New Zealand Experience* (Edited by Sandrey and Reynolds, 1990)

Assistance to inputs such as fertilizer subsidies was aimed to reduce production costs. The period in which fertilizer subsidies were granted by the government included the years covered in the study until 1986-1987.

4.8.2 Climate

The relevance of the climatic factor, represented in the study by the variable on soil moisture deficit, to the explanation of productivity changes is evident in the fact that drought, for example will cause a reduction in output in a given year without there necessarily being a reduction in inputs used. Conversely, a year characterized by good climate conditions may increase output in greater proportion than the inputs used. Over the long term, climate is likely to vary and will thus tend to have an unsystematic effect on output. But over the relatively short period covered as in the present study, climatic variations may be expected to explain some of the fluctuations in the sheep and beef farms' productivity index.

4.8.3 Trend Variable

The trend variable was used to represent the influence exerted over time by the rest of the various factors (i.e., other than output

assistance, fertilizer subsidy and climate) underlying productivity growth.

4.9 The Regression Equation

Regression analysis was carried out to test the hypothesis that output assistance, fertilizer subsidy, and soil moisture deficit did not have significant influence on productivity of the sheep and beef farm. Specifically, the hypothesis was tested by estimating the parameters in the following equation:

$$Y_t = aX_1^b X_2^c X_3^d e^{gt}$$

where

- Y_t = TFP index;
- X_1 = output assistance;
- X_2 = fertilizer subsidy;
- X_3 = soil moisture deficit;
- e = trend variable;
- a = constant to be estimated;
- t = time with values 1 to 15 corresponding to the years 1977 to 1991,¹⁶ and

¹⁶The years 1973-74 to 1975-76 have been omitted from the regression series in the absence of data on fertilizer subsidy and soil moisture deficit for these years. In addition, MWBES's data on SMPs and stabilization grants for wool, sheep and beef started in 1980-81.

b, c, d and g = the parameters to be estimated, representing elasticities, i.e., percentage changes in the dependent variable due to the percentage change in the independent variable.

Logarithms of each variable (X_1, X_2, X_3 , and Y) were taken and a linear regression carried out. The results are presented in Table 4.7.

4.9.1 The Regression Results

Table 4.7 Regression Results

Variable	Parameter Estimate	Standard Error	t-values
Intercept	2.019	0.02502	80.695
Output Assistance	-0.003	0.00459	-0.654
Fertilizer Subsidy	0.005	0.01312	0.381
Soil Moisture Deficit	0.004	0.04545	0.088
Trend	0.009	0.00346	2.570
Coefficient of Determination, R^2			0.735

Critical values for t:

At 1 percent significance level, $t = 3.169$

At 5 percent significance level, $t = 2.228$

At 10 percent significance level, $t = 1.812$

The results, shown in Table 4.7, indicate a negative coefficient for the output assistance variable and positive coefficients for fertilizer subsidy, soil moisture deficit and the trend variable. Nonetheless, in further examining the significance of each of the explanatory variables using the t-test, it was found that at 1 percent significance level, all four variables are virtually insignificant as explanatory variables for the changes in the TFP index. At the 5 percent and 10 percent levels of significance, though, the trend variable emerged as significant explanatory variable for the growth in the TFP index.

Further, when considered on its own, it was determined that the trend variable significantly explains 72 percent of the changes in the productivity of the sheep and beef farm. This result, which differs only slightly from the R^2 indicated in Table 4.7, reinforces the result of the t-test which showed the trend variable as the sole significant explanatory variable in the regression model. In this sense, the growth in the productivity of the average sheep and beef farm in New Zealand during the study period may be attributed to a growth variable which represents the combined effect of various factors other than output assistance, fertilizer subsidy and soil moisture deficit.

Based on these results, the hypothesis advanced earlier is confirmed that output assistance, fertilizer subsidy and soil moisture deficit did not have any significant influence on the productivity of the average

sheep and beef farm in New Zealand during the study period. An explanation for this is provided by Reynolds and SriRamaratnam (1990) in their study of the pastoral sector of New Zealand where they determined that much of the (input and output) assistance extended to the sector was offset by lower world prices and increasing on-shore margins. As such, output prices faced by the farmers did not increase significantly to levels that would have a direct effect on productivity. Moreover, as evidenced by a declining farmers' terms of trade (see Table 1.4), any increases in output prices that could have influenced output levels were countered by increasing farm input costs.

As regards the climate variable, it may be inferred that the effect of the number of days of soil moisture deficit did not play a major role to influence productivity in the sheep and beef farm. However, it is instructive to note the observation in Reynolds and SriRamaratnam (1990) that the effect of adverse weather (such as an increase in days of soil moisture deficit) on output levels is ambiguous, depending on whether the consequent reduction in slaughter weights or lower wool cut per sheep are sufficiently offset by an increase in slaughter rate.

CHAPTER FIVE

SUMMARY AND CONCLUSION

Productivity growth is an important factor contributing to a society's improvement of its standard of living as well as contributing to an increase in the competitiveness of its productive sectors. Changes in productivity may be viewed,

"... according to one's inclinations, as either the source of economic growth or, for certain productive measures, as the source of our salvation as they mark our progress towards making better use of our natural resources and obtaining a given output with a smaller resource use" (Ross, 1974).

Much money is allocated to research and development and education all aimed at increasing the rate of productivity growth. It is therefore essential that besides spending that money, the changes in productivity growth also are measured. Spending without knowing if any progress is being made makes little sense.

In this thesis, measurement of productivity has been undertaken for the sheep and beef sector for the period 1973-74 to 1990-91. The study looked at how an average sheep and beef farm fared in terms of productivity over the period. This period was characterized by major changes in market forces and considerable changes in government assistance to agriculture. Especially, the latter changes were very dramatic from the considerable assistance available before 1984, to the subsequent reforms foisted on the agricultural sector since 1985.

The literature review of productivity growth studies showed that productivity growth has been experienced in most countries as well as in New Zealand, both in agricultural and non-agricultural sectors. Not too much importance can be placed on the absolute magnitude of the findings as much of the variation in findings has been due to different methodological approaches.

This research has concentrated on measuring total factor productivity using an index ratio approach. The reasons for this were discussed in some of the earlier chapters, and had to do with data availability, the simplicity of this approach, as well as theoretical correctness, as compared to the production function approach.

Over the years much has been written about the most appropriate way to aggregate data and about how to measure individual variables. From a theoretical point of view, the use of the Tornqvist index for data aggregation appears to be the most appropriate and has for that reason been used in the study. Problems identified in the literature dealt with how to measure the data, i.e., to account for quality or not, or how to deal with different vintages in capital. As the aim of this research was to discover the total impact of technological advance in terms of productivity growth, no adjustments have been made for quality of different vintages.

Measuring productivity growth is one thing, trying to explain the reasons for the growth rate observed is something quite different. The review of the literature identified very few studies that successfully managed to explain the changes in productivity growth. Often the reason for this appeared to be lack of appropriate data. Of course the reasons may also be that most of the growth was hidden in the variables themselves as changes in quality, as Griliches (1963) showed. If therefore the input data were calculated more carefully in terms of quantity and quality increases, perhaps little else needed to be done to explain the changes in productivity growth.

In the case of the sheep and beef farm in New Zealand, the study has indicated a 1.6 percent per year growth in its productivity for the period 1973-74 to 1990-1991. This rate of growth was obtained from a combined 1.4 percent increase in output and a 0.21 percent decrease in input usage in the farm. Compared with the findings in similar studies, this growth in productivity is close to the estimates presented in a recent study by Philpott (1994) in which he estimated total factor productivity in "sheep, beef and cropping" to have increased at a rate of 1.7 percent per annum from 1973 to 1983, and by 1.9 percent per annum between 1983 to 1993. These results are also lower than the estimates indicated by the NZ Meat and Wool Boards' Economic Service which showed a 4.7 percent per annum increase in the productivity of the sheep farm sector for the period 1980 to 1988, and 9.3 percent

increase per annum since 1984. These estimates by the NZMWBES were calculated in terms of physical output per unit of physical current inputs. As reported, the high rates of productivity growth "appear to be the normal response when the sector is contracting. When investment and current inputs surge upwards the productivity ratios tend to fall" (Johnson, 1989 *in* Reynolds and SriRamaratnam, 1990).

In the present study, farmer terms of trade has also declined at a rate of 4.7 percent per year. This originated from the rate of increase in the cost of inputs, estimated at 12 percent per year, which rose faster as compared to the rate of increase in farm revenue which lagged at 7.3 percent per year. Likewise, returns to costs ratio has declined by 3.1 percent annually. Based on these findings, it can be said that the relative profitability of operating a sheep and beef farm in New Zealand has declined over the period 1973-74 to 1990-91. In addition, the decline in farmer terms of trade and returns to costs ratio implies that over the study period, producers in the sheep and beef sector had been disadvantaged by the high rate of increase in input costs while consumers of the products of the sector had benefitted from the relatively lower rate of increase in product prices.

The overall decline in input usage determined in the present study has been mostly attributed to the high cost of farm inputs which has prevailed during the study period. With lower farm incomes,

investment in capital inputs such as plant and machinery has mostly been foregone, as indicated by a declining quantity index of this factor. Use of discretionary inputs such as hired labour, fertilizer and maintenance expenditure were also deferred showing a decrease in the levels of this particular input group. The positive growth in the livestock input has come mostly from the running-down of sheep and beef cattle stocks.

The growth in productivity of the sheep and beef farm appeared to have been the result of the effort of farmers to maintain production with lower levels of inputs. In this sense, productivity growth can be attributed to the application of technical know-how and to changes in the structure of farms through the consolidation and re-organization of farm holdings. In other words, it may be said that the average sheep and beef farm in New Zealand achieved a considerable level of efficiency during the study period since it managed to increase its output while continually experiencing decline in input usage. To the extent that productivity indicators for competing sectors are known, knowledge of the productivity growth of the sheep and beef sector can serve as a guide in allocating resources in the agriculture sector between or among competitive enterprises on the basis of relative profitability.

In interpreting growth in total factor productivity, various factors which impinge on the production process have to be identified, and their

relative effects on productivity have to be measured. Among these factors could be research, extension services, infrastructure, education, climate, etc.

In this thesis, climate, fertilizer subsidy and output assistance were examined as potential sources of the increases in output of the average sheep and beef farm. Results of the regression analysis, however, indicated that none of these three factors emerged as significant explanatory variable for the growth in total factor productivity. In the case of the policy variable represented by fertilizer subsidy and output assistance, the regression result implies that the substantial increases in assistance to farmers and the subsequent liberalization measures were not significant as to influence farm productivity. In other words, the impact of the assistance paid to farmers was minimal because much of its expected positive effects was offset by increased domestic costs. Likewise, climatic variations have not been significant as to affect the growth of output in the sheep and beef farm.

Therefore, while it has been determined that productivity on the sheep and beef farm increased during the 18-year study period, the regression results obtained in the study remain inconclusive regarding factors that can significantly explain the growth in productivity. Knowledge about these factors is invaluable in terms of providing guidance towards improving efficiency in order to achieve higher productivity growth in

the farm. In light of the ever-increasing cost of farm inputs, knowledge of the sources of productivity growth would help in guiding expenditures into on-farm investment as well as off-farm investment into research and development. Finally, irrespective of the fact that factors causing productivity growth can be identified or not, it is important that productivity continues to increase. In the new world trade environment under GATT, competition in trade will continue to increase and as Heady wrote, "it is important that productivity of the nation's resources, ..., be increased as this competition or world need intensifies ..." (Heady, 1962). The research in this thesis has made a small contribution to this by showing that, against fears of a flattening out of productivity growth in agriculture, the rate of growth has still been significant for the sheep and beef sector of the agricultural industry.

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APPENDIX 1

Description of Survey Farms¹⁷

A. Methods of Stratification

Three main kinds of stratification have been used in the survey, namely:

1) Geographical Stratification

The aim is to spread the total sample of approximately 530 farms over the main sheep and beef farming districts in New Zealand by a process of random selection proportionate to the sheep and beef farm populations.

2) Flock Size Stratification

Initially, all farms with less than 750 stock units, and Crown properties are excluded. This reduces the population to be covered by over twelve thousand flocks, and excluded about 7.0 percent of the sheep numbers. In carrying out this stratification, farms are randomly selected in proportion to the distribution of flock sizes within the geographical stratification. A deviation from rigorous adherence to the population distribution of size groups is caused by the need to have at least 25 to 30 farms in a stratum before it is of any analytical use.

3) Farm Class Stratification

The survey results are classified into eight farming sub-groups. While it is realized that these cannot cover every sheep and beef farm type completely, this has proved a reasonably satisfactory method of classification.

¹⁷Source: The New Zealand Sheep and Beef Farm Survey, 1990-1991. NZ Meat and Wool Boards' Economic Service.

B. Definition of the Eight Farm Classes1) SOUTH ISLAND HIGH COUNTRY

Extensive run high country located at high altitude carrying fine wool sheep, with wool as the main source of revenue. Located mainly in Marlborough, Canterbury and Otago.

2) SOUTH ISLAND HILL COUNTRY

Mainly fine wool sheep with a carrying capacity of around three stock units per hectare. Wool and sales of cast-for-age ewes are a major source of revenue. Mainly in Canterbury.

3) NORTH ISLAND HARD HILL COUNTRY

Carrying around eight stock units per hectare with twelve sheep per cattle beast. Sheep provide approximately three quarters of the revenue, the balance being derived from the sale of cattle. Mainly located on east and west coasts and the central plateau of the North Island.

4) NORTH ISLAND HILL COUNTRY

Easier hill country and smaller holdings than Class 3. Mainly Romney sheep and carrying over ten stock units per hectare with twelve sheep per cattle beast. A high proportion of sale stock sold is in forward store or prime condition. These farms are located throughout the North Island.

5) NORTH ISLAND INTENSIVE FINISHING FARMS

High producing grassland farms carrying twelve stock units per hectare with ten sheep per cattle beast. Replacement ewes are often bought in. Mainly located in South Auckland, West Coast North Island and Hawkes Bay.

6) SOUTH ISLAND FINISHING-BREEDING FARMS

A more extensive type of finishing farm generally breeding its own replacements and frequently with some cash cropping. Mainly in Canterbury and Otago.

7) SOUTH ISLAND INTENSIVE FINISHING FARMS

High producing grassland farms carrying about thirteen stock units per hectare and with some cash crop. Mainly in Southland, South and West Otago.

8) SOUTH ISLAND MIXED FINISHING FARMS

Mainly in Canterbury with a high proportion of the revenue being derived from grain and small seeds as well as finishing stock.

APPENDIX 2

Farmer Terms of Exchange

YEAR	PRICES RECEIVED INDEX	ON-FARM INPUT PRICE INDEX	TERMS OF EXCHANGE
1972-1973	316	158	2000
1973-1974	329	180	1828
1974-1975	233	204	1142
1975-1976	343	229	1498
1976-1977	452	272	1662
1977-1978	398	314	1268
1978-1979	504	343	1469
1979-1980	614	420	1462
1980-1981	600	516	1163
1981-1982	722	604	1195
1982-1983	718	665	1080
1983-1984	788	667	1181
1984-1985	907	734	1236
1985-1986	730	831	878
1986-1987	845	894	945
1987-1988	880	960	917
1988-1989	955	976	978
1989-1990	1154	985	1172
1990-1991	1000	1000	1000

Source: NZ Meat and Wool Boards' Economic Service

APPENDIX 3

Farm Buildings Price Index¹⁸

YEAR	INDEX (1979=1000)
1973	161
1974	181
1975	209
1976	245
1977	286
1978	338
1979	389
1980	464
1981	538
1982	614
1983	638
1984	670
1985	813
1986	863
1987	899
1988	940
1989	1000
1990	1032
1991	1019

Source: Key Statistics (various issues)
Statistics Department

¹⁸1973-1979 and 1980-1988 indexes were transposed from their original Official base years (i.e., 1971 and 1979, respectively) to a 1989 base period.

APPENDIX 4

Overdraft Interest Rates

Year	Overdraft Interest Rate, %
1973-1974	6.11
1974-1975	6.01
1975-1976	6.10
1976-1977	7.73
1977-1978	9.51
1978-1979	9.93
1979-1980	12.05
1980-1981	13.48
1981-1982	13.61
1982-1983	13.86
1983-1984	12.38
1984-1985	15.55
1985-1986	23.82
1986-1987	22.30
1987-1988	22.50
1988-1989	19.25
1989-1990	19.00
1990-1991	18.83

Source: NZ Meat and Wool Boards'
Economic Service