An application of econometric modelling to Hawkes Bay apple supply.

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ABSTRACT

To enhance their standing in the market place the New Zealand Apple and Pear Marketing Board (NZAPMB) must maintain a balanced 'portfolio of products' (NZAPMB, 1990). This portfolio includes substantial volumes of traditionally traded varieties. Recent changes in the NZAPMB price mechanism have meant that orchardists are now paid closer to true market returns. There is now increasing financial pressure on orchardists to change their varietal mix to new 'preferred' and more profitable apple varieties. These varietal changes are expected to have serious consequences on the volume of traditional varieties supplied to the NZAPMB.

New Zealand apple orchardists are expected to be profit maximising. Orchardists are expected to adapt to varietal price movements by renovating their orchards to a more profitable varietal mix. In the short run orchardists can reduce their varietal supply through tree removal. However, the apple production function dictates the speed at which orchardists can increase supply. Consequently, supply expansion to the NZAPMB can only occur some time after a price signal, while supply contraction can occur instantly.

The French and Matthews (1971) supply response model provided a theoretical framework for this study. However, it is often limited by its exhaustive data requirement. The derivation of models within the French and Matthews framework was again restricted by data limitations. Simple models explaining varietal supply expansion and supply contraction were developed. The models showed that price significantly influenced supply contraction and supply expansion.

The NZAPMB forecast supply expansion through monitoring varietal plantings and then applying yield functions. Supply expansion can be forecasted with reasonable accuracy. A robust econometric model which forecasts short run supply contraction would be of immediate use to the NZAPMB. This study identified the data required and the potential of a model to be developed for this purpose.

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CHAPTER 1. INTRODUCTION

1.1. Introduction to the New Zealand pipfruit industry

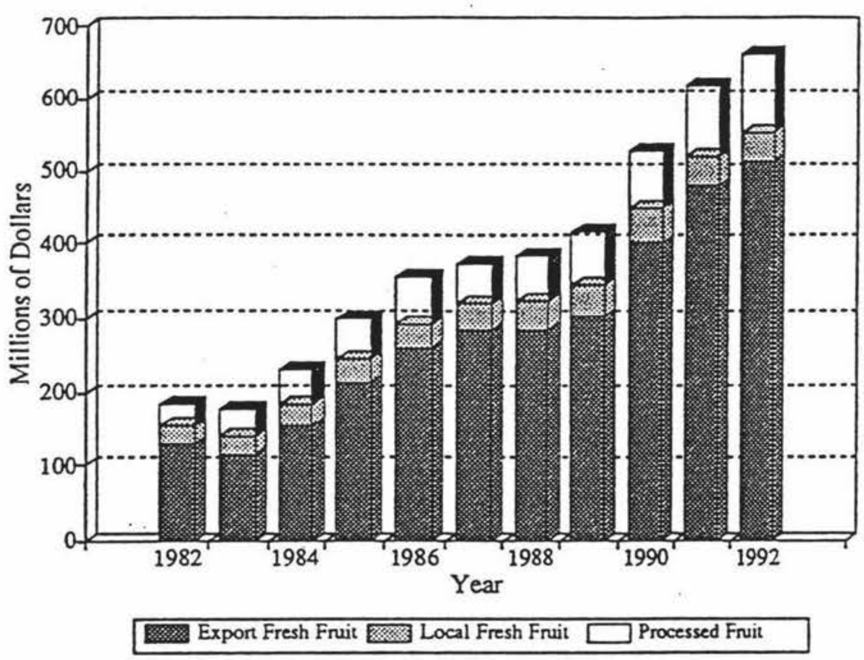
The first commercial pipfruit orchards in New Zealand were planted in the 1870's on the Heretaunga plains (Boyd, 1984). The area planted in pipfruit eventually peaked in the late 1920's when some 10,000 hectares had been planted (Wilton, 1989a). Planted area declined during the 1930's and 1940's largely as a result of the lack of industry organisation. By 1948 the planted area of pipfruit had declined to 2,350 hectares. At that time it was decided to form the New Zealand Apple and Pear Marketing Board (NZAPMB) to organise the marketing and distribution of New Zealand pipfruit. The Apple and Pear Marketing Act of 1948 gave the NZAPMB sole rights to acquire and market apples and pears grown in or imported to New Zealand. Since the early 1950's the area of pipfruit grown in New Zealand has increased to approximately 10,000 hectares (Wilton, *ibid.*), producing 22 million tray carton equivalents[1] of fruit in 1992.

The NZAPMB consider themselves to be a marketing organisation. Their mission statement is 'to maximise the return to its suppliers primarily by the worldwide marketing of pipfruit, horticultural products and related products and services' (NZAPMB, 1992a). The NZAPMB represent New Zealand pipfruit growers in 'an oversupplied Northern Hemisphere market' (Pope, 1989). The Board deal with giant super-market chains who account for between 60 and 80 percent of apple sales in various European countries and 99 percent of apple sales in North America (Pope, 1989). Consumers are discerning favouring, and paying for, quality 'preferred' apple varieties. The NZAPMB realised some of the highest returns ever by variety in 1992 alongside some of the lowest for less preferred varieties (NZAPMB, 1992a).

[1]A tray carton equivalent represents one bushel of fruit. A bushel is a volumetric measure. One bushel of apples weighs approximately 18.5 kg. This bushel weight is used for the remainder of this study.

Fresh fruit exports currently earn 78% of the total income received by the NZAPMB. The balance of income is generated from local market sales and processed fruit. The gross income generated from NZAPMB pipfruit sales for the past ten years is illustrated in Figure 1.1. New Zealand pipfruit producers, therefore, are largely dependent on income from overseas markets.

Figure 1.1. Gross income from New Zealand sales of pipfruit and related products.



Prices received by the NZAPMB for individual apple varieties are determined by consumer demand in respective markets. However, prices paid to New Zealand producers are determined by the NZAPMB. Income generated from New Zealand pipfruit sales is distributed by the NZAPMB to New Zealand orchardists. Prior to 1988 the NZAPMB cross-subsidised between varieties to ensure that all varieties received similar returns. However, between 1988 and 1990 cross-subsidisation was gradually removed. The NZAPMB now pay pipfruit orchardists close to market returns for their fruit. Consequently returns between varieties are now wide ranging. Higher priced varieties offer significantly greater returns to orchardists than those traditionally grown.

Rational producers are expected to attempt to maximise profits[2] and in doing so change their supply levels as output prices change. Therefore, assuming that pipfruit orchardists are rational, supply to the NZAPMB is expected to change in response to changes in output prices. Supply responses in recent years are expected to be pronounced given the recent changes in the pricing mechanism.

1.2. Problem statement

To conserve and build on their standing in the market place the NZAPMB must maintain a balanced 'portfolio of products', including substantial volumes of the most commonly traded varieties (NZAPMB, 1990). Ideally the volume of fruit submitted to the NZAPMB should fulfil the quantities required to meet customer demands. Changes in the prices paid to apple orchardists are expected to cause changes in the volume of apples submitted to the Board. Furthermore, changes in price differentials between varieties will cause changes in the proportions of different varieties submitted to the NZAPMB within this portfolio of products.

Over the past ten years apple submissions to the NZAPMB have increased significantly from 10 million tce[3] in 1982 to 21 million tce in 1992. Within the increasing supply, the portfolio of apple varieties submitted has changed considerably. This appears to be the direct result of market prices being returned to growers. The changing volumes of important export varieties of apples submitted to the NZAPMB between the years 1982 and 1992 is presented in Figure 1.2.

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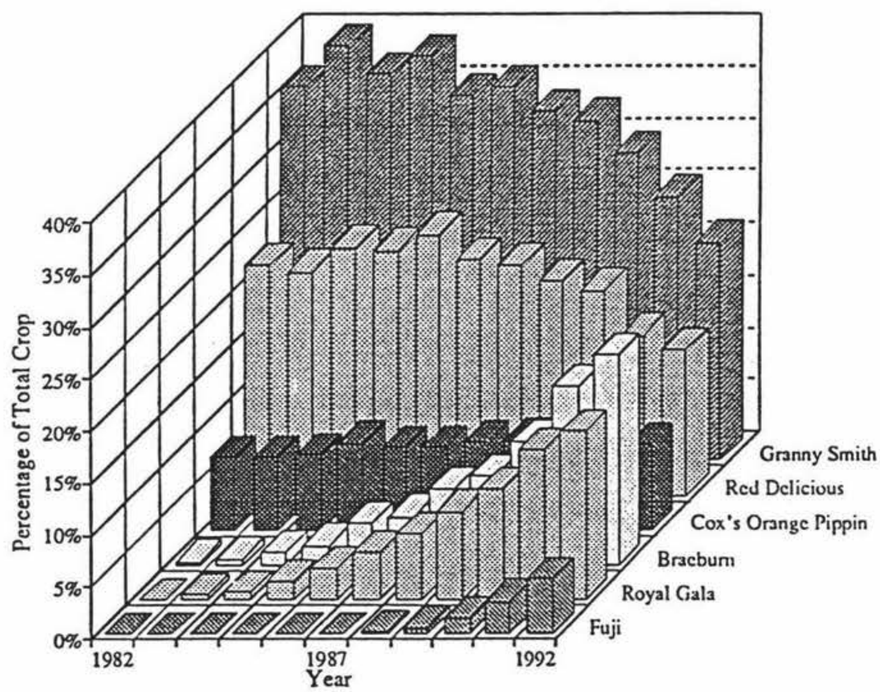
[2]While profit maximisation may not be the primary goal of all producers The Theory of the Firm (Coase, 1937) is a useful model to predict rational behaviour. Lockhart (1990) reported that some 79% of pipfruit growers on the Heretaunga Plains have primarily profit orientated goals.

[3]A tce is the industry's abbreviation for tray carton equivalent, a bushel equivalent of apples whose end use may be either process of fresh consumption.

Similarly the mix of varieties within the export portfolio has changed. Currently the main varieties exported from New Zealand, in declining order as a percentage of total export volume, are; Braeburn (22%), Red Delicious (20%), Royal Gala (17%), Granny Smith (17%), Cox's Orange Pippin (7%), Fuji (4%), Gala (4%) and others of insignificant volumes (NZDS, 1992). However, ten years ago the main varieties were; Granny Smith (47%), Red Delicious (22%), Golden Delicious (7%), Cox's Orange Pippin (7%), and Sturmer (6%) (NZDS, 1982).

Figure 1.2. The changing varietal mix of apple submissions to the NZAPMB 1982-1992.



The NZAPMB requires accurate crop forecasts to organise the annual handling, distribution and marketing operations for the expanding pipfruit supply. Crop estimates are made each year prior to harvesting for this purpose. Longer-term forecasts, based on actual plantings and removals from annual orchard surveys, are used for strategic planning. However, the NZAPMB has no objective means of measuring how changes in price will effect supply. The NZAPMB, therefore, is reactive to changing supply rather than pro-active. Forecasting expected plantings, removals and subsequent changes in apples volumes resulting from changing prices will be of immediate assistance to the NZAPMB. The capital requirements for packing, storing, and transportation of increasing volumes of pipfruit can then be determined more accurately. Therefore, knowledge of future supply will aid essential strategic planning decisions. Similarly, accurate forecasts of the changing varietal mix will assist the NZAPMB in their marketing operations.

The NZAPMB stress that maintaining a crop mix which satisfies market requirements is essential for obtaining the highest returns to its suppliers. The crop mix currently satisfies that desired by the NZAPMB. However, changes over the next five years are expected to continue, significantly altering the desirability of the mix submitted.

For planning purposes it is important for the NZAPMB to be able to estimate future production by variety. One approach to forecasting is to investigate past changes to varietal production levels in response to changing prices. Econometric supply response modelling provides such a means. The purpose of this study is to use econometric modelling techniques to investigate, measure and explain changes in export fruit submissions to the NZAPMB in response to changes in varietal price.

This study is limited to apple supply. Given that pear supply to the NZAPMB represents three percent of New Zealand's pipfruit production, the influences of pear prices and production on apple production are assumed to be minimal at a regional or aggregate level. Furthermore, the study is limited to the Hawkes Bay Region. Hawkes Bay was chosen because of its well established pipfruit industry. Climatic conditions affecting apple production across a region, as opposed to across the nation, are assumed (for this study) to be consistent. Planting, fruit submission, end use and price data are collected by the NZAPMB on a regional basis, therefore, a regional rather than aggregate study was appropriate.

1.3. Hypothesis

The supply of apples to the NZAPMB in a given year is produced from a stock of bearing trees. The stock of bearing trees is the result of planting and removal decisions from past and present years. Fluctuations in supply from year to year will result from changes to the number of bearing trees, climatic variability, and incremental technological improvements.

It is assumed that planting and removal decisions are influenced largely by expectations of profit. Profit on apple orchards is largely determined by input costs, output price, yield and packout. An orchard is made up of a number of different varieties. Differences between varietal price are expected to cause on-orchard changes to the variety mix and the subsequent portfolio of apples submitted to the NZAPMB. Given the relationship between price and area the dynamics of supply can be examined using econometric modelling. Structural relationships underlying supply are theoretically derived and tested for significance. In this study the principal null hypothesis (H_0) to be tested is:

> *Price fluctuations between varieties do not cause changes within the portfolio of apples submitted by growers to the NZAPMB.*

In the event of rejecting the null hypothesis, the alternative hypothesis (H_A) will not be rejected. That is:

> *Price fluctuations between varieties cause changes within the portfolio of apples submitted by growers to the NZAPMB.*

1.4. Methodology

Ferguson and Maurice (1970) describe economists as being in three classes; 'Extreme apriorists' believe that no aspect of economic theory is susceptible of empirical test. 'Ultra empiricists' think that every facet of theory can and must be proved empirically at each step in a chain of analysis. While the 'positive economists' take a middle position asserting that conclusions (or theorems) of a model should be tested.

A positive approach is adopted for this study. Firstly, economic theory is discussed with respect to the competitive producer in a perfectly competitive market. From this discussion the *a priori* expectations of producer behaviour are established. Supply response models, which build on previous work by other authors, are then derived based on established expectations. Adapted theoretical models are then applied to model apple producer behaviour and supply responses in the Hawkes Bay Region. Using ordinary least squares regression analysis individual equations for export varieties are empirically derived.

Results obtained are compared with the *a priori* expectations of apple producer behaviour. The statistical significance of the results are examined and the null hypothesis will be rejected or fail to be rejected. If the null hypothesis fails to be rejected the model will be used to forecast future changes within the varietal mix.

1.5. Outline

The 'apple orchard firm' is introduced in Chapter 2. The characteristics of the apple tree production function are then discussed with respect to the limitations it imposes on orchardists' supply response. The 'rigidity' of the production function, making apple industry supply side economics subtly different from traditional theory, is discussed. Changing supply and demand for apple varieties introduces the phenomenon of the 'variety life cycle'. It is argued that the phase at which a variety is at influences its price. Other macro-economic factors affecting price are also discussed.

A definition of 'econometric modelling' is presented in Chapter 3. For such modelling, measures of producer profit expectations invariably need to be derived. Possible derivation techniques are then examined. The potential difficulties faced for modelling perennial crops are discussed. Finally, a review of theoretical and applied supply response models pertaining to perennial crops is presented. The success of these models is assessed with reference to their practicality and performance.

In Chapter 4 a historical perspective of the factors influencing orchard renovation is presented. A theoretical supply response model, specific to varietal changes within the Hawkes Bay apple supply is developed. The data collected are presented and an explanation of its suitability for variable derivation is given. Given the available data applied models, based on previously established theoretical models, are derived and tested.

Results of the practical application of models developed in Chapter 4 are presented in Chapter 5. The statistical significance and 'goodness of fit' of the models are analysed. Models by variety are also compared and the reasons for differences between the models are discussed.

Finally, in Chapter 6 conclusions are drawn pertaining to the potential use of derived models for forecasting supply. Furthermore, attention is paid to limitations of derived models. Improvements to the models presented are discussed and opportunities for further study are identified.

CHAPTER 2. THE APPLE ORCHARD

2.1. Introduction

New Zealand apple orchardists typically grow a mix of apple varieties. Changing the mix involves the removal and replacement of existing orchards, or new plantings. Removals cause instant supply changes. However, new plantings require a number of years to mature to full bearing as dictated by the 'apple production function'. The mix of varieties required by apple orchard firms and the uniqueness of the apple production function provide the basis for a discussion of the theoretical *a priori* economic behaviour of a perfectly competitive orchard firm. This behaviour is explained and adapted with respect to orchard development and renovation decisions. The behavioral characteristics identified influence supply. Similarly, there are other influences within the macro-economic environment. These influences are discussed with respect to their impact on the supply from New Zealand apple orchardists.

2.2. The Characteristic Apple Firm

The characteristic apple firm produces a 'portfolio' of apple varieties each requiring specific cultural attention. Physiological events occur at distinct times of the year making the timing of cultural orchard operations critical and inflexible. For example, picking must occur within harvesting dates, set by the NZAPMB, when fruit maturity is at an optimum relative to post harvest storage requirements. These characteristics mean that exposure to production risk or demands for labour for an individual variety are high at specific times. By growing a number of varieties the orchard manager can spread production risk and seasonal labour demands. The use of several varieties also fulfils the cross-pollination requirements of some varieties. Therefore, within the characteristic apple orchard a number of different varieties are likely to be grown.

The orchard manager can make adjustments to the productive stock of trees within the orchard by replacing or top-working[1] existing trees. Alternatively the orchardist can extend the orchard by purchasing new land or by developing existing land if available. The degree of change within the orchard mix, in response to changing economic conditions, will be constrained by the seasonal labour resources, pollination requirements, the orchard manager's risk averseness, cashflow requirements and capital resources.

Each orchard firm is unique in its management resources, capital constraints, existing orchard, cost structures and size. Therefore, orchard firms are expected to respond differently to changing economic conditions.

2.3. The Characteristic Apple Production Function

The most important production function confronting apple production is the relationship between yield and tree age. Yield over time, for perennial crops, generally follows a characteristic sigmoid pattern (Jackson, 1986). Firstly, a lag phase occurs between planting and first economic output. Output then increases exponentially after which an extended period of maturity, where output is harvested from the planting, eventually transpires. Variability in mature yields will occur due to characteristic biennial bearing and climatic influences. However, astute orchard managers will endeavour to reduce seasonal variability in an attempt to avoid biennial bearing and its detrimental effect on yields and fruit size.

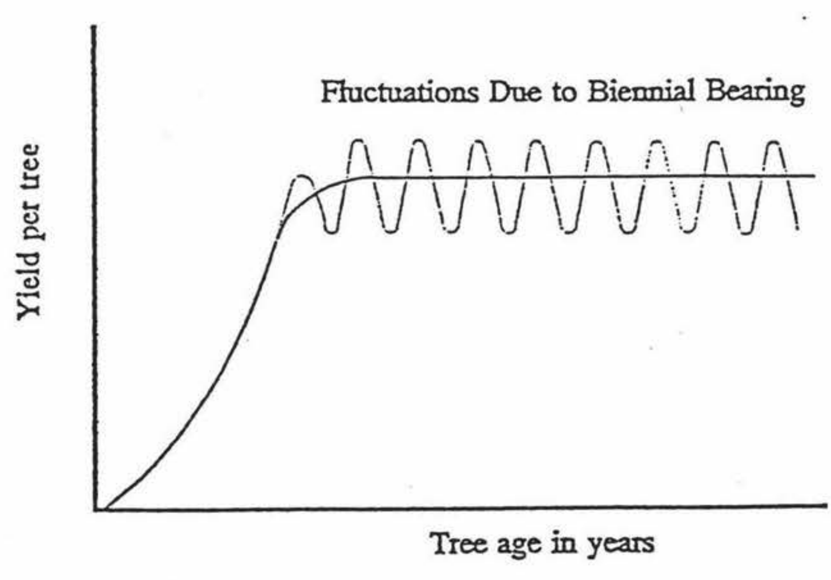
The actual life span and productivity of a perennial crop is dependent on its species and variety. The typical production function for apple production is presented in Figure 2.1. For newly planted apple trees the initial lag phase continues until years three or four. Output increases until trees are mature, usually in years seven to ten. The actual age that trees reach maturity will be influenced by biological factors, the planting system used and the management ability of the orchardist. With correct management trees continue to bear heavy yields for an undefined number of years. Fluctuations in yields may occur from year to year

[1]Top-working is a colloquial expression used to describe the process of limb removal and grafting on of budwood from a different variety.

due to the influences of biennial bearing, seasonal variability or disease. Events such as frosts or disease may cause a severe reduction in crop in a particular year. The following year a heavy crop will often result. The cycle, known as biennial bearing, is then established (Jackson, 1986). Production stability in some instances can be returned by the correct management techniques. Following maturity production typically goes through a period of decline due to aging. Alternatively trees may decline prior to this point due to infestation by pests and disease, for example, fireblight.

As an alternative to planting new trees, the orchardist can 'top-work' an existing orchard. Top-working involves grafting alternative varieties onto an established tree framework. The production function for top-working is different from that of tree planting. The lag phase is markedly shorter than that of new plantings so mature yields are reached earlier in the life cycle of the 'new' tree. However, topworked trees are not 'expected' to live for as long as new plantings supposedly owing to the accumulation of subclinical levels of pest and disease.

Figure 2.1. The characteristic apple production function of yield over time from planting.



Initially apples grown in New Zealand were those well established elsewhere, particularly in Britain, USA and Australia (Janick and Moore, 1975). The New Zealand pipfruit industry was originally dependent on varieties such as Sturmer Pippin and Cox's Orange Pippin from Britain, Jonathan, Delicious and Golden Delicious from USA, and Granny Smith from Australia. These varieties have now been grown successfully for 100 to 165 years (Bultitude, 1983) and are well represented commodity varieties in world markets (Moore and Ballington, 1990). With no improved alternatives trees of these varieties are expected to finish their physical life cycle before being replaced. However, a more recent phenomenon is that a variety may finish its 'economic' life cycle before its physical life cycle because consumers are becoming more discerning. The popularity of specific varieties is changing rapidly. In response to consumer preferences new varieties are grown that offer improved quality, storage, and consumer appeal such as Braeburn, Royal Gala, Fuji and GS2085[2].

2.4. Supply-Side Economics of the Apple Industry

Some characteristics of the New Zealand apple industry are similar to that of a perfectly competitive industry. The industry consists of some 1600 relatively small orchard firms which individually can not influence market output price. Orchard firms produce a set of homogenous apple varieties and as yet there are no barriers to entering the industry other than those imposed by individuals' resource constraints. New Zealand growers submit their produce to the NZAPMB who sell it on the growers behalf to a market made up of a large number of consumers. The New Zealand orchard firm has no choice but to accept prices, determined by, and distributed through the NZAPMB. The NZAPMB can be considered as the 'channel' through which growers receive price signals from the market place. Payments from the NZAPMB, therefore, provide the stimuli for orchard adjustments by growers.

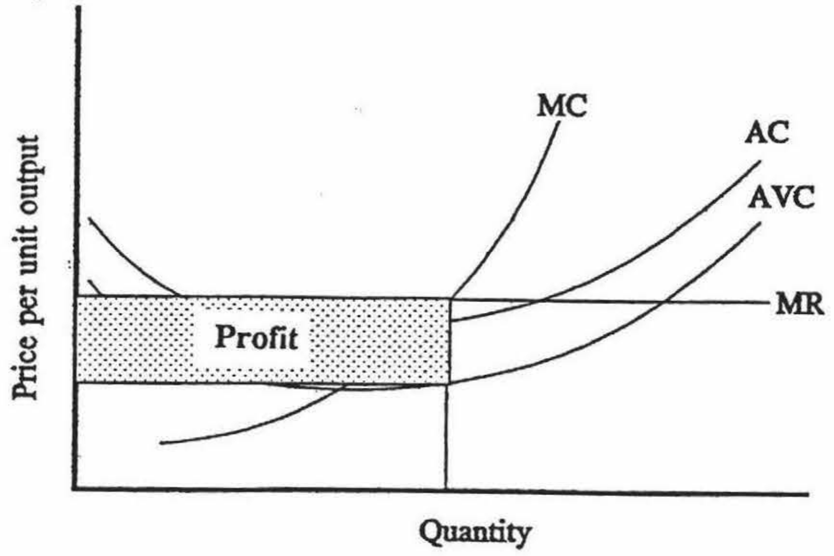
[2]GS2085 is one of a series of varieties of Gala-Splendour crosses released by FIPIA (Fruit Industry Plant Improvement Agency) in 1990. GS2085 is yet to be named.

2.4.1. Profit Maximisation of the Competitive Apple Firm

Individually, the competitive apple firm cannot influence the market price. Increases or decreases of fruit volume from an individual producer are considered to have an insignificant affect on aggregate supply and, therefore, price. Under these conditions the orchard firm has a horizontal demand curve at the output price level. The sale of an extra unit of output at the given price level will return a *marginal revenue* (MR) equal to the price.

The theoretical profit maximisation of the competitive apple firm occurs where MR or price of an extra unit of output equals the *marginal cost* (MC) of an extra unit of input (Baumol and Blinder, 1985). At this point, MC = MR, the profit maximising level of production occurs. Figure 2.2 depicts the profit maximisation equilibrium of the competitive firm. At point A profits are maximised, that is, MC = MR. This point provides the equilibrium output level where producers are expected to produce in order to maximise profits. Profits equal the price times quantity at equilibrium, minus total costs (average cost times quantity) which is represented by the shaded area in Figure 2.2. In the situation shown in Figure 2.2 'super-normal' profits are being made. That is, the price per unit output exceeds the average cost of production. For individual producers the theoretical profit maximising level may not be the same due to dissimilar cost structures across orchard firms.

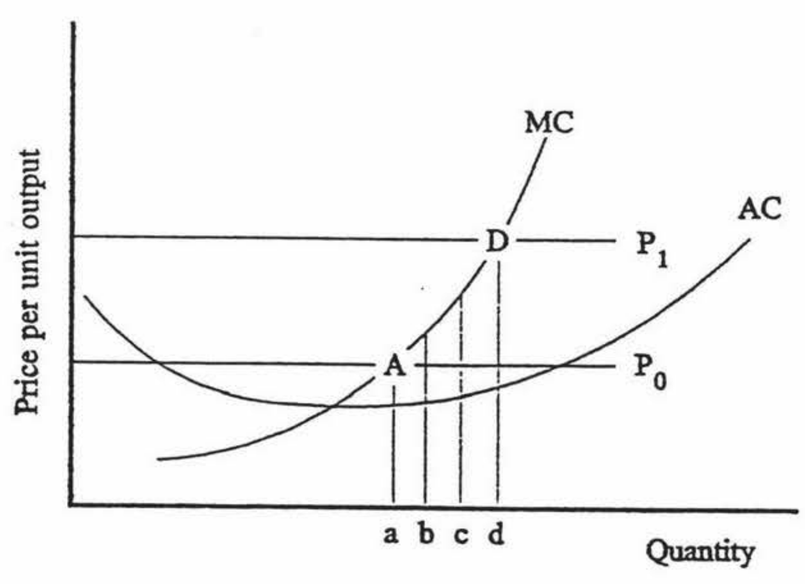
Figure 2.2. Profit maximisation of the competitive firm.



From Figure 2.2 the theoretical *supply curve* of the competitive firm for both the short-term and long-term can be derived. In the short-term a firm's supply curve is its MC curve above the point where it intersects the *average variable cost* (AVC) curve. The long-term supply curve of the competitive firm is its MC curve above the point where it intersects with the *average cost* (AC) curve because in the long run all costs are considered variable. As the MR changes the desired production level which maximises profits changes. Where the MR is less then the AVC the firm will stop producing.

The principles of the supply from the competitive firm can be applied to the supply of an individual variety produced by an orchard firm. When the price of an individual variety changes, as has occurred in recent years in the New Zealand apple industry, each producer is expected to respond by increasing or decreasing production of that variety to a new profit maximising level. That is, where the MR of producing the variety is equal to the MC of production. Figure 2.3 shows the change to a new profit maximising point, D, given an increase in the price level of a variety. The subsequent theoretical profit maximising level of production is shown as position *d* in Figure 2.3.

Figure 2.3. Attaining the profit maximising level of varietal production of the competitive apple orchard firm.



In reality, orchard firms are somewhat inflexible and cannot change the level of production easily. Therefore, the profit maximising level of production is not easily attained. Supply changes, due to changes in the price level, need to be described in terms of short run and long run supply responses. Baumol and Blinder (*ibid*) describe the long run as 'a period of time long enough for all the firm's commitments to come to an end', and the short term as a period of time 'so that some, but not all, of the firm's commitments will have ended'. For an apple firm the long run can be considered as a period of time long enough for all the firm's productive stock adjustment decisions to reach their mature production levels. For top-working and new planting decisions the long run can be as long as five or ten years respectively. The short run can be considered as the period of time over which the firm's yearly obligations have ended. Tree removals and tactical orchard decisions such as pruning, spraying, thinning, and picking regimes, therefore, can be considered as short run decisions (some of which may have influences beyond 12 months).

Short Run Orchard Firm Supply Changes

Due to the temporal nature of apple growing, the production increase to the theoretical profit maximising quantity *d*, as shown in Figure 2.3, can not occur instantaneously. The volume of fruit produced from mature apple trees tends to be relatively constant (disregarding biennial bearing and climatic influences). In the short run the apple producer can not markedly increase total output. However, the grower can increase the 'pack-out' of export quality fruit. Fruit of sufficient quality is packed for export markets, first rejects are sent to the local market while unsatisfactory fruit is directed to processing and is of little real value to growers.

Given a higher output price, attention can be paid to improved cultural and management techniques to increase packouts. These may involve frost protection measures over critical periods of production, improved spray protection to reduce the incidence of pest and disease, exactness of thinning to obtain ideal fruit size and/or three to four select pickings to ensure optimal fruit colour. Such activities increase varietal pack-out at the expense of greater input costs. Total supply is expected to remain unchanged, however, the proportion of export quality fruit can be increased.

In response to price decreases, orchardists can reduce the level of production by removing a proportion of the productive stock of trees. Orchardists' desired level of production resulting from price decreases, therefore, can be reached in the short-run. Orchardists are also expected to reduce input costs in response to lower output prices. Consequently, pack-outs are expected to decline further reducing the volume of export quality fruit.

Long Run Orchard Firm Supply Changes

Long run apple supply changes result from changes in the productive stock of trees. An increase in the price level, as shown in Figure 2.3, is expected to cause an increase in the productive stock of trees to a level which potentially fulfils the desired long run level of production, *d*. Over time production will increase through points *b*, *c* to *d*, where *d* is the desired long run level of production where profits are maximised.

Apple producers have three alternative strategies for increasing the productive stock of an individual variety. Orchardists can either replace existing trees of unprofitable varieties with more profitable alternatives, top-work unprofitable varieties, or extend the orchard area to accommodate new plantings.

Orchard firms are expected to adjust their productive stock of trees of each variety to levels which will produce the desired output level of production. However, orchard firms may not be in the position to fully adjust their production base in the short-term. Therefore, tree stock or area responses to changing prices will still be lagged.

2.4.2. The Apple Industry Supply Curve

If growers behave in a similar fashion their responses to changing price conditions will cause aggregate changes in total industry and export fruit supply. Short run and long run supply response by growers will directly influence short and long run aggregate supply changes.

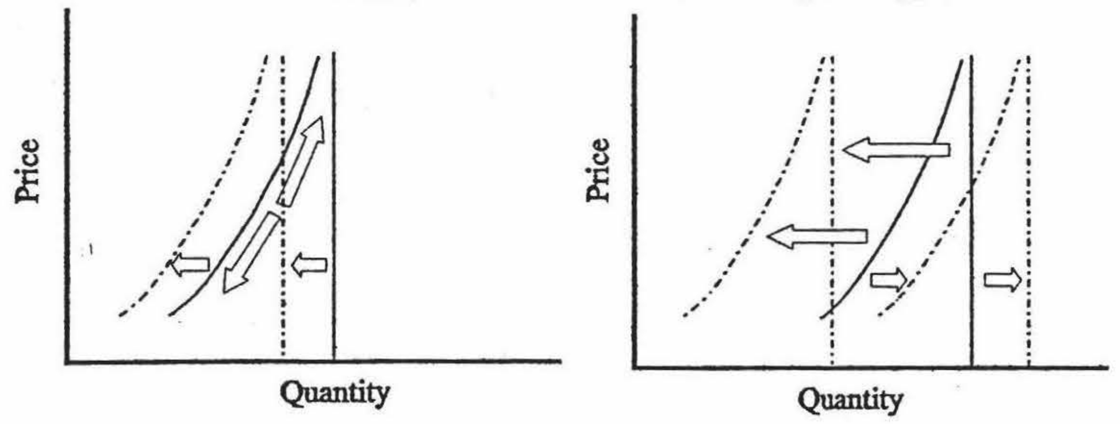
Short Run Industry Supply Changes

The short-term industry supply curve for the perfectly competitive industry can be derived by horizontally summing the supply curves of all the firms in the industry (Baumol and Blinder, 1985). The short-term industry supply curve shows the current level of total production. Because apple producers can not increase their level of total production readily, the short term total industry supply curve approaches vertical. The supply curve for export fruit is less steep because growers can influence export supply more readily by altering pack-outs using policies such as improved spray management, selective picking, or summer pruning.

In the short term both the total supply curve and the export supply curve can only move to the left as shown in Figure 2.4a. That is, removal of trees in response to price immediately decreases supply. Such removals will quickly reduce supply as has happened with Granny Smith and Red Delicious where 8.5% and 18.5% of total planted area was removed in 1990 (NZAPMB, 1992b) Consequently, in 1991 supply declined by 8.5% and 22.5% respectively. Price increases cause movements up the supply curve as producers increase input costs to obtain extra units of output. Movements along the flatter export fruit supply curve will result in more significant supply fluctuations.

Figure 2.4. Possible shifts of total and export supply in the short and long run.

2.4a Short run supply shifts **2.4b Long run supply shifts**



Short run supply will also be effected by changes beyond the farm gate. Tightening grade standards set by the NZAPMB cause more fruit to be directed towards domestic or process markets. In recent years the NZAPMB has stressed the importance of quality for the success of the New Zealand apple industry and in 1992 was working on gaining accreditation to the ISO 9000 series[3] international quality standard for fresh fruit (NZAPMB, 1992). Subsequently, the volume of fruit being processed over the past five years has increased significantly while export volumes have remained relatively constant.

Adverse or favourable weather conditions will shift the short run supply curve to the left or right respectively. In the 1991-1992 season cold weather resulted in small sized fruit, particularly in Gala types. Similarly, hail damage in the Wairarapa significantly reduced the export quality fruit volume from this region. Although the Wairarapa is not a major production area crop volumes from the area were half that expected (Robertson, 1991). Anticipated export volume was reduced by approximately 3 million cartons (NZAPMB, 1992). Adverse weather conditions may also have a residual effect in the consecutive year due to subsequent biennial bearing.

Long Run Industry Supply Changes

In the long run the number of firms in the industry, the area of apples grown by each firm, the varieties and yields per hectare are not fixed. Therefore, the supply curve may shift over time to either the left or to the right as shown in Figure 2.4b. If producers are making profits more firms will enter the industry and existing firms will increase planted area. Alternatively, if producers are making losses they will exit the industry or reduce the stock of productive trees. Supply reductions are observed in the short run because of the instantaneous impact of tree removals.

[3]The ISO 9000 series is an internationally recognised quality assurance standard involving total quality management. Quality assurance is becoming increasingly important for gaining access to markets and consumer acceptance.

The availability of improved technology inevitably moves the supply curve outwards as output increases from the same area. Again this has been a factor in the New Zealand apple industry where average production per hectare has increased from 950 bushels to 2580 bushels over the past 40 years (Wilton, 1989a).

2.5. The Apple Industry Demand Curve

The industry has a downward sloping demand curve unlike the horizontal demand curve of the competitive firm. The quantity demanded, therefore, exhibits an inverse relationship with price. Changes in price such as those caused by changing supply, results in movement along a fixed demand curve. For example, at the beginning of the 1992 season New Zealand apples received high prices in continental Europe. This was largely due to reduced European production, caused by severe frosts in 1991, resulting in a low carryover of fruit into the market in 1992 (NZAPMB, 1992a).

Movements of the demand curve are likely to occur for several reasons. Short term movements of the demand curve may be caused due to fluctuations in the price of competing products. The NZAPMB (*ibid.*) reported a collapse in the European apple market in 1992 due to the early arrival of massive berry and stone fruit harvests. The oversupply of very cheap, good quality summer fruits coinciding with a very hot summer changed consumer buying habits and put downward pressure on apple prices. Apples were subsequently withdrawn from the marketplace and either processed or dumped. A similar situation was reported to prevail in the North American market. The short run demand curve for New Zealand apples, therefore, appears to be steep and highly mobile in these markets.

In the long run increases in population can increase total sales. Expanding market regions, new export markets, or increases in personal income may move the aggregate demand curve to the right. The NZAPMB consider market access critical for future growth and have begun exporting fruit to Mexico and establishing market opportunities in Venezuela, Japan, Korea, India, Russia and Central Europe (NZAPMB, *ibid.*). The demand curve for New Zealand apples should, therefore, move to the right as new markets are established. Other factors that are likely to cause the demand curve to shift are intangible factors such as tastes of consumers. These change gradually over long periods of time as whole societies change their dietary customs (Kotler and Armstrong, 1986). Alternatively, substitute varieties can offer improved fruit quality, therefore, superseding existing varieties. For example Royal Gala, a bud sport[4] of the variety Gala, offers improved fruit colour over its parent. Consequently it has greater consumer appeal and so is in greater demand then its parent.

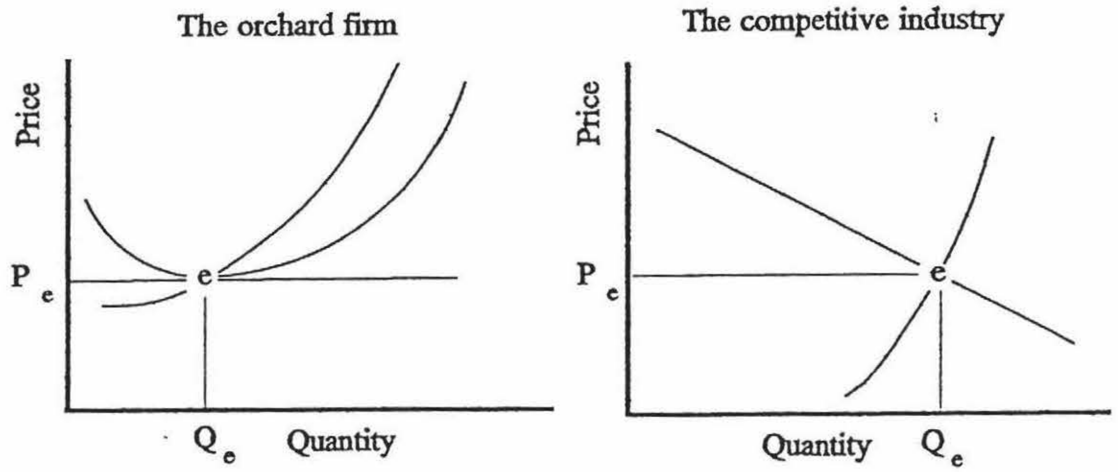
2.6. The Apple Industry Equilibrium

In the apple industry a theoretical equilibrium price exists where quantity supplied equals quantity demanded. In the analysis of the competitive orchard firm it was argued that short run profits (or losses) cause producers to change their desired long run production levels. The industry supply curve moves if profits (or losses) are being made by producers. For the competitive orchard firm an equilibrium price exists where a stable industry equilibrium is reached, *ceteris paribus*. At the equilibrium point orchard firms are making zero economic[5] profits. The equilibrium position of the competitive firm where industry equilibrium exists is presented in Figure 2.5. It is represented as point *e*.

[4]A bud sport is a variant of an inherited characteristic arising in a cell from which a bud and subsequent shoots and branches eventually develop. The most commonly observed bud sports are those affecting fruit appearance (Janick and Moore, 1975).

[5]When economists measure average costs, they include the costs of all the firm's inputs, including the opportunity cost of capital provided by the firm's owners. Zero economic profit corresponds to some positive amount of profit as measured by conventional accounting techniques.

Figure 2.5. The orchard firm in the competitive apple industry.



(Based on Baumol W.J., and Blinder A.S. (1985) Economics: Principles and Policies. Third edition, New York, Harcourt Brace Jovanovich, pp 479.)

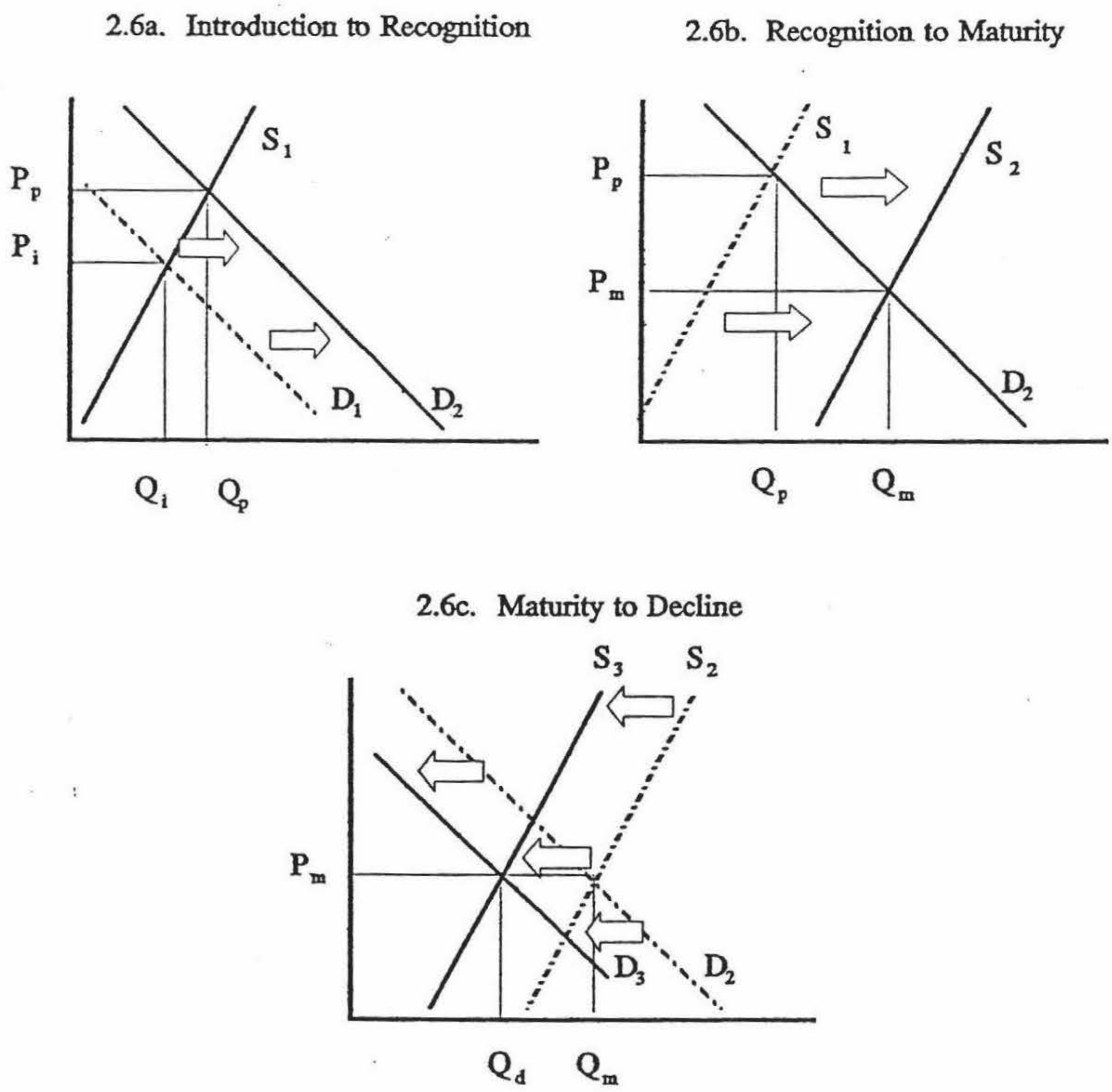
However, in reality a stable industry equilibrium may never be reached, primarily due to the lagged characteristics of apple production. The lagged characteristics may result in cyclical price and supply patterns. As producers increase their planted area to obtain the desired level of production, in response to high prices, long run aggregate supply increases. Increasing supply causes lower prices resulting in a new, lower desired level of production. Market demand conditions are continually fluctuating, resulting in unstable equilibria. Therefore, the competitive apple firm may never reach the desired profit maximising level of production.

2.7. The Varietal Life Cycle

The theories of perfect competition within the New Zealand apple industry can be used to explain the variety life cycle. Apple varieties come in and out of 'fashion' as alternatives become available. Wilton (1989b) suggests that for apples the life cycle of a variety characteristically follows a fairly well defined pattern. The characteristic variety life cycle is presented in Figure 2.6.

At the time of its introduction an unknown variety has little demand due to a lack of consumer awareness. For example, the as yet, unnamed Gala-Splendour cross GS2085 is currently being introduced and tested in overseas markets by the NZAPMB. Recognition of the new variety may be established over time through consumer trials and promotion of the variety. However, newly introduced varieties will be not always be successful. Vernon (1966) in his *Product Cycle Theory*, explains that in the early stages of production a new product may be 'unstandardised' whereby its inputs, its processing and handling, and its final specification may cover a wide range. Initial production, therefore, is risky and supply is likely to be low.

Figure 2.6. Introduction, maturity and decline phases of the apple varietal life cycle.



The successful introduction of the variety is followed by an expansion phase where demand increases. That is, the demand curve, D_1, moves to the right, D_2, as shown in Figure 2.6a. At this point excess demand prevails. Excess demand causes a price increase to P_p where producers make super-normal profits. Current examples of this are Fuji and Braeburn which have become recognised varieties in world markets. High profitability encourages producers to increase production so industry supply expands. Vernon (*ibid*) suggests that 'as the demand for a product expands, a certain degree of standardisation usually takes place'. Also that 'if we can assume that highly standardised products tend to have a well-articulated, easily accessible international market and to sell largely on the basis of price, then it follows that such products will not pose the problem of market information quite so acutely for the less-developed countries'. For apples, less-developed, low cost producers can easily transfer existing technology to their shores. Profit opportunities encourage growers to expand supply or new growers to enter the world market so the supply curve, S_1, moves to the right as shown in Figure 2.6b. Increased supply causes downward pressure on prices which move to P_e, a point described by Wilton (*ibid*) as 'maturity'.

Wilton (*ibid.*) explains that at maturity supply is in balance with demand and the price has stabilised. In terms of an industry of perfectly competitive producers, maturity or equilibrium is where zero economic profits are being made. This is theoretically feasible, however, in reality it may never occur due to dynamically changing economic conditions. Maturity of a product is likely to occur earlier in countries where the costs of production are higher[6].

Following the maturity period varieties characteristically decline in popularity as improved varieties become available or consumer preferences change. As a result the demand curve moves from D_2 to D_3 as depicted in Figure 2.6c. Prices decline further to a point where the variety is no longer profitable so producers reduce production moving the supply curve from S_2 to S_3 in order to maintain price. In New Zealand this has been demonstrated in recent years where the supply of Red Delicious and Granny Smith has declined dramatically.

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[6]In New Zealand labour costs are generally high compared with other Southern Hemisphere producers. Therefore, New Zealand producers are less able to counter lowering prices so need to grow higher priced, 'unique' varieties. The NZAPMB maintains that in the future specialist varieties will be essential for the success of the New Zealand pipfruit industry (NZAPMB, 1990).

2.8. Other Macro-Economic Factors Affecting Price of New Zealand Apples

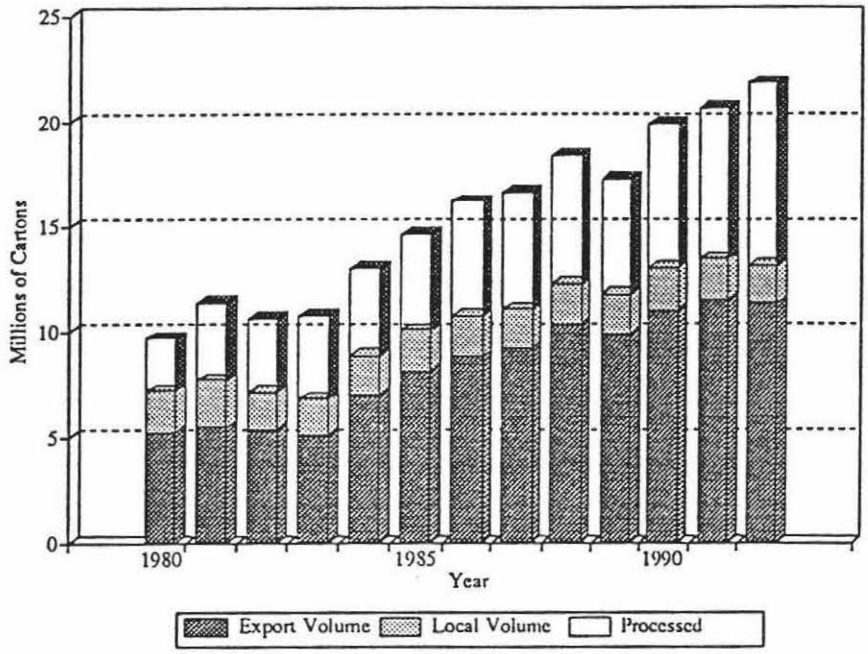
The price mechanism 'guides' production and consumption of agricultural products. Baumol and Blinder (1985) suggest that the price mechanism lets consumers and producers pursue their own best interests. Therefore, pricing decisions made on the basis of market forces (or political considerations) have important economic consequences.

Agricultural output prices in unsubsidised, open economies are characteristically volatile and unstable. For apples this is primarily due to marked weather patterns influencing production levels and the existence of substitute products. Price volatility has been apparent in the recent past season for New Zealand apples in overseas markets. Price levels were shown to be affected by aggregate supply and demand. For many farm products changes in supply induce relatively large changes in price (Tomek and Robinson, 1981). However, prices paid to producers are also influenced by other macro-economic factors.

Nominal costs involved in growing pipfruit in New Zealand have gradually increased over time. In the domestic market similar increases in nominal output price are expected so that producers' real profit remains relatively constant. However, as the large proportion of the New Zealand crop is exported, price making forces in the apple industry are not confined to the domestic economy. An important difference between domestic and export markets is that produce in export markets is paid for in foreign currency.

The current success of the New Zealand apple industry is a direct result of pipfruit exports. In 1992 exports of 11.3 million cartons represented 52% of total apple submissions to the Board. Export volume over the past five years has not significantly increased as shown in Figure 2.7. However, total income generated from fresh fruit exports has increased significantly. The value of fresh fruit exports and processed exports as a percentage of total income has been relatively static at between 75% and 85% (NZAPMB, 1992).

Figure 2.7. Volume of export, local and process pipfruit sales by the NZAPMB 1982-1992.



(Soucred from various NZAPMB Annual Reports)

The New Zealand dollar was floated in 1984. However, the New Zealand Reserve Bank endeavours to maintain the New Zealand dollar within a 'comfort zone' measured by a Trade Weighted Index[7]. For the New Zealand pipfruit industry, where most income is derived from exports, and input costs are generally determined by local market conditions the changing exchange rate will affect output price and orchard profitability. The relationship between output price and input price is termed the terms of exchange. A formal description of terms of exchange is given by Robinson and Reynolds (1989) as 'a comparison of the prices (at farm gate) a farmer (or industry) receives for their output with the prices they pay for their inputs'. Exchange rate movements will result in changing on-farm terms of exchange. The changes in terms of exchange for the pipfruit industry have been studied by Bruhn (1992). Bruhn found that the terms of exchange facing New Zealand's pipfruit growers decreased from 1971 until 1990. However, since 1990 the terms of exchange have increased markedly due to; increased average payouts to pipfruit growers, low inflation, and declining debt

[7]TWI, Trade Weighted Index is defined by a basket of currencies of our major trading partners such as Australia, USA, UK and Japan.

servicing costs in New Zealand. Bruhn suggests that the recent increase in pipfruit growers terms of exchange explains the massive recent investment in New Zealand's pipfruit growing industry.

2.9. The Affect of the NZAPMB Price Mechanism on Price

It was argued that the laws of supply and demand affect the price of apples. However, in New Zealand price signals from the market have been distorted through various NZAPMB pricing mechanisms. Prior to Government liberalisation of the agricultural sector in the mid 1980's, farming activities were heavily subsidised and protected through supplementary minimum pricing policies, low interest rate loans and tax incentives. Government price guarantees ensured apple orchardists received economic returns for all varieties grown.

Guaranteed prices set by the NZAPMB were published in *NZAPMB Price list and Terms of Supply* prior to harvest. The price schedule offered similar returns for different apple varieties and count sizes through an unknown amount of cross-subsidisation. Consequently, price differentials between varieties and size counts were small and did not provide strong economic stimuli for orchardists to change their crop mix to newer unrecognised, but potentially higher priced, varieties.

The lack of between variety price differentials meant that the influence of factors other than price were of more importance. Orchardists made replacement decisions based on ease of husbandry and potential yield. Established orchardists maintained their crop mix with traditional varieties with which they were familiar. These varieties offered dependable Government guaranteed returns and consistently high packouts. Therefore, the replacement of traditional varieties was rarely considered. Orchard renovation was only required to maintain health and productivity.

In the late 1970's and early 1980's 'new' varieties received slightly higher prices than those traditionally grown. However, the prices were related to production costs not market returns. Higher priced varieties were more expensive to grow, so higher prices did not provide a strong incentive for change. The costs involved in replacing traditional with newer varieties was not warranted under this pricing mechanism. Furthermore, the knowledge required to grow new varieties was less developed and packouts were often low. New varieties were generally planted in new block developments by existing orchardists or by new entrants into the industry.

In the mid 1980's, prices based more on market returns began to diverge. Between variety price differences provided some economic stimuli for orchard renovation. However, market signals were still 'dampened'. Year to year price fluctuations could not decrease or increase by more than 5% and 10% respectively. Furthermore, up until 1988, guaranteed 'total payment' for different varieties and grade standards were cross-subsidised by a price stabilisation fund. Income earned from a variety over and above the guaranteed price was 'pooled' into the stabilisation fund which could then be used to 'subsidise' varieties not obtaining their guaranteed price. Orchardists were seldom able to identify which varieties had subsidised others or had received subsidies. Remaining stabilisation funds were distributed to growers as a lump sum payment calculated on a per tray carton equivalent basis. Some funds were also retained by the NZAPMB. Retained funds from previous years ensured that total payments were paid even if market returns over all varieties was not satisfied.

After 1988 the NZAPMB disbanded the stabilisation fund, marking a significant change towards more market orientated grower returns. Guaranteed prices were reduced to the 'advance rate'[8] only. If the actual market return for all varieties was less than the advance rate the NZAPMB arranged to cover the short fall. Also, if the actual market return for some varieties was less than the advance then no extra payments would be made to any varieties until the deficit on those achieving less than the advance had been transferred. If the actual return for a variety exceeded the advance payment additional variety pool payments brought the total payment for a variety up to 80% of the 'market indicator rate'[9]. The remaining funds were paid out as a general pool in a manner to be decided by the Board.

[8]The advance payment is paid to growers soon after submitting their fruit.

[9]The market indicator rate is the expected total payment for a variety. Up until 1992 the market indicator rate was established from each variety's combined local and export actual returns from the previous two years, plus the estimated returns in the current year as its base. In 1993 the market indicator rate was established from each variety's estimated export returns only.

From 1988 the guaranteed advance rate represented 70% of the market indicator rate. However, the advance rate decreased to 60% in 1992 and to 50% in 1993. As a result prices between varieties are now wide spread. Price signals provide significant economic stimuli for growers to produce higher priced varieties. Price differentials between different count sizes are now significantly different so growers are directed towards producing optimal sized fruit. The NZAPMB price policies now direct varietal mix and fruit size on orchards. Other factors such as yields, management ease and familiarity also contribute to varietal choice decisions.

2.9. Summary

The New Zealand apple industry is made up of many orchardists producing a number of varieties within each orchard. Supply from New Zealand orchards is derived from a productive base of apple trees which have characteristic production functions. No useful output is sold for three to four years after planting. Production then increases until maturity is reached some seven to ten years after planting where it remains for an undefined number of years.

Apple producers exist within an industry similar to that defined as perfectly competitive. *A priori* expectations are that they will produce at a level of production where marginal costs equal price. In the short run price declines can cause significant reductions in aggregate supply. However, short term price increases cannot cause total production increases. In the long run changes in the productive stock of trees will cause the industry supply curve to shift. The desired area may be reached in the relatively short term, but, given the nature of the apple production function, supply increases are lagged. Once the desired production level is reached changes in other factors will have resulted in a new desired level of production. The supply of apples from the New Zealand apple industry, therefore, is dynamically changing in response to output price fluctuations. To measure changes in supply a model which incorporates the dynamic characteristics of apple production is required.

CHAPTER 3. ECONOMETRIC MODELLING

3.1. Introduction

The common techniques of estimating expected price are introduced and developments of econometric supply response modelling are then discussed. The techniques discussed include simple 'naive' models, weighted averages, and more sophisticated behavioural models. Supply response models for perennial crops are then examined. Particular attention is paid to models proposed by Nerlove (1958), Wickens and Greenfield (1973) and French and Matthews (1971).

3.2. Econometric Modelling

Literally interpreted *econometrics* means 'economic measure' (Gujurati, 1988). The scope of econometrics, however, is much broader. Economic theory makes statements of hypotheses that are mostly qualitative in nature. Econometrics provides a quantitative context to economic theory. Malinvaud (1966) suggests that 'the art of the econometrician consists of finding the set of assumptions that are both sufficiently specific and sufficiently realistic to allow him to take the best possible advantage of the data available to him'. Gujarati (*ibid*) defines econometrics as 'an amalgam of economic theory, mathematical economics, economic statistics, and mathematical statistics'. The application of these tools for economic measure is known as econometric modelling. From empirical, survey or available data the econometrician develops and empirically tests theoretical economic principles.

Gujarati (*ibid*) describes the methodology of econometric modelling as follows. Firstly, the econometrician forms a statement of theory or null hypothesis. For example, 'apple orchardists do not increase planted area in response to price increases'. A model describing the functional relationships between the dependent variable and the independent variables is then specified to test the theory. Ideally the relationships within the model should be specified through well-founded logic, however, the flexibility of specification may well depend on data availability. The parameters within the chosen model are estimated using mathematical techniques such as ordinary least squares, two stage least squares, three stage least squares, or maximum likelihood regression theory. The results of analysis are then used to reject or not reject the null hypothesis depending upon the statistical and *a priori* acceptability of parameter estimates. Spurious or insignificant models should be re-specified and reassessed. A statistically and theoretical acceptable model may be used further for predicting and analysing possible affects and implications of policy decisions.

Econometric models have been used extensively in agricultural economics for annual crops and to a lesser extent for perennial crops (Askari and Cummings, 1976). Initial models were illustrative in nature providing the foundations for further modelling (Nerlove, 1958; French and Matthews, 1971; Wickens and Greenfield, 1973; Albusi and Blandford, 1983). However, such models have also been employed in applied studies. French and Bressler (1962) used econometric modelling to explain the cyclical phenomena in agriculture. Rae and Carman (1975) made supply forecasts using econometric modelling to aid the planning of packing, storage, and processing facilities in the New Zealand apple industry. Similarly, French *et al* (1985), measured potential future production from existing acreage and structural changes associated with market intervention programmes. Baritelle and Price (1974) also compared future returns and production variables of alternative marketing strategies using econometric modelling.

3.3. Measurements of Producer Price Expectations

Expected price plays a significant role in determining supply responses by orchardists, as shown in Chapter 2. For arable cropping, price movements may cause rapid changes in area, whereby, farmers adjust area each season (Anderson, 1974). The adjustment in area may be influenced directly by last year's price, an average of past prices, or more realistically by a weighted average of recent past prices. For perennial crops, however, area changes in response to changing prices may be lagged because of capital resource constraints faced by farmers and/or the farmer's slow expectation adjustment (Johnson, 1960). In this situation past prices lagged by some time period, indicative of the crop's lag phase, may be the major influence of changing supply.

Expected price is unobservable, therefore, it must be estimated. A number of methods have been developed and used by various authors for dealing with this difficulty. Askari and Cummings (1976) mention that the earliest and simplest explanation of agricultural price expectations assumed that producers were influenced solely by the most recent season's prices and that price expectations are that the most recent season's price will prevail in the next season. This is known as the 'cobweb' or 'naive' model which has the simple equation of:

$$P_t^e = P_{t-1} \tag{3.1}$$

where; P^e_t = the expected price in time t,
P_{t-1} = the actual price in t-1.

Similar simple models use moving averages (French and Matthews, 1971; Rae and Carman, 1978) where farmers expect price to be the average of previous recent season's prices as shown in Equation 3.2 below:

$$P_t^e = \sum_{i=1}^{k} \frac{P_{t-i}}{k} \tag{3.2}$$

where; k = the number of periods used in the moving average.

The number of time periods used in moving averages may reflect important characteristics of the crop determinants of price. For example, a two or three year moving average might be used for apples supplied to the NZAPMB[1]. However, the most statistically sound model which satisfies previous expectations should ultimately be used. French and Matthews (*ibid*), for their study of asparagus, found that a two year moving average was the most statistically significant. Rae and Carman (*ibid.*), in their study of New Zealand apples and French *et al* (1985) for their study of Cling peaches, both used four year moving averages. Studies on citrus by Alston *et al* (1980) and French and Bressler (1962) used five year moving averages. This suggests annual variations in the price of asparagus are less marked than those of peach and apple, and in turn, citrus.

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[1]The NZAPMB derive their "Market Indicator Rate" from the previous two season's combined actual local and Export returns, plus an estimate of the current year as a base (NZAPMB, 1989).

The moving average can be further modified to a weighted moving average where weights are given to previous prices over a certain time period as shown in Equation 3.3. The number of years of past prices may also vary depending on the situation being modelled.

$$P_t^e = \sum_{i=1}^{k} \phi_i P_{t-i} \tag{3.3}$$

where; Φ_i = a given weight in year i.

Goodwin (1947) developed a model accommodating a farmer's learning process. The model was known as an Extrapolative Expectations Model. This model formulated the expected price as actual price in the last period plus (or minus) some proportion of the change in actual price between the second to last and the last period. The Extrapolative Expectations Model is presented in the Equation 3.4 below:

$$P_t^e = P_{t-1} + \delta(P_{t-1} - P_{t-2}) \tag{3.4}$$

where; δ = a given value between -1 and 1.

Values for δ less than zero indicate that farmers expect prices to reverse upward or downward trends. Alternatively, values greater than zero suggest that farmers expect a continuation of existing price trends. Like moving average models, arbitrary values of δ are tested.

A more sophisticated weighted average model, as suggested by Koyck (1954), assumed that all past prices do not have equal influence and that greater weight should be placed on more recent prices. The model is similar to the weighted moving average model except the weights (Φ_i) of the P_{t-i} variable form a geometrically declining series. That is:

$$P_t^e = \sum_{i=0}^{k} \beta(1-\beta)^i P_{t-i-1} \tag{3.5}$$

where; β = the coefficient of expectation.

For the Koyck model β is a given constant between 0 and 1. The value of β affects the farmers' weighting placed on past prices. If β is zero, actual prices are totally divorced from expectations, while a unitary value implies a cobweb model. Different values of β can be examined and that which is closest to real trends is selected. The Koyck Distributed Lag model was further developed by Nerlove (1958) who intuitively derived the value of β within the Nerlovian Price Expectations Model. The derivation of β is discussed in Section 3.5.

A further advancement to the geometrically declining lag model was developed by Almon (1965). The 'Almon Lag' assumes that successive weights lie on a polynomial. Weights (Φ_i) of the P_{t-i} variable are derived from a polynomial series of weights as shown in Equation 3.6.

$$P_t^e=\sum_{i=0}^{k}(\alpha_0+\alpha_1 i+\alpha_2 i^2 ...+\alpha_n i^n)P_{t-i-1} \tag{3.6}$$

where; i = the ith year in the lag structure,
k = the length of the lag structure,
α_1, α_2, .. α_n are coefficients to be estimated.

It is generally considered that a low-order polynomial is appropriate for most econometric work (Chen *et el*, 1972; Wickens and Greenfield, 1973; Baritelle and Price, 1974). When $i=k$ it is assumed that the weight equals zero because price changes no longer affect current production. Therefore, for the second order polynomial;

$$(\alpha_0 + \alpha_1 k + \alpha_2 k^2) = 0 \tag{3.7}$$

$$\therefore \alpha_0 = -\alpha_1 k - \alpha_2 i^2 \tag{3.8}$$

α_0 can be substituted into the polynomial lag structure which, after simplification, is in turn substituted into the supply equation to derive the following equation (3.9) for a second-order polynomial:

$$Q_t=\alpha_0+\alpha_1\sum_{i=0}^{k}(i-k)P_{t-i-1}+\alpha_2\sum_{i=0}^{k}(i^2-k^2)P_{t-i-1} \tag{3.9}$$

where; Q_t = quantity in time t.

The method makes the individual lag coefficients dependent on a few parameters all of which can be estimated using regression analysis. Other explanatory variables can simply be added to the end of the derived supply equation, (3.9), (Chen *et al*, *ibid.*; Almon, *ibid.*). Since the length of the distributed lag is generally not known in advance it is necessary to estimate the distribution using varying numbers of periods, and to choose the most statistically significant lag model (Almon, *ibid.*; Baritelle and Price, *ibid.*). For example, the lag coefficient suitable for an apple price expectations model may be determined intuitively and then tested empirically.

Price expectation models are used within the specification of supply response models. Nadda (1987), citing perennial crop supply models by Bateman (1968), Baritelle and Price (1974) and French and Matthews (1971) noted that each formulation had tried different price expectation models. Nadda suggested that nothing specific could be derived from previous models concerning the price expectation behaviour pattern followed by perennial crop growers. However, frequently simplistic moving average models have provided the most statistically significant results. The selection of an appropriate model will depend on the situation being modelled and the statistical reliability obtained.

Other measures of profitability can be used in expectation models as a substitute for price. Nominal prices, deflated by an appropriate index[2], can be used to represent price in real terms. Gross margin data could also be used in situations where yield and cost data are available. However, such data is generally unavailable over a sufficient time series. Price ratios may also be appropriate particularly in situations where a number of substitute products are used as explanatory variables. Price ratios increase the degrees of freedom by reducing the number of explanatory variables. They are particularly useful in situations where only limited time series data is available. The choice of the profitability measure will depend on the situation being modelled. It is up to the modeller to select and examine the profitability variable and the price expectation model which best suits *a priori* expectations and the empirical model itself.

[2]For supply response models involving farm output, Farm Input Price Indices should by used. In New Zealand indices are available for different farm classes.

3.4. The Difficulty of Modelling Perennial Crops

Askari and Cummings (1976) describe the planting of a perennial crop as being very much like the acquisition of capital. Output is harvested from the stock of plants of varying ages the existence of which reflects past and present profitability expectations. The time horizon, necessary for perennial crops, introduces a unique set of modelling problems.

Askari and Cummings (*ibid.*) identify two principal problems. Firstly, if output is studied over a period of *n* years, information regarding such variables as prices and climate, must be available for several years before the beginning of the time when output is observed. It is assumed that planting decisions are made on the basis of expected prices, or other measures of profitability which have subsequently been derived from past events. Price and profitability expectations, therefore, require lagged data for their derivation. Furthermore, perennial crops inherently have lags between initial planting and output. Therefore, the difficulty of significant lags between observed output and price expectations arises. In the case of apples this lag may be as long as seven to ten years due to the time required for trees to reach bearing age (discussed in Section 2.3) plus an additional time period after placing orders, for orchardists to receive planting material from nurseries.

Climatic data prior to observed output data may be required to explain current output. Phenomenon such as flooding, freezes, or drought can significantly affect the long term productive area of certain perennial crops, for example, grapefruit in Florida (Kalaitzandonakes and Shonkwiler, 1992). For apples in Hawkes Bay climatic phenomena such as freezes and flooding are unlikely to cause tree loss. Similarly drought conditions are usually avoided by the use of irrigation. In Hawkes Bay unusual climatic phenomena are more likely to cause short term supply changes, such as biennial bearing in apples.

The second difficulty identified by Askari and Cummings (*ibid.*) is that time series data must be sufficiently long enough to allow for degrees of freedom to the estimating procedure if it is to have any significance when all econometrically relevant variables have been included. Again, the use of lagged variables reduces the number of useful observations within the data series. Therefore, a longer time series data set is required. The longer the period under study, the more likely infrastructure changes will be included. For example, new technology will result in shifts in the underlying supply structure. A particular difficulty with modelling New Zealand apple supply responses are the technological changes which have occurred over time. For example, during the 1950's and 1960's orchard performance improved substantially as a result of improved pest and disease control and improved cultural growing techniques. In the 1970's the new semi-intensive centre leader training system was introduced offering growers greater production and subsequent income per hectare. Growth regulators for chemical fruit thinning were introduced in the 1980's (Wilton, 1989a), the cumulative affect of these technologies was reported in Section 2.4.2.

3.5. Econometric Supply Response Models for Perennial Crops

Supply response models for perennial crops received significant attention in the 1960's. Since then a number of models have been developed which attempt to describe direct changes in supply or changes in the stock of plants and the subsequent supply of a crop. The following review discusses the developments in supply response modelling for perennial crops which have taken place over the last 30 years. Past applications of supply response models are acknowledged and their relative merits discussed.

French and Bressler (1962) developed one of the earliest supply response models for a perennial crop. These agricultural economists modelled supply response in the Californian lemon industry. The model involved two equations; an equation that explained the area of trees planted annually and the consequential additions to production some five years later, and an equation that accounted for the average number of trees removed from production annually. French and Bressler used the cobweb model of producer price expectation behaviour hypothesising that producers based decisions on current and recent past prices. They specified an equation (3.10) for plantings as:

$$\frac{N}{B_{t-i}} = \beta_0 + \beta_1 P^e_{t-1} + \beta_2 \frac{A_{t-1}}{B_{t-1}} + v_{t-1} \tag{3.10}$$

where; N_t = the acres planted in year *t*,

B_{t-1} = the bearing acres in year *t-1*,

P^e_{t-1} = the long-run profit expectation in year *t-1*,

A_{t-1} = the bearing area aver a given age in year *t-1*,

v_{t-1} = the disturbance term for omitted variables,

β_0, β_1 and β_2 are parameters to be estimated.

New plantings, therefore, were expressed as a percentage of total bearing area. The ratio of trees over 25 years of age to total bearing area accounted for the effect of anticipated removals of aging trees on new plantings, the value of which was insignificant.

The removals equation was specified as:

$$\frac{R_t}{B_t} = \alpha_0 + \alpha_1 P_t + \alpha_2 \frac{A_t}{B_t} + \frac{K_t}{B_t} + u_t \tag{3.11}$$

where; R_t = the acres removed in year *t*,

B_t = the bearing acres in year *t*,

P_t = the short-run profit in year *t*,

K_t = the removals due to urban expansion in year *t*,

A_t = the bearing area aver a given age in year *t*,

u_t = the disturbance term for omitted variables in year *t*,

α_0, α_1 and α_2 are parameters to be estimated.

The parameter for the proportion of trees of over 25 was again insignificant. Also data pertaining to removals due to urban expansion was unavailable, so the proportion of trees removed due to urban expansion could not be identified. Furthermore, the parameter estimate of the profit variable was insignificant. As a result tree removals were simply expressed as a yearly average.

The change in bearing acreage was then given by the difference between the acreage coming into production and the acreage removed. By multiplying bearing area by yield the acreage response was converted to a supply response equation. French and Bressler felt that the model developed was a useful analytical device shedding a 'good deal of light' on the past and possible future behaviour of the lemon industry. The explanatory power of the model, however, was reduced due to the simplifications. The model did provide a useful starting point for further supply response studies.

From the mid to late 1960's a number of authors adopted a model proposed by Nerlove (1958). Nerlove was an agricultural economist who extensively studied the role farmer's expectations of future prices play in shaping their decisions of how many acres to devote to each crop. The Nerlove supply response model was originally developed for annual crops. It has been extensively and successively used for annual crops by a number of authors[3]. Braulke (1982) suggests that the Nerlove model 'is one of the most successful econometric models introduced into literature'.

The basic Nerlovian model stripped to its essentials, involves three equations. The first relates to a grower's desired area to past prices (and other variables if specified). The equation (3.12) is specified as:

$$A_t^* = \alpha_0 + \alpha_1 P_t^e + u_t \tag{3.12}$$

where; A^*_t = the desired area in year t,

P^e_t = the expected price level at time t,

u_t = unobserved factors affecting area in year t,

α_0 and α_1 are the regression coefficients to be estimated.

Nerlove suggested that the expected price can be expressed as a function of the difference between last period's actual and expected "normal" prices, similar to the Koyck model, Equation 5. That is:

[3] An extensive review of studies on annual crops is presented by Askari and Cummings (1976).

$$P_t^e - P_{t-1}^e = \beta(P_{t-1} - P_{t-1}^e) \tag{3.13}$$

where; P_t = the actual price of the crop in year t,

β = the coefficient of expectation.

Nerlove also postulated that actual area (A) is a function of long-run equilibrium area (A^*) and time. Since A^* changes over time Nerlove expressed an equation analogous to the expected price model as:

$$A_t - A_{t-1} = \gamma(A_t^* - A_{t-1}) \tag{3.14}$$

where A_t = the actual area under cultivation in year t,

A^*_t = the desired or equilibrium area in year t,

γ = the coefficient of adjustment.

That is, in each period actual area is adjusted by some fraction (γ) of the difference between long run equilibrium area (the desired output level) and the actual area in the previous period. This is described as the 'stock adjustment model' and suggests that farmers do not or cannot necessarily adjust to the desired level of output in one period. Therefore, the Nerlove Model represents some of the supply response difficulties introduced in Chapter 2. Elimination of the unobservable variables A^*_t and P^e_t leads immediately to the reduced form equation (Nerlove, 1958) presented in Equation 3.15:

$$A_t = b_0 + b_1 P_{t-1} + b_2 A_{t-1} + b_3 A_{t-2} + v_t \tag{3.15}$$

where v_t = the random disturbance term,

$b_0 = \alpha_0\beta\gamma$, $b_1 = \alpha_1\beta\gamma$, $b_2 = (1-\beta)+(1-\gamma)$, and $b_3 = -(1-\beta)(1-\gamma)$.

The regression of the derived supply response equation yields estimates of the coefficients b_0, b_1, b_2, and b_3. By assuming that γ=0, the coefficient of expectation, β, could be empirically derived. Alternatively, the coefficient of expectation can be directly substituted by the coefficient of adjustment, λ. The coefficient of adjustment is applicable in situations where farmers only partially adjust area due to an inability to immediately change to the desired level of area as a result of physical or financial constraints. Both β and γ cannot be estimated together.

The influential nature of Nerlove's work provided a methodology that was adopted further for estimating perennial crop supply responses. Askari and Cummings (1976) suggested that the capital-stock nature of perennial crops promotes an approximately equal sensitivity to prices realised in each of the two or three seasons immediately preceding planting with declining attention paid to successive earlier prices. Therefore, they suggested that the Nerlove model was appropriate for the study of perennial crops.

Askari and Cummings (1976) referred to a study by Bateman (1965) as being one of the first major studies to apply a dynamic Nerlovian supply model to a perennial crop. Bateman (*ibid.*) made little or no modification to the Nerlovian model for her study of perennial crops. Bateman focused on the forces that motivate farmers to plant new trees and on the relationship between acres planted and output harvested from a cocoa crop. Using the Nerlovian price expectations model the area planted annually in cocoa was specified in terms of discounted future returns of both cocoa and coffee and some proportion of the previous year's area. However, data on newly planted acreage were not available so Bateman reformulated her model in terms of output from cumulative plantings. By combining the area and the output equation the final output estimating equation was derived in terms of the previous year's quantity, past prices, present prices and rainfall. The results suggested that recent producer prices had little effect on harvesting decisions. Furthermore, the rainfall variable did not prove to be significant at an aggregate level.

Behrman (1968) modified Bateman's model by suggesting that the area in cocoa is a function of the expected prices of both cocoa and the principal alternative crop, coffee. Behrman, like Bateman, had difficulties obtaining data regarding area planted in cocoa so formulated his model in terms of lagged prices of cocoa, its alternative coffee, and previous years' yields. The Nerlovian supply response model was shown to be perform reasonably well by both Bateman and Behrman.

In the early 1970's a number of different supply response models for perennial crops were proposed. In 1973 Wickens and Greenfield (1973) proposed that 'a preferable solution [to the Nerlove supply response model] was to estimate directly the individual structural relationships underlying supply from perennial crops'. Wickens and Greenfield suggested that the application of the Nerlovian approach to perennial crops was more complicated than simply uniformly applying a longer time lag. They offered two main criticisms firstly, concerning the 'ad hoc nature of the model' and secondly, the fact that the 'dynamic has been added to the static'. Wickens and Greenfield suggested that the success of the Nerlovian model for field crops is not a sufficient justification for its use for tree crops.

Wickens and Greenfield (*ibid.*) specified the structural relationships underlying supply of perennial crops. However, noting the major data requirement of estimating the individual structural relationships directly, they derived a reduced form supply function. They applied their model, incorporating an Almon polynomial lag function, to Brazilian coffee. Wickens and Greenfield suggested that the model provided an alternative formulation derived from an optimising model and that it also had the appeal of simplicity. Wickens and Greenfield further stated that their approach 'appears to be both theoretically and empirically attractive for the study of the supply of tree crops'. However, the model proved to be very similar to Nerlove's model and, despite their original intent, used nearly the same variables as Nerlove's.

Dowling (1979) used the Wickens and Greenfield supply response model as a tool for the estimation of the rubber supply in Thailand. The method successfully determined the rubber output response despite the lack of reliable data for area planted. Later, Hartley *et al* (1987) analysed rubber supply in Sri Lanka. They suggested that many supply response investigations relied on reduced-form equations which failed to capture important structural features of the supply response of perennial crops. On this basis and noting that data was only available on output, producer prices, and cultivated area Hartley *et al* specified a modified Wickens and Greenfield model.

Models of perennial supply response that focus on new investment, as does the Wickens and Greenfield formulation, are not appropriate for the study of a mature industry (Hartley *et al*, 1987). For the mature industry response to prices and other factors take the form of uprooting and replanting existing stands. This conflicts with the Wickens and Greenfield model which implicity assumes that uprooting and abandonment occurs randomly. Furthermore, the model assumes that planting density remains constant. Where new planting density is changing over time, as is the case with apples, the relationship between investment and output varies.

A more descriptive model of perennial supply response was developed by French and Matthews at a similar time to that of Wickens and Greenfield. French and Matthews (1971) noted that past supply response studies for perennial crops had made particular reference to less developed areas and warm climate commodities. French and Matthews developed an alternative model which they suggested 'seemed more appropriate to United States produced perennial crops'. The model provided a structural base for estimating response relationships for perennial crops which encompassed the planting, removals, yields, and time dimensions of perennial crops. The model involved five major components: (1) a pair of functions that explain the quantity of production and bearing acreage desired by growers; (2) a new planting function defined by adjustments that would shift acreage toward the desired level; (3) an equation to explain acreage removed each year; (4) relationships between unobservable expectation variables and observable variations; (5) an equation that explains variations in the values of average yields.

In its simplest form the model can be represented firstly as two identity equations. That is:

$$Q_t = A_t \times Y_t \qquad (3.16)$$

and

$$A_t = A_{t-1} + N_{t-k} - R_t \qquad (3.17)$$

where;
- Q_t = the quantity in year t,
- A_t = bearing acreage in year t,
- Y_t = yield per area in year t,
- N_{t-k} = new plantings made in t-k,
- R_t = acreage removed at the beginning of year t.

The identity equations are explained by the following behavioural equations:

$$A^{*}_{t+k} = A_{t-1} + a_1 P^{e}_{t} + a_2 Pc^{e}_{t} + u_{1t} \tag{3.18}$$

$$N^{*}_{t} = A^{*}_{t+k} - A_{t-1} + R^{e}_{kt} - N_{kt-1} \tag{3.19}$$

$$R^{e}_{kt} = b_1 A^{O}_{t-1} + b_2(N_{kt-1} + A_{t-1} - A^{O}_{t-1}) + u_{2t} \tag{3.20}$$

where; A^{*}_{t+k} = grower's desired area in $t+k$,
P^{e}_{t} = expected price in time t,
Pc^{e}_{t} = expected price of alternative(s) in time t,
N^{*}_{t} = grower's desired level of planting in year t,
R^{e}_{kt} = expected removals over kt years,
A^{O}_{t-1} = the area of old trees in t-1,
u_{1t} and u_{2t} are disturbance terms.

French and Matthews postulated three important assumptions necessary to validate their model. Firstly, that producers are faced with similar product and factor prices and similar production functions. Secondly, producers attempt to maximise profits. Thirdly, the behaviour of the individual producer is conditioned by expectations concerning the behaviour of other producers and the probable impact of this behaviour on output levels. Therefore, producers were expected to have in mind a long-run 'normal' or equilibrium rate of profitability per unit of output. Given producers' equilibrium expectations, producers were expected to attempt to adjust the level of average production so as to achieve the long-run normal level of profitability.

French and Matthews applied their model to asparagus production in California, the Eastern Midwest and Northwest of America. The data available for the application consisted bearing areas, yields and prices received by growers. Although faced to delete some unobtainable variables, French and Matthews were able to modify the basic model so as to utilise the kinds of information typically available.

The French and Matthews perennial crop supply response has been used and modified by a number of different authors. Rae and Carman (1975) used the model as a base for their study on a supply response model for New Zealand apples. However, Rae and Carman modified the model to incorporate an equation illustrating the time pattern of adoption of planting innovation. Alston *et al* (1980), whilst building on the French and Matthews model framework, developed a model from a demand function for desired input of services, and an investment model, to derive a function for plantings in the Australian orange growing industry.

French *et al* (1985) cited a study on the Californian cling peach industry by Minami *et al* (1979) as the only study undertaken where the current age composition of existing industry acreage was known. Using the French and Matthews supply response model, French *et al* extended this study to show more precisely how tree removals may vary both with tree age and short run profit expectations and how planting response had varied with and without marketing order[4] volume-control programs in effect.

French *et al* (1985) stated that to be of maximum value as a forecasting tool, supply response studies should include information on removals by age and variations in yields by age. They suggested that supply response models have had some success, notably French and Matthews (1971), Baritelle and Price (1974) and Rae and Carman (1978) in cases using time series production data from total bearing and non-bearing area, and average yields. The models used direct estimation of a function that related changes in total bearing area to lagged prices and costs. However, French *et al* noted that these models had ignored the changing age composition and used lengthy lags compounding specification and estimation problems and reducing degrees of freedom.

The French and Matthews supply response model for perennial crops provides a detailed framework from which other models can be developed. However, the data requirements are demanding. Most authors using the French and Matthews Model have noted that in supply response studies difficulties have been encountered because of incomplete or unavailable data.

[4]The role of marketing order and other subsidy programmes in the United States of America is discussed in detail by Robinson (1989).

Nerlovian, Wickens and Greenfield and reduced forms of the classical French and Matthews Model have been used and modified in an attempt to overcome such difficulties.

3.6. Summary

A number of different supply response models for perennial crops have been proposed in the past, ranging from the simple Nerlove models to the applied and data exhaustive French and Matthews Model. The important characteristics of the models reviewed are summarised in Table 3.1.

Table 3.1. Summary of the important characteristics of models reviewed.

Year	Authors	Crop	Model type	Price model	Data availability
1958	Nerlove	Annuals	Own derivation	Nerlove price expectations	Sufficient
1962	French and Bressler	Lemons	Own derivation	Five year moving average	Limiting
1965	Bateman	Cocoa	Nerlove	Nerlove price expectations	Limiting
1965	Behrman	Cocoa	Nerlove	Cobweb	Limiting
1971	French and Matthews	Asparagus	Reduced form French and Matthews	Two year moving average	Limiting
1973	Wickens and Greenfield	Coffee	Wickens and Greenfield	Almon Lag	Sufficient
1975	Rae and Carman	Apples	Modified French and Matthews	Four year moving average	Limiting
1979	Dowling	Rubber	Wickens and Greenfield	Almon Lag	Sufficient
1980	Alston *et al*	Oranges	Modified French and Matthews	Five year moving average	Limiting
1985	French *et al*	Peaches	French and Matthews	Four year moving average	Sufficient
1987	Hartley *et al*	Rubber	Wickens and Greenfield	Almon Lag	Sufficient

The selection of a suitable model is largely dependent on the data availability for the crop being studied. To be of most use, where possible, a highly explanatory model should. In the following chapter the data available for this study is introduced and an appropriate model is specified which measures the varietal supply response to changing varietal price for the Hawkes Bay Region.

CHAPTER 4. SUPPLY RESPONSE VARIABLES

'Everything depends on everything else; but most things depend in an essential way upon a few other things.'

(Marshall, cited in Ferguson and Maurice, 1970).

4.1. Introduction

A theoretical model based on the French and Matthews Model is presented. Data available for the study is then described and discussed. Appropriate models explaining changes to the Hawkes Bay apple supply are then developed. These models are based on varieties with rapidly expanding supply and those with declining supply. The models use important economic and non-economic variables derived from the available data. The derived models are then empirically tested using ordinary least squares regression. Statistically significant models are presented in Chapter 5.

4.2. Theoretical Model Derivation for New Zealand Apples

In Chapter 3 a number of theoretical models were introduced which attempted to explain changing supply. It was noted that the most descriptive, but most data demanding model, was that presented by French and Matthews (1971) (Equations 3.16-3.20). This model served as the starting point for the derivation of a supply response model for Hawkes Bay apples.

Varietal supply is from a stock of trees of different ages. Different aged trees provide different yields as discussed in Section 2.3. Therefore, supply will be influenced by the ages of the tree population. However, to simplify the modelling problem trees can be bifurcated into groups of non-bearing and bearing trees. Supply is only derived from bearing trees.

Therefore, supply is determined as:

$$S_t = BA_t \times Y_t \tag{4.1}$$

where; S_t = supply in year t,

BA_t = bearing area in year t,

Y_t = yield in year t per unit of bearing area.

However, the yield may vary from year to year due to the influence of climatic changes or biennial bearing. That is:

$$Y_t = f(Cl_t, BB_t) \tag{4.2}$$

where; Cl_t = climatic influences affecting supply in year t,

BB_t = the affect on biennial bearing on supply in year t.

As a result of orchard renovation and development bearing area is not constant over time. Bearing area in year t will be equal to the previous year's bearing area plus non-bearing trees reaching 'maturity', minus removals of bearing trees. That is:

$$BA_t = BA_{t-1} + NP_{t-n} - R_t \tag{4.3}$$

where; NP_{t-n} = the area of trees planted n years earlier which reach maturity in year t,

R_t = the area of trees removed in year t.

A priori expectations are that new plantings of a variety in year $t-n$ will be influenced by expected profit of the variety, and the profit of its competitors, the variety's management ease and orchardists' familiarity with the variety, all in year $t-n-m$. The period m is the additional time required for orchardists to implement planting decisions in response to a price signal.

The new planting function can be expressed as:

$$NP_{t-n} = f(P_{t-n-m}, P^c_{t-n-m}, M_{t-n-m}, F_{t-n-m}) \tag{4.4}$$

where; P_{t-n-m} = the price of the variety in year *t-n-m*,

P^c_{t-n-m} = the price of the competitors in year *t-n-m*,

M_{t-n-m} = the orchardists perception of the management ease of the variety,

M_{t-n-m} = the orchardists familiarity with the variety.

Similarly, removals in year *t* will be influenced by expected profit of the variety and of its competitors in year *t-m*, the area of unhealthy trees and the area of removals due to urban expansion in year *t*. That is:

$$R_t = f(P_{t-m}, P^c_{t-m}, A^u_t, U_t) \tag{4.5}$$

where; A^u_t = the area of unhealthy trees in year *t*,

U_t = the area of removals due to urban expansion in year *t*.

Equations 4.1-4.5 provide a simple representation of the French and Matthews supply response model for perennial crops. Equations for new plantings, removals and yield can be derived empirically from past observations. Derived equations can be imputed into the bearing area identity equation and then the supply equation to derive the supply of a variety in year *t* or for some time in the future. However, to derive empirical estimates for these relationships data on supply, yield, price, new plantings, removals, bearing area, old bearing area, urban expansion and climate are required. The data available for this study is presented in the following sections.

4.2.1. The Supply Variable

Total apple submissions by variety for Hawkes Bay have been reported in the NZAPMB Annual Reports since 1970. Hawkes Bay apple submissions by variety are used as the dependent variable, or used for the derivation of the dependent variable. A consistent series of data was available from the 1970 to 1992 harvest seasons. An additional estimation for the 1993 crop was also used. Submissions to the NZAPMB of the eight major current export varieties from Hawkes Bay growers are presented in Table 4.1.

Table 4.1. Annual apple submissions from Hawkes Bay orchardists for eight important export varieties, 1975-1993 (thousands of bushels).

Year	Braeburn	Cox's Orange	Gala	Royal Gala	Golden Delicious	Granny Smith	Red Delicious	Sturmer	% of Total[1]
1975	1.0	63.2	32.2	-	201.0	1180.9	404.4	203.7	81.8
	0.8	73.7	56.4	-	275.3	1369.9	570.4	217.8	85.6
	1.0	48.7	58.9	-	207.5	981.6	440.7	148.9	87.2
	0.7	83.1	107.5	-	267.3	1683.3	776.9	204.8	86.0
	1.7	65.3	162.2	-	235.3	1476.7	560.8	196.6	83.0
1980	2.7	96.4	224.5	-	298.3	1623.7	932.3	236.9	79.8
	5.5	99.3	348.0	-	280.0	2271.7	1113.1	245.9	86.1
	11.2	104.9	331.3	-	250.9	2255.7	1356.1	227.9	91.4
	21.9	123.8	336.2	24.5	195.8	2378.7	1256.1	195.1	92.8
	89.2	136.1	409.4	62.4	220.1	2614.5	1904.8	141.3	93.9
1985	150.7	251.1	498.3	171.7	174.6	3394.3	2060.7	136.8	94.5
	386.9	241.0	524.9	357.5	156.2	3124.7	2483.7	90.0	94.6
	436.1	334.4	497.9	472.0	133.8	3305.8	2341.6	94.9	93.1
	761.0	373.0	511.6	716.9	115.3	3383.5	2607.5	66.1	91.7
	753.4	410.6	498.6	897.7	72.9	3419.6	2269.7	62.9	91.9
1990	1179.5	444.9	539.5	1230.0	61.1	3265.9	2541.7	43.5	92.0
	1663.3	462.5	544.3	1688.7	39.1	2913.7	1907.6	37.0	90.1
	2080.5	389.5	493.2	1888.4	35.5	2075.3	1818.8	32.0	87.6
	*2370.0	*464.5	*508.0	*2305.0	*33.0	*2130.0	*1749.0	*25.0	-

* NZAPMB crop estimates for the 1993 season.
1 The percentage of total submissions represented by the eight varieties listed.

The dependent variable was specified as a variety's annual change in supply. However, yearly supply changes fluctuate significantly, especially when a biennial bearing cycle has been induced. To 'smooth' the affects of biennial bearing the supply change was presented as a two year moving average. A two year moving average was expected to increase the statistical reliability of the model.

4.2.2. The Price Variable

The selection and derivation of an appropriate price variable was essential. At the end of each season the NZAPMB provides each orchard with a summary of apple submissions and income by variety. Orchardists can then derive the average price received for each variety. A derived average price implicitly includes the influences on crop value of reduced packout due to tightening grade standards or increasing fruit volumes directed to local or process markets.

At the national level the average price per carton distributed to growers has been reported since 1949. However, this information is not available on a varietal basis. Information held by the NZAPMB necessary to derive such a measure was not in a useable or easily accessible format, or may have been disposed of. Surprisingly, an aggregate measure of average varietal price was not available. Therefore, it was necessary to derive an average price for export fruit.

Prior to a harvest season orchardists receive the *NZAPMB Price List and Terms of Supply*. The average price of an export carton for each variety was derived from this series of publications. A number of price books were obtained from the NZAPMB. Additional price books, not accessible from the NZAPMB, were obtained from a Hawkes Bay orchardist. An average nominal price was derived for each variety studied by weighting the prices of different size counts by the percentage of export fruit in each count size[1]. Unfortunately, information on the average fruit count size was only available from 1987. A breakdown of the proportions of export, local and processed fruit on a varietal basis was available from 1987.

The size distributions used for different varieties were derived using a five year average of size distributions from the Hawkes Bay Region. Over time size distributions are likely to have changed. However, it was assumed for this study that these changes were consistent across all varieties. Given the lack of data the derived price disregarded the crop's final usage. The derived price, therefore, did not take into consideration year to year variability of packout percentages or size distributions. Subsequently, the derived price may be distorted relative to

[1]The derivation of price schedule for the main varieties are shown in Appendix 1.

the actual average varietal price paid to orchardists. The derived average export price from 1975 to 1993 for the eight major apple varieties examined in this study are presented in Table 4.2.

Table 4.2. Derived prices for major export varieties, 1975-1993 (dollars per bushel).

Year	Braeburn	Cox's Orange	Gala	Royal Gala	Golden Delicious	Granny Smith	Red Delicious	Sturmer	Preferred[1]
1975	2.23	2.94	3.07	-	2.44	2.68	2.69	1.73	2.98
	2.40	3.06	3.23	-	2.50	2.97	2.85	1.87	3.13
	2.79	3.23	3.14	-	2.88	3.20	3.10	2.20	3.18
	3.54	3.55	3.67	-	2.94	3.55	3.51	2.47	3.64
	3.98	4.25	3.64	-	3.09	3.75	3.43	2.94	3.82
1980	4.52	4.57	4.45	4.62	3.60	4.18	3.83	3.31	4.49
	6.25	6.25	5.87	6.12	4.88	5.40	5.03	4.34	5.96
	7.14	6.74	7.81	7.18	5.16	5.97	5.33	4.65	7.54
	7.51	8.28	6.94	7.40	5.74	7.15	6.23	5.22	7.31
	8.00	8.67	7.30	7.53	5.45	6.84	6.33	5.13	7.68
1985	8.69	10.10	8.88	8.37	5.86	7.27	6.36	5.46	9.06
	10.07	10.42	9.51	9.45	6.41	8.01	6.79	6.32	9.78
	11.47	11.62	11.45	10.58	7.37	9.36	7.86	7.17	11.25
	13.80	11.80	11.98	11.87	7.68	9.28	7.69	8.36	12.53
	18.05	14.41	12.81	13.84	7.17	9.18	8.12	8.42	15.04
1990	18.04	15.11	14.23	14.67	7.54	9.06	8.12	10.88	15.97
	21.89	18.30	12.33	16.15	7.43	8.99	8.12	11.79	18.42
	23.82	24.76	17.80	21.28	12.86	14.39	12.12	15.38	23.09
	23.24	23.90	17.10	20.26	12.77	8.96	10.10	11.42	21.69

[1] The nominal price for preferred varieties was derived from a 'basket' of preferred variety prices. This was made up of the current preferred varieties - Braeburn, Cox's Orange Pippin, Fuji, Gala, and Royal Gala. Weights were specified as a percentage contribution of the variety to the total supply of preferred varieties. The derivation of the preferred varieties price series in shown in Appendix 5.

Derived nominal prices do not reflect fruit value relative to input costs. Therefore, prices were deflated by a horticultural input price index (HIPI) to establish their 'real' value. Bruhn (1992) derived a HIPI for pipfruit back to 1971. Prior to this period prices were deflated by the consumer price index (CPI). The indices diverge from one another in the early seventies then converge on the base year 1982. Since 1982 the HIPI has again diverged from the CPI[2]. Real prices were tested for significance in various derived supply response models.

Orchardists were assumed to make comparisons between alternative varieties when making varietal selection decisions. Price variables for competing varieties are sometimes specified as further explanatory variables in supply response models. However, the inclusion of competing crop price variables reduces the degrees of freedom for model estimation. A ratio of the nominal price of a variety to the nominal price of competitive varieties[3] was tested as an explanatory variable instead.

The price expectation models suggested by various authors in Section 3.3 are unique to their original application. The selection of a representative price expectation model is dependent on the characteristics of the variable being modelled and the statistical significance of the estimated parameter. A study of Hawkes Bay pipfruit orchardists by Petersen (1990) showed that the primary influence on variety choice decisions was the expected price. These expectations were largely based on prices announced by the NZAPMB. For this reason a two year moving average model is applied using nominal price, real price and the price ratio.

4.2.3. Area Data

The NZAPMB have surveyed orchardists annually since 1988. Survey results in the form of area data by variety and by age, were made available by the Hawkes Bay Office of the NZAPMB. A summary of Hawkes Bay area data by variety is presented in Appendix 3. Prior to 1988 the only tree population statistics published were in five yearly MAF surveys. However, no accurate tree population statistics were available between 1978 and 1987.

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[2]The CPI and HIPI series are shown in Appendix 2. The reasons for significant differences between the HIPI and the CPI are discussed in detail by Bruhn (*ibid.*).

[3]The price value for competitive varieties was defined as the average price of all varieties or the price of preferred varieties.

The NZAPMB tree population statistics (1988-1991) show the area of different aged trees. New plantings, removals, and the area of non-bearing and bearing trees can be derived by observing the changes in tree area by age group from year to year. For example, if the area of eight year old trees in 1988 is 20 ha, then the area of nine year old trees in 1989, given that no removals took place, should be 20 ha. An area of 15 ha of nine year old trees in 1989 would suggest that five ha of trees were removed.

Given that only four years of data was available the tree removal variable could not be derived for a sufficient time series. Similarly, for declining varieties the bearing area variable could not be defined. However, for 'new' expanding varieties, removals were not anticipated. That is, the area of eight year old trees in 1988 will equal the area of nine year old trees in 1989. Furthermore, the area of trees eight years old in 1988 is representative of the area of trees planted nine years ago in 1979.

Data presented by the NZAPMB was not reliable. For example, in the 1988 statistics the area of one year old Royal Gala trees was 143 ha. In the 1989 statistics the area of two year old trees was 163 ha suggesting that 20 ha of two year old Royal Gala trees were planted the previous year! Furthermore, the area of three year old Royal Gala trees in 1990 was 174 ha suggesting that at further 11 ha of three year old trees were planted, this is unlikely. Data inconsistencies appeared to be more common in areas of young trees.

Given the lack of accurate varietal area data, over a significant time series, area variables relating to plantings, removals and numbers of bearing and non-bearing trees could not be derived for traditional varieties. However, for new varieties where removals were not occurring new planting data could be derived. The derived new plantings are shown in Appendix 4. The lack of area data seriously restricts the potential for supply response modelling of New Zealand apples. As a consequence, explanatory models such as that used by French and Matthews (1971) could not be specified.

4.2.4. The Climate Variable

Climatic variability from year to year causes shifts to the supply curve. The inclusion of climate variables within a supply response model may be of significance. Climate data have been published by the New Zealand Meterological Service (NZMS) in *Meterological Observations* since 1960. However, from 1987 such publications were discontinued. After this date data is obtainable from the NZMS at a cost. Past publications include data from all weather stations throughout New Zealand. Tables of climatic variables report air temperature and humidity, cloud cover and sunshine hours, rainfall, wind, and the occurrence of other events such as gale, snow, hail, thunder, fog, ground frost and screen frost. There are a number of weather stations in the Hawkes Bay. Data from the Havelock North and Napier weather station were used for this study.

A number of climatic variables have been identified as influencing apple yields (Dennis, 1979; MAF, 1981; Jackson, 1986; Theile, 1993). The MAF (1981) suggest that screen frosts after mid-September should be avoided; annual rainfall should be below 1000mm; mean daily October temperatures above 12°C are preferable; more than 1200 sunshine hours are required during the October-March period and sunshine in October should exceed 180 hours; hail belts should be avoided and approximately 1500 'chilling units' are required. Dennis (*ibid.*) and Jackson (*ibid.*) confirm these specific recommendations. The information provided by the above authors, however, does not provide useful quantitative measures of the impacts of climatic variation on orchard performance.

Zhang and Theile (1993) measured the yield variability from climatic influences. The study, on Royal Gala apples grown in New Zealand identified statistically significant variables effecting fruit set, fruit size and fruit quality. In particular Zhang and Theile (*ibid.*) noted that higher maximum temperatures in late summer (February to March) and lower maximum temperatures in the late dormancy period (August to September) produced higher fruit set the following spring. Average fruit size was found to be positively correlated with November to February temperatures in the previous season. However, maximum temperatures in December and January provided the most accurate information for harvest predictions.

Climatic variables such as excessive wind and drought also influence apple production. However, the affects of wind and drought are reduced by crop protection measures such as shelter and irrigation. The occurrence of hail is isolated so its aggregate impact is not easily quantifiable. Screen frosts are generally widespread and are recorded at weather station. Like the Zhang and Theile (*ibid.*) study climatic observations were obtained from the DSIR Havelock North weather station. For this study consistent 'bright sunshine hours' data were obtained from Napier because this data was not collected at Havelock North.

The mean of climatic observations was subtracted from yearly observations for the derivation of climate variables. These variables were then expressed as a percentage change from their mean. The derived changes were represented as a positive value for favourable climatic conditions or negative value for unfavourable conditions. Different derived climatic variables were tested within the supply response model to assess and explain supply variation[4]. The climatic variables derived for testing were October sunshine hours (C_1); October to March sunshine hours (C_2); mean October temperature (C_3); November to March mean temperature (C_4); December to January mean maximum temperature (C_5); December to March mean maximum temperature (C_6); and December to March mean maximum temperature from the previous growing season (C_7).

4.2.5. Management Ease

A number of apple varieties require unique management input. The cultural management requirements of varieties such as Braeburn, Red Delicious and Granny Smith are less demanding relative to varieties such as Fuji or Cox's Orange Pippin. The ease of the management of a variety was expected to influence growers' planting decisions. Petersen (1990) identified the ease of management as a secondary criteria for the selection of apple varieties. Some orchardists suggested that they avoided varieties which were 'difficult to produce'. Therefore, it was expected, therefore, that orchardists supply response to changing prices would be greater for varieties easier to grow.

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[4]Raw climate data and derived climate variables are presented in Appendix 5.

A management variable was incorporated into models for comparative reasons. Management ease was difficult to quantitatively assess. However, by using a qualitative 0,1 dummy variable varietal supply response models can be compared.

4.3. Applied Model Derivations for Hawkes Bay Apples

The most descriptive model discussed in Chapter 3 was by French and Matthews (1971). However, as noted by a number of different authors it is data demanding so often cannot be used in its full form. Similarly, in this study data availability did not permit the use of a French and Matthews Model (see Section 4.2.3). However, their model provides the theoretical background for less data demanding applied models.

Orchard renovation decisions effect supply in two ways. New plantings result in future supply expansion while removals of existing orchards cause instant supply contraction. Therefore, it is appropriate to specify varietal models for both supply expansion and supply contraction.

4.3.1. Supply Expansion Models

For expanding supply of varieties such as Braeburn and Royal Gala the quantity of fruit submitted to the NZAPMB in year t results from a stock of bearing trees. The area of bearing trees in year t is determined by the area of bearing trees in the previous year plus 'maturing' trees. It was assumed that trees were not removed from varieties with expanding supply.

Supply changes from one year to the next were assumed to be a result of maturing new plantings. Maturing trees result from plantings in previous years (t-n), the amount of which was assumed to be influenced by orchardists' price expectations in t-n and t-n-m. Therefore, it was hypothesised that the change in aggregate supply (ΔS) in year t will be a function of price (P) in t-n. Additional fluctuations were assumed to be caused by climatic influences (C) in year t.

The change in supply in year t can be expressed as:

$$\Delta S_t = f(P_{t-n}, C_t) \tag{4.6}$$

The time period n, represented the time between the price signal and an observed supply change. Trees require from four to six years to produce significant yields. Furthermore, the speed at which orchardists make enterprise changes may be constrained by capital resources or by shortages of suitable nursery stock. Similarly, time may be needed for growers to adjust their price expectations before they commit themselves to change. As a result supply responses to changing prices were not expected to be observed until some time in the future. Therefore, price lags between four to nine years were specified and tested for significance in derived supply expansion models.

4.3.2. Supply Contraction Models

Because of the limited area data available a model was specified which was applicable to supply contraction only. The model could only be applied to varieties where the stock of trees were all full bearing. That is; observed production decline was not influenced by the maturing of new plantings.

Removal of apple trees, due to declining profitability, may occur long before the health of a tree declines given that apple trees can bear heavy yields for 40 to 50 years. That is, a variety's economic lifetime is now shorter than its physical lifetime. It was expected that orchardists considered tree removals when the profitability of the existing variety declined relative to other new varieties. However, if alternatives are not significantly more profitable than existing varieties orchardists may not implement renovation decisions. This is primarily due to the significant capital cost of orchard renovations and the income forgone while new plantings mature. Orchardists are only expected to replace less profitable trees with more profitable alternatives where significant price differentials occur. For this reason a price ratio was specified to show the comparisons between declining variety and a preferred varieties price, reported in Table 4.2.

It was hypothesised that the decline in aggregate supply in year *t* was a function of the price ratio in *t-n*. Fluctuations were also assumed to be caused by climatic influences in year *t*. The change in supply was expressed as a percentage, so that comparisons could be made between varieties irrespective of their total volume supplied. The percentage change in supply ($\%\Delta S$) in year *t* is expressed as:

$$\%\Delta S_t = f(P_{t-n}, C_t) \tag{4.7}$$

Removals of productive trees can occur 'over night'. Orchardists receive price signals from either final payments or from *NZAPMB Price and Terms of Supply* publications. These price signals do not occur until some time after winter by which time the new season has begun. Rational orchardists are not expected to remove trees which have already attracted sunk seasonal costs. Therefore, expectations are that orchardists will not reduce supply, by tree removal, until the season following critical price signals.

Significant declines in the supply of Hawkes Bay's main apple varieties, Red Delicious and Granny Smith, have occurred over the past 4 years. However, modelling supply declines for these varieties is not possible given the limited data set[5]. Instead models are derived to explain supply decline for Sturmer and Golden Delicious where supply decline has been occurring for a significant number of years and all trees are assumed to be bearing. These models are subsequently applied to Granny Smith and Red Delicious production in Chapter 5.

4.4. Modelling Methodology

The influences on supply was measured using ordinary least squares (OLS) regression. The significance of variables were tested using a *t*-test. Insignificant variables were discarded at the 95% confidence level. Models were derived in a stepwise fashion. The price variable was tested first. It was expected that price had the greatest affect on the change in the aggregate

[5]The shortness of the time series data restricts the statistical significance of derived econometric models.

level of supply. Additional climate variables were then added as explanatory variables. Significant climate variables were expected to improve the 'fit' of derived models as measured by the adjusted R-squared value.

Supply expansion models were compared using dummy variable analysis[6]. Dummy variables were added to measure the influence of management ease and from these models coefficients for price were compared. Similar comparisons were made for supply decline models. Finally, models were used for forecasting further changes in supply. The reliability of forecasts was then assessed.

4.5. Summary

A theoretical model, based on the French and Matthews Model (1971), was derived to explain the supply of apples from Hawkes Bay orchardists. Data available for the model application was presented. Data on apples supplied to the NZAPMB has been available since 1970. The limited availability of price data restricted the explanatory price variable to a derived price for export apples. Climatological observations provided sufficient data for the derivation of a number of climatic variables. It was suggested that dummy variable analysis could be used to explain the differences of management ease. However, the availability of area data was limited. Therefore, the use of the initial theoretical model was restricted. Instead models were derived specifically for supply expansion and supply contraction situations. These models can be tested by OLS regression analysis. The significance of variables can be identified using *t*-tests. Results are presented in Chapter 5.

[6]The use of dummy variables for comparing regressions is explained in Gujarati (Gujarati, D.N. Basic Econometrics, Second Edition. Singapore, McGraw-Hill: 1988, pp 446-448).

CHAPTER 5. RESULTS

5.1. Introduction

Supply expansion and supply contraction models are applied to apple varieties. The application[1] generates empirical equations to explain supply expansion of Braeburn and Royal Gala and supply contraction of Golden Delicious and Sturmer. A single supply expansion model is used to explain Braeburn and Royal Gala supply expansion and to forecast future supply. Empirical models explaining supply contraction of Golden Delicious and Sturmer are also derived. Golden Delicious and Sturmer models are shown to be significantly different from one another. Results suggest that other explanatory variables are necessary to derive explanatory supply expansion and supply contraction models appropriate to all varieties.

5.2. Supply Expansion Models

Gala was developed in New Zealand through a formal breeding programme. The variety was one selection from crosses between Kidd's Orange Red and Golden Delicious in 1965 (Moore and Ballington, 1990). Gala provided a sweet, early season apple of high quality. Over the past ten years Gala production has been overshadowed by Royal Gala. Royal Gala was derived from a chance Gala bud sport[2]. It was first identified and found to be stable in 1969. Royal Gala provided a more highly coloured Gala apple with greater consumer appeal. By 1973, 13,000 buds had been supplied to the Fruitgrowers Federation for nursery material.

Braeburn was found in the Nelson region in 1950. The variety was developed from a chance apple seedling of unknown parentage. Initial adoption of the variety was very slow. However, in the mid 1970's it was recognised as having potential as an export variety. Braeburn

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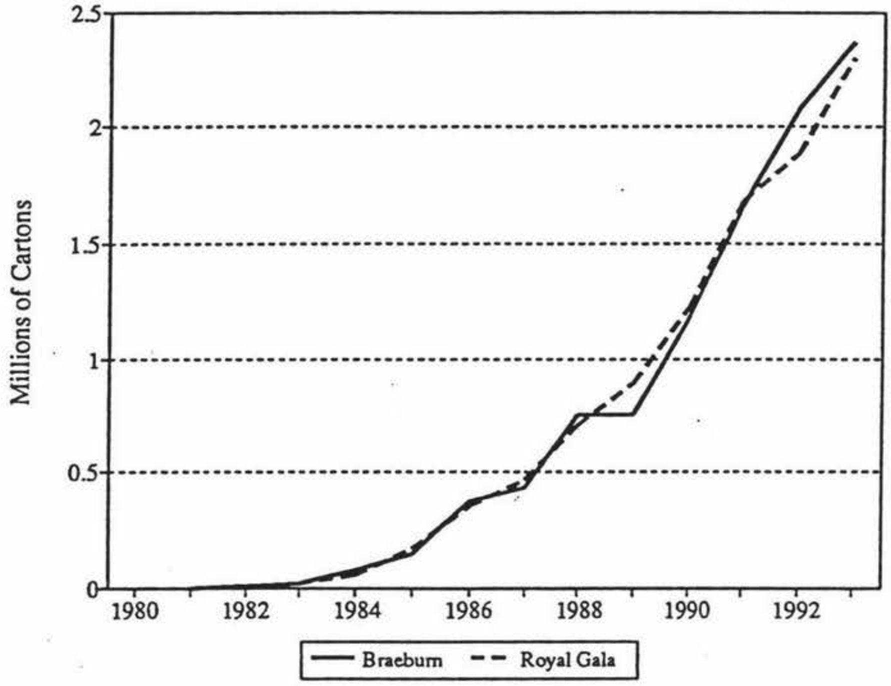
[1]SAS was used throughout this study. SAS is a software system for data analysis (SAS Institute Inc. (1988). SAS User's Guide: Basics, Version 5 Edition. Cary, NC: SAS Institute Inc.).

[2]A bud sport is a mutation of an inherited characteristic arising in a cell from which a bud and subsequent shoot and branches eventually develop (Janick and Moore, 1975). These mutations most commonly effect fruit colour.

provided a mid-season red variety which entered the European market when it was over-supplied with green varieties. The increasing supply of Braeburn and Royal Gala is shown in Figure 5.1. The varieties are 'preferred' with unsatisfied export demand. Subsequent supplies are in the expansion phase described in Section 2.7.

Figure 5.1. Hawkes Bay Braeburn and Royal Gala Submissions.



Models were developed to explain and measure the influence of price on supply expansion of Gala and Braeburn; with the intent that these models could by applied to other expanding varieties such as Fuji, Fiesta, GS2085 and GS330. However, model derivation specifically for these newer varieties is constrained by the short time series over which they have been grown.

5.2.1. Results

Data on Braeburn submissions have been published since 1974. However, only small volumes of Braeburn were produced until 1982. The rapid increase in supply in the early eighties appears to be a result of the recognition of the variety in the mid 1970's. Supply observations were used from 1982. The Braeburn price series was available from 1975 (reported in Section 4.4.2). Royal Gala submissions have been reported since 1983. Prior to 1983 Royal Gala submissions were included with Gala. Prices have only been published since 1980. The Gala price series was used as a proxy for Royal Gala prices prior to their publication in 1980.

Useful submission data restricted the number of observations for Braeburn and Royal Gala to 13 and 11 respectively. Submission data were used in two ways. Firstly, an average of the supply from years' *t-1* and *t-2* was calculated[3] and subtracted from the supply in year *t*. The change in the supply, $\Delta S_{1,i}$, was expected to be the result of lagged price and climatic affects in year *t*. That is:

$$\Delta S_{1,i} = S_t - \left(\frac{S_{t-1} + S_{t-2}}{2}\right) \tag{5.1}$$

where; $\Delta S_{1,i}$ = the change in supply of variety *i*,

S_{t-x} = the supply in year *t-x*.

A second supply change variable, $\Delta S_{2,i}$, was derived by calculating the change in a two year moving average of supply, i.e., the difference between the average of supply from years *t* and *t-1* and from years *t-1* and *t-2*. The influence of climatic variation and biennial bearing on supply change reduced by averaging submissions. The affect of price alone could then be studied. The two year moving average change in supply is presented in Equation 5.2:

$$\Delta S_{2,i} = \left(\frac{S_t + S_{t-1}}{2}\right) - \left(\frac{S_{t-1} + S_{t-2}}{2}\right) \tag{5.2}$$

where; $\Delta S_{2,i}$ = the two year average change in supply of variety *i*.

Dependent variables, $\Delta S_{1,i}$ and $\Delta S_{2,i}$ were regressed against derived price variables. Real price and price ratio variables were found to be insignificant at the 95% confidence level. Statistically significant parameter estimates, at the one percent confidence level, were obtained from two year moving averages of nominal price lagged six, seven and eight years.

Climatic variables were introduced as additional explanatory variables for $\Delta S_{1,i}$. The majority of climatic variables used to explain variations in supply for Braeburn and Royal Gala were statistically insignificant. The maximum temperature for December and January, however, was

[3]The use of an averages reduced the effects of biennial bearing and abnormal climatic conditions.

significant at the 95% confidence level for Royal Gala. As expected its value was positive. Maximum temperature for December and January lagged one year with a seven year lagged price variable was significant at the 90% confidence level for Braeburn.

The significance of the climatic variable used in Royal Gala models supports Zhang and Theiles' (1993) findings. The models suggest that maximum temperatures in December and January significantly enhanced Royal Gala yields. Zhang and Theile also suggested that average fruit size was positively correlated with November to January temperatures in the previous season. This was shown when a lagged climate variable for summer temperatures was used for Braeburn.

The addition of the climatic variable increased the R-squared value of the derived models. However, the Durbin-Watson *d* statistic indicated the possibility of autocorrelation. Classical OLS regression assumes that the disturbance term is not influenced by the disturbance term relating to any other observation (Gujarati, 1988). Sequential influences of disturbance terms indicate the presence of autocorrelation[4]. When a climatic variable was used to explain variation in supply the Durbin-Watson statistic indicated the presence of autocorrelation. Estimates for these models may be biased, therefore, they were not used for forecasting supply.

The highest R-squared values for the dependent variable $\Delta S_{2,i}$, resulted from models represented by the two year moving average lagged eight years, P_{NL8}. The use of an eight year price lag supports the results of a previous study of New Zealand apples by Rae and Carman (1974). The length of the price lag is similar to the time period required for apple trees to reach maturity. A number of explanatory models were derived for Braeburn and Royal Gala. The statistically significant supply change models are presented in Table 5.1.

[4]The consequence of using OLS estimation while disregarding autocorrelation is that (1) the residual variance σ^2 is likely to underestimate the true σ^2; (2) subsequently the R^2 is likely to be overestimated; (3) the usual *t* and *F* significance tests are no longer valid, and if applied, are likely to give seriously misleading conclusions about the statistical significance of the estimated regression coefficients (Gujarati, *ibid.*, pp 364).

Table 5.1. Braeburn and Royal Gala supply change models.

Dependent variable	Intercept	Price variable	Climate variable	Adjusted R-Squared	Durbin Watson Statistic
$\Delta S_{1,Braeburn}$	-114144*** (-1.081)	72990 P_{NL7} (4.275)	3.780** C_7 (1.907)	0.72	2.503+
$\Delta S_{1,Braeburn}$	-96042*** (-1.065)	80248 P_{NL8} (4.845)	3.161***C_7 (1.727)	0.77	2.748+
$\Delta S_{2,Braeburn}$	-104939** (-1.801)	55293 P_{NL7} (5.719)		0.76	1.722
$\Delta S_{2,Braeburn}$	-97650** (-1.993)	61195 P_{NL8} (9.260)		0.81	1.923
$\Delta S_{1,Royal\ Gala}$	-83713*** (-1.278)	70107 P_{NL7} (6.385)	1.915* C_5 (3.327)	0.88	2.268+
$\Delta S_{1,Royal\ Gala}$	-91592*** (-1.283)	74324 P_{NL8} (3.655)	1.666* C_5 (3.655)	0.92	2.949+
$\Delta S_{2,Royal\ Gala}$	-43834*** (-0.775)	44786 P_{NL7} (5.042)		0.75	1.913
$\Delta S_{2,Royal\ Gala}$	-41426*** (-0.970)	49583 P_{NL8} (6.655)		0.84	2.143

where; $\Delta S_{1,i}$ = the change in supply of variety *i* from the average of the previous two years supply,
$\Delta S_{2,i}$ = the change of the two year average supply of variety *i*,
P_{NLx} = the two year moving average nominal price lagged *x* years,
C_5 = the mean maximum temperature for December and January,
C_7 = the mean maximum temperature for December and January lagged one year,
*** indicates that parameter estimates are not significant,
** indicates that parameter estimates are significant at the 90% confidence level,
* indicates that parameter estimates are significant at the 95% confidence level,
+ indicates that the presence of autocorrelation cannot conclusively be rejected,
t values are shown in parenthesis.

Significant models for Braeburn and Royal Gala used $S_{2,i}$ as the dependent variable and P_{NL8} as the explanatory variable. This price variable was highly significant. The significance of price suggests that the null hypothesis can be rejected. Durbin-Watson values of 1.923 and 1.913 was evidence that autocorrelation was not present. R-squared values of 0.81 and 0.84 indicated that 81% and 84% of the variation in the dependent variable was explained by Braeburn and Royal Gala models respectively.

The parameter estimates for Braeburn and Royal Gala models indicated the expected change in supply for every dollar increase in the average nominal price. The model for Braeburn had a larger parameter estimate suggesting that the increase in Braeburn supply will be greater than that for Royal Gala from similar price increases. Braeburn is an easier variety to grow than Royal Gala, therefore, orchardists are more readily expected to plant Braeburn. Furthermore, the value of apple varieties directly competing with Braeburn, such as Sturmer and Red Delicious, have declined over time. On the other hand the major apple variety competing with Royal Gala, Cox's Orange Pippin, has not declined in value.

To measure the extent of the influence of management ease a dummy variable was specified. Observations for Braeburn and Royal Gala were combined to form one data set. A 0,1 dummy variable was then used where the values 0 and 1 were given to Royal Gala and Braeburn respectively. Supply was then regressed upon the dummy variable, lagged prices and lagged prices multiplied by the respective dummy variable. The results from this analysis are shown in Table 5.2.

Table 5.2. Braeburn, Royal Gala and combined supply change models.

Dependent variable	Intercept	Additive Dummy Variable	Price variable	Multiplicative Dummy Variable	Adjusted R-Square	Durbin Watson Statistic
$\Delta S_{2,Braeburn}$	-97650^{**} (-1.993)		$61195\ P_{NL8}$ (9.260)		0.81	1.923
$\Delta S_{2,Royal\ Gala}$	-41426^{***} (-0.970)		$49583\ P_{NL8}$ (6.655)		0.84	2.143
$\Delta S_{2,Combined}$	-78703^{*} (-2.382)		$56900\ P_{NL8}$		0.83	1.874
$\Delta S_{2,Combined}$	-41426^{***} (-0.693)	$-56224^{***}D$ (-0.771)	$49583\ P_{NL8}$ (4.753)	$11612^{***}DP_{NL8}$ (0.893)	0.81	1.977

Where; D = the dummy variable,
DP_{NL8} = P_{NL8} multiplied by the dummy variable.

The dummy variable technique tested whether the difference between the Braeburn and Royal Gala models was statistically significant. Findings showed that both the additive and the multiplicative dummy variable used on lagged price were insignificant. This suggested that equations for Braeburn and Royal Gala were not statistically different. This conclusion was reinforced by a Chow Test where the calculated F value of 0.194 is less than $F_{Critical\ 2,22}$ again suggesting that the regressions are not statistically different[6]. Therefore, the combined model provided an appropriate equation for explaining both Braeburn and Royal Gala. The equation (5.3) is shown below:

$$\Delta S_{2,i} = -78703 + 56900\ P_{NL8} + e \qquad (5.3)$$

where; e = an error term representing unexplained fluctuations in $\Delta S_{2,i}$.

The combined model was used to simulate supply changes for Braeburn and Royal Gala. The combined model was also tested against Fuji where the number of observations of supply were insufficient for the derivation of a varietal model.

5.2.2. Supply Simulations and Forecasts.

The combined model for change in supply $\Delta S_{2,i}$, explained by the two year moving average price lagged eight years P_{NL8}, was used to forecast supply for Braeburn and Royal Gala up until 1998. Simulations of supply change performed for Braeburn and Royal Gala from 1985 until 1998 are shown in Figure 5.2 and Figure 5.3 respectively. The percentage root mean squared error (PRMSE) was used as a measure of the error term (e), within which supply changes were expected to occur. The actual supply changes for Braeburn and Royal Gala were expected to occur within ±26% and ±20% of the predicted value respectively.

Increases in supply were accumulated from 1985 until 1998. The PRMSE was calculated for this prediction. Its value was calculated as 21% for Braeburn and 17% for Royal Gala. Forecasts of supply are shown in Figure 5.4 and Figure 5.5.

[6] The use of the Chow test is described in Gujarati (*ibid.*, pp 443-446).

Figure 5.2. Braeburn supply change - actual and simulated.

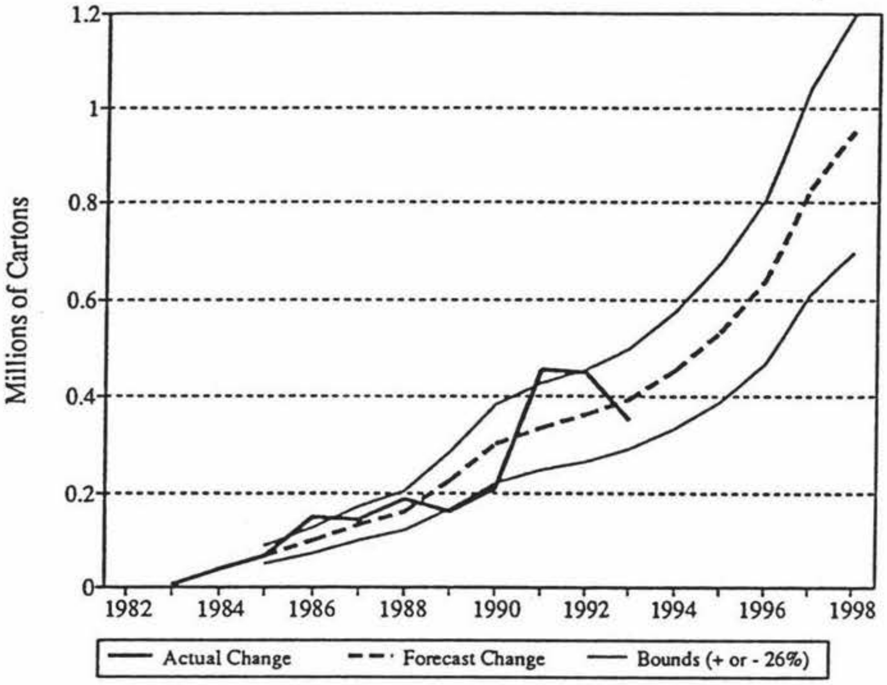


Figure 5.3. Royal Gala supply change - actual and simulated.

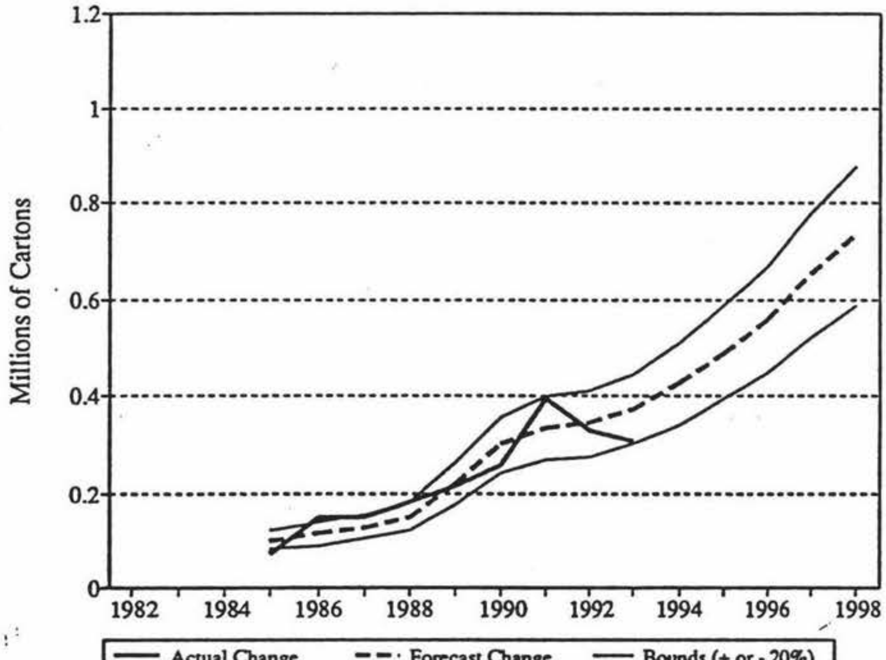


Figure 5.4. Total Braeburn supply - actual and simulated.

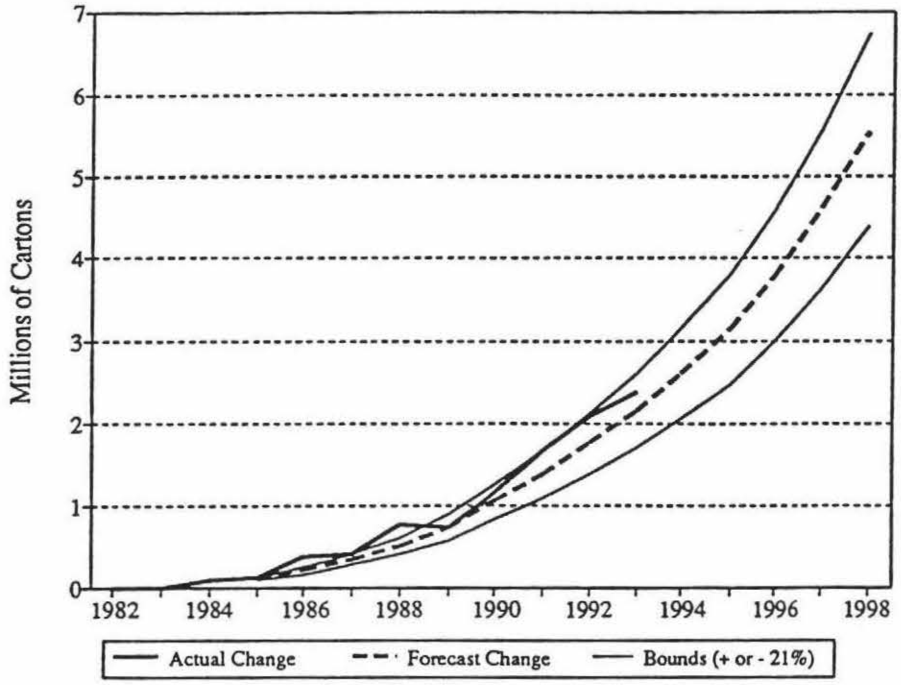
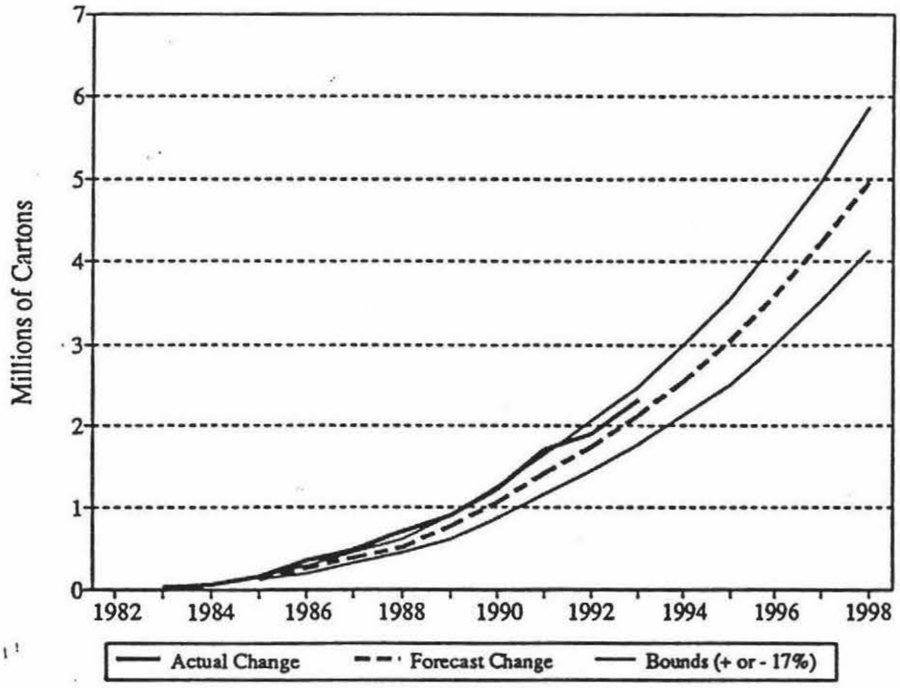


Figure 5.5. Total Royal Gala supply - actual and simulated.



5.2.3. Application of Derived Combined Supply Expansion Model to Other Varieties

Fuji was recognised in world markets long before its importation and release in New Zealand. However, consistent and reliable plant material was not available in New Zealand until the early 1980's. In 1982 a propagation and selection programme was implemented ensuring that only the best trees were grown. Fuji is highly priced and is one of New Zealand's preferred varieties undergoing an expansion phase.

The combined supply forecast model was used to simulate the changing Fuji supply. Prices for Fuji have been announced in *NZAPMB Price List and Terms of Supply* publications since 1985. Supply data have only been published since 1987. The use of P_{NL8} required that prices prior to 1985 had to be derived from the preferred price series. The results of the simulation and comparisons with actual data is shown in Table 5.3.

Table 5.3. Prediction of Fuji supply change and comparison with actual.

Year	Supply Fuji	P_{NL8}	Actual $\Delta S_{2,Fuji}$	Simulated $\Delta S_{2,Fuji}$	Lower Bound	Upper Bound
	7.0	-	-	-	-	-
1988	37.0	-	-	-	-	-
	56.4	-	24.7	-	-	-
1990	158.5	-	60.5	-	-	-
	300.2	⁺5.92	121.9	258.1	198.0	318.2
1992	567.5	⁺5.99	204.5	262.1	201.2	323.2
	˙770.0	⁺6.93	˙234.8	315.6	242.1	389.1
1994	-	8.11	-	382.8	293.6	472.0
	-	9.53	-	463.6	355.6	571.6

˙ NZAPMB crop estimate.
⁺ Moving average prices derived from the preferred varieties price series.

Results suggested that the derived combined supply expansion model over-estimated the actual supply change of Fuji. Over-estimation appears to be largely a result of the derived price series. Fuji is renowned as being difficult to grow, its packouts (45-55%) are significantly less than Braeburn and Royal Gala. Both of these varieties typically have packouts exceeding 65%. Therefore, the returns to growers from Fuji are likely to be less than

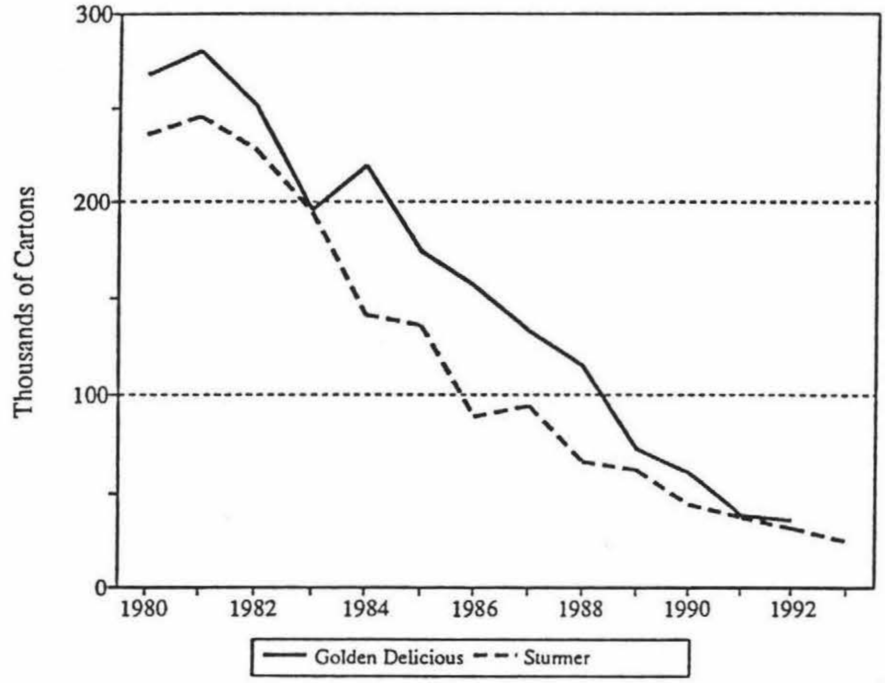
Braeburn and Royal Gala when prices are the same.

To illustrate the effect of lower export packouts, Fuji's packout was assumed as 50%, while Braeburn and Gala were 65%. At the same price the value of Fuji is expected to be some 23% less than Braeburn and Royal Gala. If price in the derived combined supply model was substituted by value then the predicted supply is more likely to be closer to the actual. A 23% reduction in predicted supply change for 1991, 1992, and 1993 results in values of 198, 201, and 243 thousand tce's respectively. The actual values for these years are 121, 204, and 234 thousand tce's (refer Table 5.3). Values for 1992 and 1993 are within the expected boundaries. The 1990 value is low due to early plantings of Fuji being restricted by the availability of nursery stock. This analysis is by no means statistically significant. However, it provides an illustration of the possible distortions caused by using a price series based on derived export price. A profit variable incorporating packouts and yield is required for the derivation of a single supply expansion model.

5.3. Production Contraction Models

Prices for Granny Smith and Red Delicious, New Zealand's main export varieties, have significantly declined in recent years. Orchardists have responded by removing trees. Consequently, supply of these varieties has begun to contract. The development of models specifically for Granny Smith and Red Delicious is not possible given the short time period over which supply contraction has occurred. However, supply contraction has occurred for Golden Delicious and Sturmer over a significant length of time. Models were developed to explain and measure the influences of price on the supply contraction of Golden Delicious and Sturmer; with the intent that these models could be applied to Granny Smith and Red Delicious. The supply contraction of these varieties is shown in Figure 5.6.

Figure 5.6. Supply contraction of Golden Delicious and Sturmer.



5.3.1. Results

Data for the supply and price of Golden Delicious and Sturmer were available since 1970 and 1975 respectively. However, supply data for Sturmer was used only from 1978. Supply up until 1978 was increasing suggesting that some Sturmer trees were still maturing.

Dependent variables for supply changes were derived in a similar fashion as those for the supply expansion models. However, the changes were expressed as percentages of the previous two years' average supply ($\%\Delta S_{1,i}$), and the percentage change of the moving average supply ($\%\Delta S_{2,i}$). By expressing supply change as a percentage comparisons could be made between varieties where absolute differences in total volume supplied were markedly different.

Price variables identified in Section 4.3.2 were used as independent variables. Of these variables a moving average of the price ratio provided the most significant results. The price ratio used the price of the examined variety divided by a weighted average of prices of preferred varieties - Braeburn, Cox's Orange Pippin, Fuji, Gala, and Royal Gala. Weights were specified as the percentage contribution of a variety to the total supply of preferred varieties in a given year[6]. (Orchardists were expected to compare the price of existing varieties with newer varieties).

The percentages of the previous two years' average supply ($\%\Delta S_{1,i}$) fluctuated from year to year due to the influences of climatic. Such variations resulted in low R-squared values. Climatic variables were introduced to improve models. However, climatic variables were not significant or had spurious negative coefficients which were contrary to *a priori* expectations and known physiological performance.

To 'smooth' the affects of climatic variation, $\%\Delta S_{2,i}$ was specified as the dependent variable. Again, the moving average of the price ratio lagged one and two years was used as an explanatory variable adding further support to the rejection of the null hypothesis. These models were the most statistically significant with the highest R-squared values. The value of the Durbin-Watson *d* statistic indicated that autocorrelation was not present. These models, presented in Table 5.4, were chosen for further analysis and supply forecasting.

Table 5.4. Golden Delicious and Sturmer supply change models.

Dependent variable	Intercept	Price Variable	Climate Variable	Adjusted R-Squared	Durbin Watson Statistic
$\%\Delta S_{2,G.Delicious}$	-66.9 (-8.901)	81.1 P_{RAL1} (7.670)		0.79	1.742
$\%\Delta S_{2,G.Delicious}$	-71.0 (-5.861)	83.8 P_{RAL2} (5.016)		0.63	1.976
$\%\Delta S_{2,Sturmer}$	-142.0 (-6.033)	195.2 P_{RAL1} (5.517)		0.69	1.660
$\%\Delta S_{2,Sturmer}$	-108.7 (-3.174)	144.5*P_{RAL2} (2.817)		0.35	0.880**

where $\%\Delta S_{2,i}$ = the change of supply in years *t* +*t-1*, expressed as a percentage of years *t-1* + *t-2*,
P_{RALx} = a ratio of the price of Golden Delicious to the price of preferred varieties,
** = indicates the presence of autocorrelation.

[6]The derivation of the 'preferred varieties' price series is shown in Appendix 6.

Comparisons were made between Golden Delicious and Sturmer models using the dummy variable technique reported in Section 5.2.1. The results of the analysis are shown in Table 5.5.

Table 5.5. Golden Delicious, Sturmer and combined supply change models.

Dependent variable	Intercept	Additive Dummy Variable	Price Variable	Multiplicative Dummy Variable	Adjusted R-Squared	Durbin-Watson Statistic
$\%\Delta S_{2,G.Delicious}$	-66.9 (-8.901)		81.1 P_{RAL1} (7.670)		0.79	1.742
$\%\Delta S_{2,Sturmer}$	-142.0 (-6.033)		195.2 P_{RAL1} (5.517)		0.69	1.660
$\%\Delta S_{2,Combined}$	-142.0 (-6.352)	75.1 (3.167)	195.2$^{*}P_{RAL1}$ (5.809)	-114.1 DP_{RAL1} (-3.222)	0.74	1.705

where; DP_{RAL1} = the dummy variable multiplied by P_{RAL1},
* = indicates that the parameter estimates are significant at the 95% confidence level.

The multiplicative and the additive dummy variables were both highly significant. The results suggested that removals of Golden Delicious and Sturmer would begin at a price ratio of 0.81 and 0.74 respectively. These values are not greatly different, however, the combined model showed that the rate of contraction of the varieties was still significantly different. Sturmer declined more rapidly as the result of a declining price ratio. A 10% decline in the Sturmer price ratio caused a corresponding 15.5% decline in supply the following year. A 10% decline in the Golden Delicious price ratio caused a supply decline of 6.5% the following year. Possible reasons for the faster removal of Sturmer include the competition by Braeburn for harvest labour. Conversely, Golden Delicious harvest starts at the end of the Royal Gala season and finishes at the beginning of the Braeburn harvest. By retaining some Golden Delicious orchardists retain continuity of harvest labour demands. The models derived for supply contraction of Golden Delicious are shown in Equation 5.4 and Equation 5.5.

$$\%\Delta S_{2,G.Delicious} = -66.9 + 81.1\ P_{RAL1} + e \qquad (5.4)$$

$$\%\Delta S_{2,Sturmer} = -142.0 + 195.2\ P_{RAL1} + e \qquad (5.5)$$

5.3.2. Supply Simulations and Forecasts

Supply contractions and simulations of supply contraction for Golden Delicious and Sturmer are shown in Figures 5.7 and 5.8. Forecasts for 1993 and 1994 are expected to fall within the values of the error. These values are ±4.4% of the forecasted supply change for Golden Delicious and ±4.2% for Sturmer. Total supply curves were derived by summing the absolute supply change to the previous years simulated supply. Total derived supply curves are presented in Figures 5.9 and 5.10. Supply forecasts for Golden Delicious and Sturmer had PRMSE values of 15% and 9% respectively. The simulated models followed the decline with reasonable accuracy. Supply change models were then applied to Granny Smith and Red Delicious.

Figure 5.7. Golden Delicious supply change - actual and simulated.

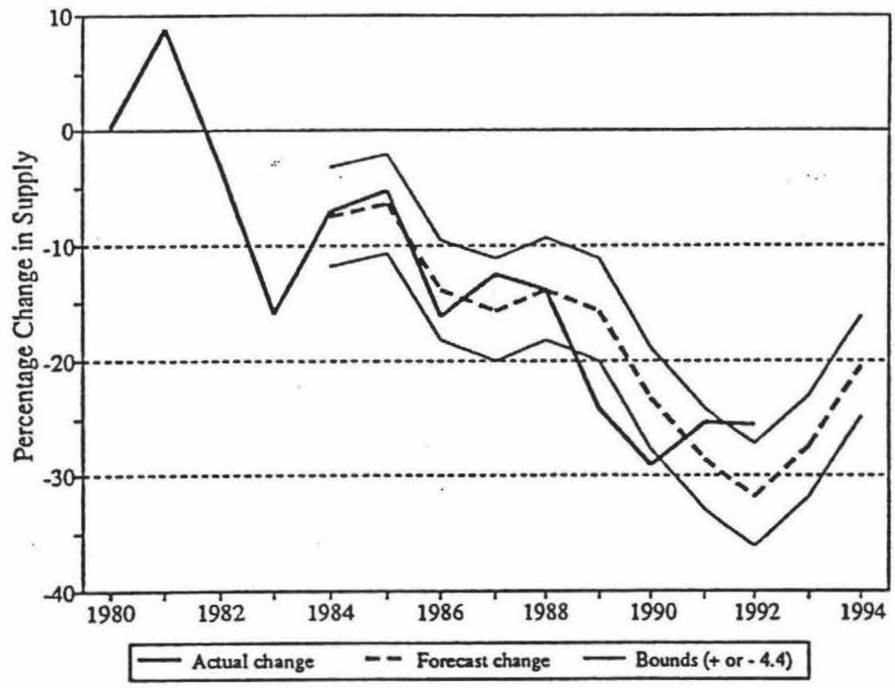


Figure 5.8. Sturmer supply change - actual and simulated.

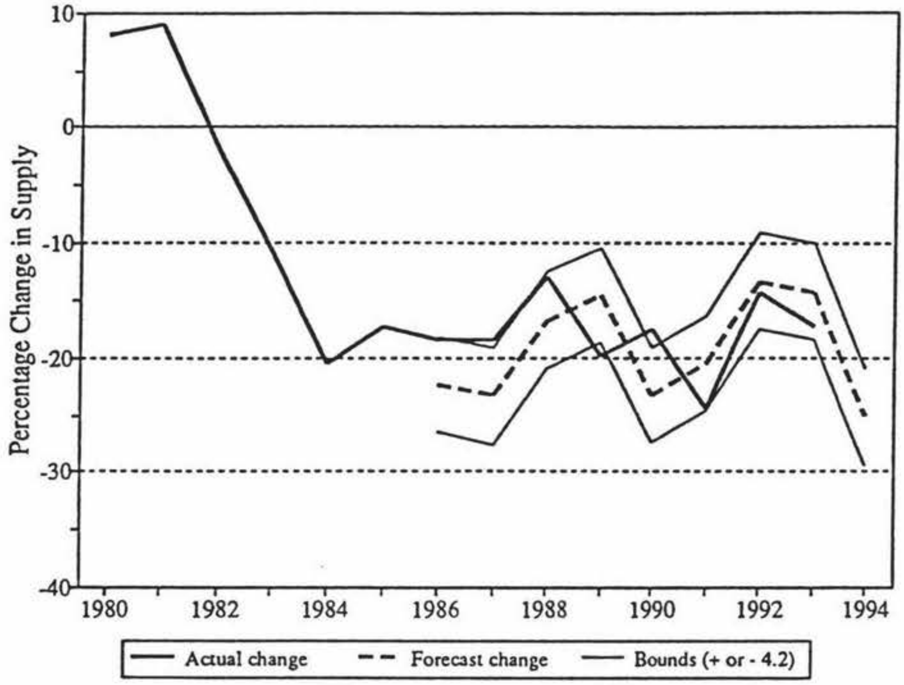


Figure 5.9. Total Golden Delicious supply - actual and simulated.

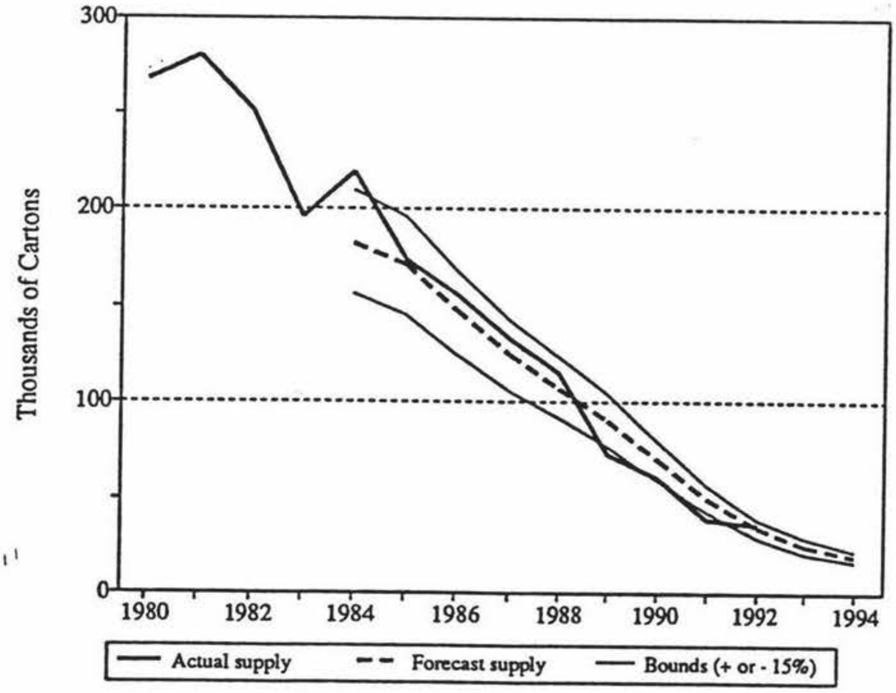
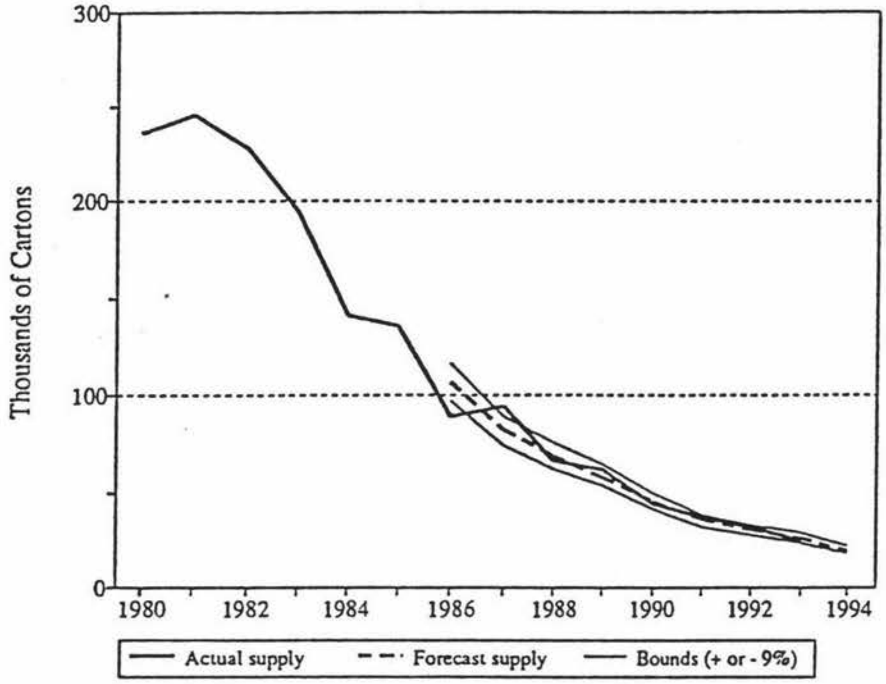


Figure 5.10. Total Sturmer supply - actual and simulated.



5.3.3. Application of Derived Supply Contraction Models to Other Varieties

Red Delicious is harvested at a similar time to Golden Delicious when the demand for labour by preferred varieties is relatively low. Similarly, the only preferred variety competing for harvest labour over the Granny Smith season is Fuji. However, Fuji is harvested over a much shorter period than Granny Smith. The supply contraction of Sturmer, where Braeburn competes directly for harvest labour was not appropriate for modelling Granny Smith and Red Delicious. Instead supply decline for both Granny Smith and Red Delicious were simulated using the Golden Delicious supply contraction model. Golden Delicious was expected to provide a preferable model than Sturmer because, it did not have competition for harvest labour. The results of these simulations are shown in Tables 5.6 and 5.7.

Table 5.6. Prediction of Granny Smith supply change and comparison with actual supply, 1987-1993.

Year	Supply	P_{RAL1}	Actual $\%\Delta S_{2,Granny\ S.}$	Simulated $\%\Delta S_{2,Granny\ S.}$	Lower Bound	Upper Bound
	3305.8	-	-	-	-	-
1988	3383.5	-	-	-	-	-
	3419.6	0.785	0.0	-3.2	-7.6	1.2
1990	3265.9	0.675	0.0	-12.1	-16.5	-7.7
	2913.7	0.590	-7.6	-19.0	-23.4	-14.6
1992	2075.3	0.530	-19.3	-23.9	-28.3	-19.5
	•2130.0	0.555	•-15.7	-21.9	-26.3	-17.5
1994	-	0.510	-	-25.5	-29.9	-21.1

Table 5.7. Prediction of Sturmer supply change and comparison with actual supply, 1987-1993.

Year	Supply	P_{RAL1}	Actual $\%\Delta S_{2,R.Delicious}$	Simulated $\%\Delta S_{2,R.Delicious}$	Lower Bound	Upper Bound
	2341.6	-	-	-	-	-
1988	2607.5	-	-	-	-	-
	2269.7	0.657	0.0	-13.6	-18.0	-9.2
1990	2541.7	0.577	0.0	-20.1	-24.5	-15.7
	1907.6	0.524	-7.5	-24.4	-28.8	-20.0
1992	1818.8	0.475	-16.2	-28.4	-32.8	-24.0
	•1749.0	0.483	•-4.3	-27.7	-32.1	-23.3
1994	-	0.469	-	-28.9	-33.3	-24.5

The simulations showed that the model over-estimated the supply contraction for Granny Smith and Red Delicious. The probable cause for over-estimation is that the price series used was derived from export prices. Between 30-40% of the Golden Delicious crop has been exported over the period of decline. The price series, therefore, grossly over-estimated the value of the variety. Granny Smith and Red Delicious exports represented between 45-55% and 60-70% of total supply of these varieties respectively. The value of these varieties was, therefore, much greater.

A single supply contraction model could not be derived based on the price variable available for this study. A reliable price variable, which incorporates export packouts, is required to give a true representation of the value of a variety. With such a variable a more robust model would undoubtedly be derived.

CHAPTER 6. SUMMARY AND CONCLUSIONS

6.1. Model development

Econometric modelling was used to examine and measure the affect of price movements on apple submissions from Hawkes Bay orchardists to the NZAPMB. Profit maximising orchardists were expected to change their orchard mix in response to varietal price changes. Orchardists responses to changing profits were explained by a derived price variable.

Tree population dynamics and the apple production function result in a certain level of aggregate supply. Therefore, modifications to the tree population causes aggregate supply change. Accurate and comprehensive tree population statistics and production functions could be used to explain aggregate supply descriptively. However, the use of descriptive models such as that suggested by French and Matthews (1971) is currently restricted by data limitations.

Alternative models were specified to estimate changes in the supply of apple varieties with limited data. The models were unique to either supply expansion or supply contraction. Assumptions for the derivation of the expansion model were that no trees were removed and that plantings were not restricted by land constraints. These assumptions hold true for Braeburn and Royal Gala in Hawkes Bay. For supply contraction models it was assumed that all trees were mature, this was the case for Golden Delicious and Sturmer. Red Delicious and Granny Smith plantings made within the past five years are still reaching maturity. The presence of immature plantings reaching maturity 'masks' contractions in supply from removals.

The null hypothesis that price fluctuations between varieties do not cause changes within the portfolio of apples supplied to the NZAPMB was tested. Prices received by orchardists were shown to cause significant changes to apple supply. Orchardists expanded supply in response to increasing Braeburn and Royal Gala prices, and contracted supply in response to decreasing Golden Delicious and Sturmer prices relative to other varieties. The models were not always sufficiently robust to apply to other varieties.

6.2. Model applications

Models were derived to explain the supply expansion of Braeburn and Royal Gala. The models used lagged nominal price as an explanatory variable. Comparisons between the models showed that they were not statistically different from each other. A combined model was used for forecasting supply of Braeburn and Royal Gala. The statistical 'closeness' of the varietal supply change was expected given that Braeburn and Royal Gala both had export packouts of approximately 65%, produce high yields and are easy to grow. Braeburn and Royal Gala forecasted supply based on lagged prices, is shown in Table 6.1.

Table 6.1. Actual and forecasted Braeburn and Royal Gala submissions from Hawkes Bay orchards, 1990-1998.

Year	Braeburn Supply Actual	Braeburn Supply Forecast	Royal Gala Supply Actual	Royal Gala Supply Forecast
1990	1179.5	1087.9	1230.0	1082.4
	1663.3	1425.9	1688.7	1418.5
1992	2080.5	1788.5	1888.4	1764.5
	*2370.0	2184.6	*2305.0	2138.2
1994	-	2639.6	-	2566.5
	-	3173.8	-	3057.6
1996	-	3814.0	-	3617.6
	-	4641.4	-	4270.4
1998	-	5589.5	-	5004.6

The combined supply expansion model was applied to Fuji. It appeared that the model did not perform well. However, this could not be conclusively and statistically proven, nor could a comparative varietal model be developed because of the extremely limited data availability. The short time frame over which Fuji has been grown further restricts the data set. It is unlikely that the same combined model, using the derived price variable, would be appropriate for Fuji given its characteristically low packouts.

Supply contraction models were derived for Golden Delicious and Sturmer. These models were shown to be significantly different from each other. Therefore, a single supply contraction model explaining both Golden Delicious and Sturmer supply decline could not be derived. This appears to be due to the timing of harvest of these varieties compared with the harvest periods of competing preferred varieties. Harvesting of Sturmer coincides with Braeburn, while Golden Delicious harvests occur in a 'window' between preferred varieties. The supply contraction model for Golden Delicious was applied to forecast supply contraction of Granny Smith and Red Delicious. There are no preferred varieties competing for the entirety of labour during harvest. Simulations of supply contraction for Granny Smith and Red Delicious were significantly different to actual changes. Granny Smith and Red Delicious packouts and yields are markedly different from Golden Delicious and Sturmer, therefore, the derived price variable was inappropriate.

6.3. Model limitations and methodological pitfalls

Profit on pipfruit orchards is largely influenced by input costs, output price, yields and packouts. Packout changes will effect profit whenever input costs, yields and price remain the same. Given the lack of any alternative it was necessary to derive a price series from *NZAPMB Price and Terms of Supply* publications. Actual final varietal price paid to orchardists may be significantly different form the derived price. The final average price paid to growers for a variety will be higher the greater the percentage of fruit reaching export grade standards. A derived estimating model for Fuji would be significantly different from those derived for Braeburn and Royal Gala. The derivation of a single model explaining supply expansion for all varieties cannot be derived without actual aggregate price data by variety.

The derived price series ignores differing mature yields from different varieties, some apple varieties produce significantly different yields per hectare. Granny Smith is renowned for prolific yields and is relatively easy to grow. Therefore, the variety can be grown profitably and at lower output prices than the varieties used for the derivation of the supply contraction models in this study. Accurate yield profiles on a varietal basis would also be of significant benefit for the derivation of supply response models.

6.4. Recommendations and opportunities for further study

Applied research is largely an iterative process. Past research is reviewed and appropriately modified in an effort to solve a related problem. Inconclusive results, although not satisfactory to the researcher, can be examined in retrospect and new ideas developed in the following iteration. The results of this study are useful for the varieties studied but are by no means conclusive. Supply expansion and contraction models should not be variety dependent. However, the review of past models and an attempt at modelling Hawkes Bay apple supply provides a well defined and statistically sound starting point for further applied research.

This study provided an empirical measure of the impact of price on supply on selected varieties. The models presented were, however, simplified representations of real world situations and can only be used for the varieties and situations for which they were developed. The supply response problem was greatly simplified by considering only price, climate and management ease. Climate and management variables were used appropriately. Unfortunately the derived price variable remains circumspect. The accuracy of econometric models is reliant on the availability and accuracy of data.

More robust explanatory models could be derived with improved data through accurate and detailed monitoring of plantings and removals in Hawkes Bay. The NZAPMB have now surveyed orchards annually for five years. However, the accuracy of survey data available for this study appeared questionable[1]. Current and continued collection of tree population statistics presents the NZAPMB with an excellent opportunity for the future implementation of a French and Matthews (1971) framework for modelling supply response.

The apple production function dictates the speed at which orchardists can increase supply. The NZAPMB surveys orchards and nurseries to monitor new apple plantings. Supply forecasts can then be made from knowledge of the population dynamics and the use of accurate yield profiles.

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[1]It has recently been brought to the author's attention that the latest NZAPMB Hawkes Bay orchard survey has attempted to reconcile inaccuracies in the tree population statistics.

Supply contraction models appear to offer the greatest benefit to the NZAPMB. Supply decline can occur in an immediate in response to a price signal. Therefore, a model which measures supply contraction resulting from declines in the actual price paid to growers would be beneficial. The impact of changes in factors which determine actual price such as grade standards, export price, and local price could then be investigated. For example, if the NZAPMB tightened Granny Smith grade standards subsequently reducing export packout, actual price paid to growers for Granny Smith will decline. Growers may respond, understandably, by removing part or all of their Granny Smith trees. Subsequently, a portion of the productive base is lost. A model which measures the point at which supply decline occurs and the rate at which it occurs would be of assistance to the NZAPMB. Its derivation is relatively straight forward without data limitations concerning actual price.

The NZAPMB offers its customers a range of products including important traditional varieties such as Granny Smith. In recent years the price paid to growers for these varieties has been declining. A minimum price level must be provided to maintain the minimum supply required of traditional varieties. Traditional varieties appear to require price support from discretionary profits or other varieties to maintain price. Price support policies have been the source of public debate and recent court action by corporate orchardists who claim, justifiably, that their income has been misappropriated. The affect on supply of the removal of price support to traditional varieties is unknown.

The NZAPMB could determine the minimum price level by surveying orchardists to learn the price level at which they will remove trees[2]; by estimating the lowest minimum price based on the costs of production[3]; or by using econometric models similar to those presented. Econometric models provide the only accurate aggregate measure of growers' likely response to declining price.

[2]Previous studies (Lockhart, 1990; Petersen, 1990) have shown that Hawkes Bay orchardists did not know the varietal gross margins on their orchards. The price at which orchardists remove trees is likely to be a highly subjective opinion which may not reflect their actual behaviour at a later date.

[3]Different orchards invariably have different cost structures. The derivation of the production costs on the 'average orchard' is difficult to verify.

APPENDICES

Appendix 1. Price Derivations

Braeburn.

Year	Market Indicator Rate by count size and count size weight												Price
	64/O	72/O	80/AA	88/AA	100/A	113/A	125/B	138/B	150/C	163/C	175/D	198/D	
	0.02	0.07	0.11	0.17	0.26	0.15	0.11	0.06	0.03	0.01	0.01	0.00	
1970													1.69
													1.77
													1.81
													2.11
													2.15
1975	1.43	1.43	2.02	2.02	2.40	2.40	2.56	2.56	2.46	2.46	2.14	2.14	2.23
	1.54	1.54	2.18	2.18	2.58	2.58	2.74	2.74	2.58	2.58	2.30	2.30	2.40
	1.87	1.87	2.53	2.53	2.99	2.99	3.18	3.18	2.93	2.93	2.62	2.62	2.79
	2.55	2.55	3.23	3.23	3.87	3.87	3.93	3.93	3.20	3.20	2.64	2.64	3.54
	2.69	2.69	3.63	3.63	4.37	4.37	4.44	4.44	3.59	3.59	2.94	2.94	3.98
1980	3.09	3.09	4.11	4.11	4.96	4.96	5.03	5.03	4.20	4.20	3.40	3.40	4.52
	4.18	4.18	5.64	5.64	6.91	6.91	7.01	7.01	5.75	5.75	4.59	4.59	6.25
	3.94	3.94	6.59	6.59	7.95	7.95	8.06	8.06	6.75	6.75	4.58	4.58	7.14
	4.05	4.05	7.05	7.05	8.28	8.28	8.46	8.46	7.21	7.21	5.82	5.82	7.51
	5.72	5.72	7.35	7.35	8.69	8.69	8.90	8.90	7.41	7.41	5.72	5.72	8.00
1985	6.32	6.32	8.36	8.36	9.38	9.38	9.38	9.38	7.34	7.34	5.30	5.30	8.69
	6.67	6.67	9.09	9.09	10.29	10.29	10.29	20.29	7.87	7.87	5.47	5.47	10.07
	7.99	7.99	10.91	10.91	12.58	12.58	12.37	12.37	9.44	9.44	6.54	6.54	11.47
	9.54	9.54	13.12	13.12	15.16	15.16	14.90	14.90	11.31	11.31	7.86	7.86	13.80
	4.02	15.04	19.18	19.18	20.10	19.18	16.70	16.70	13.38	10.89	9.23	7.57	18.05
1990	10.64	14.47	16.39	19.26	21.17	19.26	16.39	16.39	12.56	10.10	8.67	7.96	18.04
	10.63	15.36	20.09	23.63	26.00	23.63	20.09	20.09	15.36	11.81	9.46	9.46	21.89
	6.63	6.63	22.78	26.80	29.48	26.80	22.78	22.78	17.43	6.63	6.63	6.63	23.82
	8.00	8.00	22.04	25.94	28.54	25.94	22.64	22.04	16.86	8.00	8.00	8.00	23.24

Cox's Orange Pippin

Year	Market Indicator Rate by count size and count size weight												Price
	64/O	72/O	80/AA	88/AA	100/A	113/A	125/B	138/B	150/C	163/C	175/D	198/D	
	0.00	0.00	0.00	0.03	0.09	0.15	0.17	0.18	0.14	0.12	0.09	0.04	
1970													2.23
													2.34
													2.39
													2.78
													2.84
1975	1.72	1.72	1.77	1.77	1.97	1.97	3.03	3.03	3.58	3.58	3.44	3.44	2.94
	1.76	1.76	1.88	1.88	2.13	2.13	3.02	3.02	3.79	3.79	3.64	3.64	3.06
	1.95	1.95	2.06	2.06	2.32	2.32	3.21	3.21	4.01	4.01	3.59	3.59	3.23
	2.04	2.04	2.11	2.11	2.76	2.76	3.57	3.57	4.36	4.36	3.57	3.57	3.55
	2.29	2.29	2.36	2.36	3.46	3.46	4.30	4.30	5.06	5.06	4.27	4.27	4.25
1980	2.75	2.75	2.82	2.82	4.09	4.09	4.55	4.55	5.30	5.30	4.38	4.38	4.57
	3.86	3.86	4.47	4.47	5.52	5.52	6.19	6.19	7.30	7.30	5.99	5.99	6.25
	3.82	3.82	5.15	5.15	6.25	6.25	6.94	6.94	8.08	8.08	6.74	6.74	7.00
	3.99	3.99	5.90	5.90	7.37	7.37	8.77	8.77	9.17	9.17	7.30	7.30	8.28
	3.64	3.64	6.12	6.12	7.62	7.62	9.47	9.47	9.42	9.44	7.42	7.42	8.67
1985	3.87	3.87	9.23	9.23	10.00	10.00	11.00	11.00	10.50	10.50	7.27	7.27	10.10
	4.07	4.07	9.52	9.52	10.32	10.32	11.35	11.35	10.84	10.84	7.48	7.48	10.42
	4.45	4.45	10.63	10.63	11.92	11.92	12.67	12.67	11.69	11.69	8.35	8.35	11.62
	4.28	4.28	10.69	10.69	11.99	11.99	12.89	12.89	11.91	11.91	8.57	8.57	11.80
				11.15	15.08	18.94	19.09	19.25	11.30	8.95	5.45	4.71	14.41
1990				8.54	15.94	21.23	21.39	19.27	12.93	7.66	5.23	2.14	15.11
				10.37	19.46	25.94	25.94	23.36	15.57	9.09	5.57	3.86	18.30
				14.07	26.37	35.15	35.15	31.63	21.10	12.30	6.63	6.63	24.76
			13.44	13.44	25.22	33.62	33.62	30.26	20.18	11.76	8.00	8.00	23.90

Gala

Year	Market Indicator Rate by count size and count size weight												Price
	64/O	72/O	80/AA	88/AA	100/A	113/A	125/B	138/B	150/C	163/C	175/D	198/D	
	0.00	0.00	0.00	0.02	0.10	0.19	0.20	0.20	0.13	0.09	0.06	0.02	
1970													2.33
													2.44
													2.49
													2.89
													2.96
1975	1.92	1.92	2.07	2.07	3.03	3.03	3.18	3.18	3.03	3.03	2.91	2.91	3.07
	2.12	2.12	2.28	2.28	3.19	3.19	3.35	3.35	3.19	3.19	3.07	3.07	3.23
	1.95	1.95	2.56	2.56	3.13	3.13	3.28	3.28	3.04	3.04	2.82	2.82	3.14
	2.15	2.15	3.11	3.11	3.71	3.71	4.07	4.07	3.30	3.30	2.50	2.50	3.67
	2.20	2.20	3.12	3.12	3.87	3.87	3.87	3.87	3.31	3.31	2.58	2.58	3.64
1980	2.52	2.52	3.91	3.91	4.69	4.69	4.69	4.69	4.11	4.11	3.31	3.31	4.45
	3.33	3.33	5.06	5.06	6.15	6.15	6.25	6.25	5.40	5.40	4.24	4.24	5.87
	3.47	3.47	5.78	5.78	6.95	6.95	9.95	9.95	6.15	6.15	4.91	4.91	7.81
	3.46	3.46	6.06	6.06	7.55	7.55	7.35	7.35	6.15	6.15	4.79	4.79	6.94
	3.25	3.25	6.43	6.43	8.01	8.01	7.77	7.77	6.40	6.40	4.84	4.84	7.30
1985	3.37	3.37	9.44	9.44	10.34	10.34	9.47	9.47	7.06	7.06	5.25	5.25	8.88
	3.61	3.61	10.38	10.38	11.07	11.07	10.14	10.14	7.54	7.54	5.59	5.59	9.51
	4.25	4.25	12.46	13.46	13.27	13.28	12.17	12.17	9.10	9.10	6.80	6.80	11.45
	4.12	4.12	12.88	12.88	13.71	13.71	12.84	12.84	9.61	9.61	7.32	7.32	11.98
	4.39	4.39	18.25	18.25	10.03	18.03	14.03	14.03	10.01	9.00	4.97	4.39	12.81
1990			19.90	19.90	19.90	19.90	14.61	14.61	9.77	8.44	5.10		14.23
			17.43	17.43	17.43	17.43	12.60	12.60	8.01	6.87	5.57		12.33
		24.88	24.88	24.88	24.88	24.88	18.25	18.25	11.62	9.95	6.63	6.63	17.80
			23.72	23.72	23.72	23.72	18.18	16.60	11.06	9.48	8.00	8.00	17.10

Golden Delicious

Year	Market Indicator Rate by count size and count size weight												Price
	64/O	72/O	80/AA	88/AA	100/A	113/A	125/B	138/B	150/C	163/C	175/D	198/D	
	0.00	0.00	0.01	0.05	0.15	0.19	0.20	0.18	0.14	0.07	0.01	0.00	
1970													1.92
													2.01
													2.05
													2.39
													2.44
1975	1.17	1.17	1.71	1.71	2.27	2.27	2.66	2.66	2.57	2.57	1.98	1.98	2.44
	1.33	1.33	1.86	1.86	2.34	2.34	2.69	2.69	2.64	2.64	2.09	2.09	2.50
	1.55	1.55	2.17	2.17	2.92	2.92	3.03	3.03	2.76	2.76	2.40	2.40	2.88
	2.09	2.09	2.86	2.86	3.08	3.08	3.02	3.02	2.66	2.66	2.14	2.14	2.94
	2.20	2.20	2.99	2.99	3.23	3.23	3.17	3.17	2.80	2.80	2.30	2.30	3.09
1980	2.37	2.37	3.50	3.50	3.75	3.75	3.69	3.69	3.30	3.30	2.49	2.49	3.60
	3.34	3.34	4.74	4.74	5.09	5.09	5.00	5.00	4.43	4.43	3.48	3.48	4.88
	4.02	4.02	4.99	4.99	5.38	5.38	5.28	5.28	4.67	4.67	4.18	4.18	5.16
	3.55	3.55	5.52	5.52	6.23	6.23	5.83	5.83	4.93	4.93	4.26	4.26	5.74
	3.24	3.24	5.33	5.33	5.94	5.94	5.54	5.54	4.63	4.63	3.62	3.62	5.45
1985	3.41	3.14	6.03	6.03	6.45	6.45	6.03	6.03	4.67	4.67	3.75	3.75	5.86
	3.72	3.72	6.59	6.59	7.06	7.06	6.59	6.59	5.10	5.10	4.70	4.70	6.41
	4.11	4.11	7.62	7.62	8.12	8.12	7.62	7.62	5.78	5.78	5.17	5.17	7.37
	4.01	4.01	7.97	7.97	8.48	8.48	7.97	7.97	5.89	5.89	5.48	5.48	7.68
	4.17	4.17	4.17	7.90	9.31	9.31	7.00	5.68	5.56	4.63	4.17	4.17	7.17
1990			6.84	8.16	9.47	9.47	6.54	6.54	6.54	6.54			7.54
			7.31	8.77	11.70	11.70	5.86	5.57	5.57				7.43
			12.68	15.22	19.02	19.02	12.68	7.62	7.62	6.63	6.63		12.86
		8.00	12.26	14.72	18.4	18.4	12.26	8.00	8.00	8.00	8.00		12.77

Granny Smith

Year	Market Indicator Rate by count size and count size weight												Price
	64/O	72/O	80/AA	88/AA	100/A	113/A	125/B	138/B	150/C	163/C	175/D	198/D	
	0.01	0.03	0.06	0.13	0.24	0.18	0.14	0.09	0.06	0.03	0.02	0.00	
1970													2.03
													2.13
													2.17
													2.53
													2.58
1975	1.84	1.84	2.21	2.21	2.94	2.94	2.82	2.82	2.77	2.77	2.19	2.19	2.68
	1.98	1.98	2.48	2.48	3.21	3.21	3.17	3.17	3.12	3.12	2.47	2.47	2.97
	2.30	2.30	2.90	2.90	3.44	3.44	3.35	3.35	3.05	3.05	2.58	2.58	3.20
	2.70	2.70	3.40	3.40	3.80	3.80	3.63	3.63	3.31	3.31	2.59	2.59	3.55
	2.90	2.90	3.59	3.59	4.01	4.01	3.83	3.83	3.49	3.49	2.74	2.74	3.75
1980	3.27	3.27	4.02	4.02	4.46	4.46	4.27	4.27	3.90	3.90	3.31	3.31	4.18
	4.12	4.12	5.17	5.17	5.78	5.78	5.51	5.51	4.99	4.99	4.22	4.22	5.40
	4.29	4.29	5.67	5.67	6.43	6.43	6.14	6.14	5.58	5.58	4.33	4.33	5.97
	4.46	4.46	6.84	6.84	7.69	7.96	7.30	7.30	6.56	6.56	4.96	4.96	7.15
	4.52	4.52	6.64	6.64	7.41	7.41	7.00	7.00	6.21	6.21	4.51	4.51	6.84
1985	5.78	5.78	7.30	7.30	7.80	7.80	7.30	7.30	6.29	6.29	4.78	4.78	7.27
	7.01	7.01	8.18	8.18	8.57	8.57	7.96	7.96	6.75	6.75	5.14	5.14	8.01
	8.26	8.26	9.70	9.70	10.00	10.00	9.29	9.29	7.58	7.58	5.94	5.94	9.36
	8.24	8.24	9.61	9.61	9.90	9.90	9.22	9.22	7.60	7.60	6.04	6.04	9.28
	8.25	9.32	10.65	10.65	10.65	9.59	8.52	7.45	5.69	5.19	4.62	4.62	9.18
1990	6.54	8.00	10.90	10.90	10.90	9.46	8.00	6.54	5.64	5.64	5.64	2.14	9.06
	6.54	8.00	10.90	10.90	10.90	9.46	8.00	6.54	5.64	3.85	3.85	3.85	8.99
	6.63	12.73	17.83	17.83	17.83	15.28	12.73	10.18	6.63	6.63	6.63	6.63	14.39
	8.00	8.00	10.08	10.08	10.08	8.64	8.00	8.00	8.00	8.00	8.00	8.00	8.96

Red Delicious

Year	Market Indicator Rate by count size and count size weight												Price
	64/O	72/O	80/AA	88/AA	100/A	113/A	125/B	138/B	150/C	163/C	175/D	198/D	
	0.01	0.04	0.06	0.11	0.21	0.17	0.13	0.09	0.07	0.05	0.04	0.02	
1970													2.04
													2.13
													2.18
													2.53
													2.59
1975	1.82	1.82	2.41	2.41	2.76	2.76	2.98	2.98	2.76	2.76	2.32	2.32	2.69
	1.93	2.38	2.38	2.89	2.89	3.11	3.11	2.90	2.90	2.45	2.45	2.10	2.85
	2.47	2.63	2.63	3.12	3.12	3.34	3.34	3.13	3.13	2.69	2.69	2.56	3.10
	3.31	3.28	3.28	3.55	3.55	3.70	3.70	3.40	3.40	3.05	3.05	3.06	3.51
	3.31	3.22	3.22	3.47	3.47	3.59	3.59	3.35	3.35	3.06	3.06	2.70	3.43
1980	3.26	3.26	3.62	3.62	3.90	3.90	4.03	4.03	3.76	3.76	3.43	3.43	3.83
	4.37	4.37	4.75	4.75	5.12	5.12	5.31	5.31	4.92	4.92	4.50	4.50	5.03
	3.87	5.09	5.09	5.48	5.48	5.67	5.67	5.27	5.27	4.84	4.84	1.34	5.33
	4.12	4.12	5.92	5.92	6.49	6.49	6.67	6.67	6.14	6.14	5.28	5.28	6.23
	3.97	3.97	6.09	6.09	6.71	6.71	6.68	6.68	6.20	6.20	5.14	5.14	6.33
1985	4.16	4.16	6.10	6.10	6.83	6.83	6.59	6.59	6.10	6.10	5.13	5.13	6.36
	4.50	4.50	6.51	6.51	7.29	7.29	7.04	7.04	6.51	6.51	5.51	5.51	6.79
	5.25	5.25	7.53	7.53	8.44	8.44	8.15	8.15	7.53	7.53	6.40	6.40	7.86
	5.24	5.24	7.38	7.38	8.23	8.23	7.95	7.95	7.38	7.38	6.31	6.31	7.69
	5.41	6.37	7.32	8.28	8.75	8.75	8.75	8.28	7.32	6.37	6.37	6.37	8.12
1990	5.61	5.61	6.30	6.99	9.06	9.06	9.06	8.37	7.69	6.99	6.99	6.30	8.12
	6.51	6.51	6.93	7.61	9.00	9.00	9.00	8.31	7.61	6.23	6.23	3.86	8.12
	7.58	7.85	9.73	10.82	14.07	14.07	14.07	12.98	11.90	6.63	6.63	6.63	12.12
	8.00	8.00	8.00	9.22	11.74	10.90	10.90	10.06	9.22	8.00	8.00	8.00	10.10

Royal Gala

Year	Market Indicator Rate by count size and count size weight												Price
	64/O	72/O	80/AA	88/AA	100/A	113/A	125/B	138/B	150/C	163/C	175/D	198/D	
	0.00	0.00	0.00	0.03	0.13	0.20	0.20	0.18	0.11	0.08	0.05	0.02	
1970													2.33
													2.44
													2.49
													2.89
													2.96
1975													3.07
													3.23
													3.14
													3.67
													3.64
1980	2.72	2.72	4.11	4.11	4.89	4.89	4.89	4.89	4.31	4.31	2.88	2.88	4.62
	3.61	3.61	5.35	5.35	6.44	6.44	6.44	6.44	5.62	5.62	4.53	4.53	6.12
	3.47	3.47	6.36	6.36	7.52	7.52	7.52	7.52	6.65	6.65	5.50	5.50	7.18
	3.46	3.46	6.57	6.57	7.92	7.92	7.74	7.74	6.67	6.67	5.45	5.45	7.40
	3.14	3.14	6.62	6.62	8.20	8.20	7.96	7.96	6.59	6.59	5.03	5.03	7.53
1985	3.26	3.26	8.34	8.34	9.46	9.46	8.90	8.90	6.66	6.66	4.97	4.97	8.37
	3.56	3.56	9.89	9.89	10.72	10.72	10.02	10.02	7.42	7.42	5.58	5.58	9.45
	3.96	3.96	10.98	10.98	11.99	11.99	11.22	11.22	8.34	8.34	6.30	6.30	10.58
	3.85	3.85	12.61	12.61	13.44	13.44	12.57	12.57	9.34	9.34	7.05	7.09	11.87
	4.02	4.02	18.46	18.46	18.19	18.19	13.68	13.68	9.65	8.64	4.60	4.02	13.84
1990			20.01	20.01	20.01	20.01	14.23	14.23	9.86	8.57	5.10		14.67
			21.76	21.76	21.76	21.76	15.81	15.81	10.53	9.13	5.57	5.57	16.15
		29.25	29.25	29.25	29.25	29.25	20.75	20.75	13.22	11.32	6.63	6.63	21.28
		27.66	27.66	27.66	27.66	27.66	20.52	18.74	12.50	10.70	8.00	8.00	20.26
		27.66	27.66	27.66	27.66	27.66	20.52	18.74	12.50	10.70	8.00	8.00	20.26

Sturmer

Year	Market Indicator Rate by count size and count size weight												Price
	64/O	72/O	80/AA	88/AA	100/A	113/A	125/B	138/B	150/C	163/C	175/D	198/D	
	0.00	0.00	0.03	0.12	0.20	0.22	0.17	0.12	0.08	0.04	0.03	0.00	
1970													1.31
													1.37
													1.41
													1.63
													1.67
1975	1.12	1.12	1.14	1.14	1.64	1.64	1.99	1.99	2.14	2.14	1.85	1.85	1.73
	1.26	1.26	1.34	1.34	1.76	1.76	2.12	2.12	2.27	2.27	1.95	1.95	1.87
	1.57	1.57	1.65	1.65	2.15	2.15	2.49	2.49	2.44	2.44	1.94	1.94	2.20
	2.02	2.02	2.12	2.12	2.42	2.42	2.71	2.71	2.64	2.64	2.04	2.04	2.47
	2.30	2.30	2.43	2.43	2.88	2.88	3.25	3.25	3.16	3.16	2.39	2.39	2.94
1980	2.56	2.56	2.69	2.69	3.27	3.27	3.63	3.63	3.54	3.54	2.78	2.78	3.31
	3.37	3.37	3.57	3.57	4.26	4.26	4.80	4.80	4.67	4.67	3.58	3.58	4.34
	4.04	4.04	4.04	4.04	4.51	4.51	5.09	5.09	4.95	4.95	4.21	4.21	4.65
	4.15	4.15	4.72	4.72	5.04	5.04	5.67	5.67	5.49	5.49	4.88	4.88	5.22
	3.85	3.85	4.44	4.44	4.97	4.97	5.66	5.66	5.46	5.46	4.43	4.43	5.13
1985	4.02	4.02	4.86	4.86	5.54	5.54	6.31	6.31	3.07	6.07	4.66	4.66	5.46
	4.33	4.33	5.26	5.26	6.29	6.29	6.92	6.92	6.55	6.55	5.04	5.04	6.32
	4.76	4.76	5.62	5.62	7.28	7.28	8.02	8.02	7.06	7.06	5.37	5.37	7.17
	4.65	4.65	7.10	7.10	8.37	8.37	9.25	9.25	8.13	8.13	6.73	6.73	8.36
	4.82	4.82	4.82	8.14	9.22	9.22	9.22	8.14	7.06	5.98	4.91	4.82	8.42
1990			8.33	10.36	12.37	12.37	12.37	10.36	8.33	6.31			10.88
			8.96	11.20	13.43	13.43	13.43	11.20	8.96	6.71			11.79
			11.53	14.42	17.30	17.30	17.30	14.42	11.53	8.65	6.63		15.38
			9.48	10.52	12.64	12.64	12.64	10.52	8.42	8.00	8.00	8.00	11.42

Appendix 2. Price Indices

Year	Consumer Price Index	Horticultural Input Price Index
1971	250	251
1972	262	268
1972	289	284
1974	326	316
1975	378	353
1976	436	404
1977	504	470
1978	553	502
1979	645	562
1980	750	732
1981	867	869
1982	1000	1000
1983	1035	1008
1984	1133	1047
1985	1207	1236
1986	1544	1308
1987	1693	1370
1988	1773	1445
1989	1901	1495
1990	1993	1610
1991	2012	1596

Appendix 3. Area Data

Braeburn

Year	Area of trees (ha) in age class.										Bearing Status.		
	1	2	3	4	5	6	7	8	9+	Total	Non-bearing	Semi-bearing	Full-Bearing
1988	94.2	81.4	59.2	81.2	84.7	55.9	28.8	25.3	17.3	528.6	316.2	194.0	17.3
1989	66.6	107.1	90.7	73.2	83.8	86.6	56.1	29.0	41.5	634.6	337.6	255.5	41.5
1990	100.8	98.3	117.6	88.2	80.2	85.1	88.3	59.1	72.3	789.8	404.9	312.6	72.2
1991	112.3	115.7	126.1	118.8	104.5	81.5	76.6	82.8	129.8	183.4	472.8	345.3	129.8

Cox's Orange Pippin

Year	Area of trees (ha) in age class.										Bearing Status.		
	1	2	3	4	5	6	7	8	9+	Total	Non-bearing	Semi-bearing	Full-Bearing
1988	1.0	3.4	6.6	26.4	29.3	27.8	25.7	22.4	79.6	205.9	37.4	88.9	79.6
1989	0.4	0.9	3.4	5.4	24.8	26.3	30.1	25.6	80.7	197.6	10.1	106.8	80.7
1990	0.6	0.4	0.9	4.1	4.9	22.6	25.4	30.5	102.3	191.6	5.1	84.2	102.3
1991	0.7	0.6	0.9	1.5	3.0	5.1	22.2	23.3	126.2	183.4	3.7	53.5	126.2

Fuji

Year	Area of trees (ha) in age class.										Bearing Status.		
	1	2	3	4	5	6	7	8	9+	Total	Non-bearing	Semi-bearing	Full-Bearing
1988	108.7	42.6	14.9	9.0	2.6	0.8	0.2	0.2	0	178.9	175.2	3.7	0
1989	56.1	119.5	45.9	18.4	10.6	1.3	0.8	0.2	0.2	253.0	239.9	12.9	0.2
1990	53.8	65.6	129.8	48.5	19.4	10.4	1.2	1.4	0.5	330.6	381.8	32.4	0.5
1991	47.0	65.7	90.7	130.5	53.3	19.4	10.47	1.3	1.8	420.2	334.0	84.4	1.8

Royal Gala

Year	Area of trees (ha) in age class.										Bearing Status.		
	1	2	3	4	5	6	7	8	9+	Total	Non-bearing	Semi-bearing	Full-Bearing
1988	143.0	80.0	52.64	50.7	63.9	42.5	28.5	16.2	17.0	494.4	326.4	151.0	17.0
1989	65.3	162.9	90.1	59.6	54.6	62.2	47.5	28.6	34.7	605.5	377.8	192.9	34.7
1990	93.4	88.7	174.6	91.3	62.7	54.9	61.8	52.3	65.0	744.6	447.9	231.6	65.0
1991	65.7	108.6	117.0	173.7	91.5	62.4	54.7	57.0	115.0	183.4	465.0	174.2	115.0

Golden Delicious

Year	Area of trees (ha) in age class.										Bearing Status.		
	1	2	3	4	5	6	7	8	9+	Total	Non-bearing	Semi-bearing	Full-Bearing
1988	0	0	0	0	0.6	0	0	0	29.5	30.2	0	0.5	29.5
1989	0	0	0	0	0	0	0	0	23.3	23.3	0	0	23.3
1990	0	0	0	0	0	0	0	0	16.8	16.8	0	0	16.8
1991	0	0	0	0	0	0	0	0	12.3	12.3	0	0	12.3

Granny Smith

Year	Area of trees (ha) in age class.										Bearing Status.		
	1	2	3	4	5	6	7	8	9+	Total	Non-bearing	Semi-bearing	Full-Bearing
1988	116.2	41.3	15.8	23.2	42.5	35.6	45.9	36.3	615.9	972.7	196.5	160.3	615.9
1989	13.2	105.9	38.7	16.6	22.9	46.9	38.7	46.6	630.3	969.9	174.4	155.2	630.3
1990	2.6	13.9	88.9	28.4	16.3	23.1	48.2	48.3	662.9	932.6	133.8	135.9	662.9
1991	0.5	2.8	13.6	70.2	23.2	15.3	20.8	38.3	668.5	853.1	87.1	97.6	668.5

Red Delicious Strains

Year	Area of trees (ha) in age class.										Bearing Status.		
	1	2	3	4	5	6	7	8	9+	Total	Non-bearing	Semi-bearing	Full-Bearing
1988	94.4	52.8	47.2	69.7	88.2	56.5	82.3	53.7	461.6	1006.4	264.1	280.7	461.6
1989	14.7	98.2	55.2	56.2	68.2	84.4	69.0	81.1	482.5	1009.5	224.3	302.8	482.5
1990	8.3	16.5	92.6	52.1	56.1	70.1	81.3	77.6	536.6	991.1	169.4	285.2	536.6
1991	0.9	8.9	19.7	76.8	49.7	50.6	59.8	64.5	477.6	808.4	106.2	224.6	477.6

Sturmer

Year	Area of trees (ha) in age class.										Bearing Status.		
	1	2	3	4	5	6	7	8	9+	Total	Non-bearing	Semi-bearing	Full-Bearing
1988	0	0	0	0	0	0	0.2	0.1	26.6	26.8	0	0.3	26.6
1989	0	0	0	0	0	0	0	0.2	27.2	27.4	0	0.2	27.2
1990	0	0	0	0	0	0	0	0	23.3	23.3	0	0	23.3
1991	0	0	0	0	0	1.3	0.1	0	18.5	19.8	0	1.4	18.45

Appendix 4. Area of new apple plantings in Hawkes Bay

Braeburn

	Year															
Data Year	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
1988	1.3	1.3	3.0	4.6	5.5	25.3	28.8	55.9	84.7	81.2	59.2	81.5	97.3			
1989	0.7	1.3	3.5	4.6	5.7	24.2	29.0	56.1	86.6	83.8	73.2	90.7	107.1	66.7		
1990	0.9	1.5	3.5	4.8	5.2	25.7	29.1	59.1	88.3	85.3	80.2	88.2	117.6	98.3	108.8	
1991		0.8	3.3	4.6	5.1	27.5	28.1	58.2	82.8	79.6	81.5	104.5	118.7	126.1	115.7	112.3
Average	1.0	1.2	3.3	4.7	5.4	25.7	28.9	57.3	85.6	81.7	73.5	91.2	110.2	97.0	112.3	112.3

Cox's Orange Pippin

	Year															
Data Year	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
1988	1.1	2.4	7.3	11.5	17.8	22.4	25.7	27.8	29.3	26.4	6.6	3.4	1.0			
1989	1.1	2.5	7.8	10.2	15.3	19.9	25.6	30.1	26.3	24.8	5.4	3.4	0.9	0.4		
1990	1.4	2.8	7.8	9.2	15.0	18.2	25.4	30.5	25.4	22.6	4.9	4.1	0.9	0.4	0.6	
1991		2.7	7.6	8.6	14.7	16.4	25.2	29.2	23.3	22.2	5.1	3.0	1.5	0.9	0.6	0.7
Average	1.2	2.6	7.6	9.9	15.7	19.2	25.5	29.4	26.1	24.0	5.5	3.5	1.1	0.6	0.6	0.7

Fuji

Data Year	1975	1976	1977	1978	1979	1980	1981	Year 1982	1983	1984	1985	1986	1987	1988	1989	1990
1988						0.2	0.2	0.8	2.6	9.0	14.9	42.6	108.7			
1989						0.2	0.2	0.8	1.3	10.6	18.4	45.9	119.5	56.1		
1990						0.2	0.3	1.4	1.2	10.4	19.4	48.5	129.8	65.6	53.7	
1991						0.2	0.3	1.4	1.3	10.5	19.4	53.3	130.5	90.7	65.7	47.0
Average						0.2	0.3	1.1	1.6	10.1	18.0	47.6	122.1	70.8	59.7	47.0

Royal Gala

Data Year	1975	1976	1977	1978	1979	1980	1981	Year 1982	1983	1984	1985	1986	1987	1988	1989	1990
1988	0.8	2.7	2.4	3.6	5.8	16.2	28.5	42.5	63.9	50.7	52.6	80.0	143.0			
1989	0.9	2.9	3.0	3.9	5.8	16.3	28.6	47.5	62.2	54.6	59.6	90.1	162.9	65.3		
1990	1.0	2.9	3.1	4.2	5.9	16.2	29.7	52.3	61.8	58.7	62.7	91.3	174.6	88.7	93.4	
1991		2.5	3.3	4.2	6.2	16.0	28.9	50.6	57.0	54.7	62.4	91.5	173.7	117.0	108.6	65.7
Average	0.9	2.8	3.0	4.0	5.9	16.2	28.9	48.2	61.2	54.7	59.3	88.2	163.6	90.3	101.0	65.7

Appendix 4. Climate data

	Havelock North mean monthly temperatures for year of Harvest (July - June)												
Year	July	August	September	October	November	December	January	February	March	April	May	June	Average
1970	6.4	8.5	11.8	11.5	14.9	18.7	19.5	17.3	17.5	13.9	9.6	9.0	13.2
	8.2	9.3	11.9	13.6	14.5	16.6	17.9	18.6	15.3	14.0	12.0	10.0	13.5
	8.2	9.8	11.0	12.8	14.6	16.4	17.1	16.3	17.4	14.0	9.7	6.4	12.8
	8.3	7.2	11.1	13.5	16.6	15.4	18.7	18.3	16.9	14.2	11.4	8.7	13.4
	7.7	9.2	11.5	13.2	16.7	16.4	16.8	19.7	14.3	14.7	10.8	9.1	13.3
1975	9.1	8.5	12.1	13.2	14.7	17.4	18.9	19.3	17.7	14.1	12.0	7.8	13.7
	7.4	8.7	10.3	13.7	13.8	16.5	18.3	15.6	15.9	13.2	9.3	7.7	12.5
	7.7	9.7	10.5	12.2	13.2	16.7	17.3	17.1	16.2	12.9	8.9	8.3	12.6
	8.2	9.4	9.0	12.2	13.7	15.9	18.3	18.7	17.0	15.7	10.9	8.4	13.1
	8.3	8.8	10.4	11.0	14.5	16.5	19.2	17.7	18.0	13.3	10.3	8.5	13.0
1980	8.4	8.9	11.3	13.2	15.2	17.6	18.9	18.6	15.6	12.8	11.0	7.9	13.3
	7.4	8.3	11.4	13.0	14.0	16.1	19.0	18.2	18.3	14.6	10.3	10.3	13.4
	8.9	8.4	10.8	12.8	14.2	18.7	18.5	18.0	16.2	12.6	10.3	7.8	13.1
	7.2	8.1	10.1	10.9	17.0	16.1	16.7	16.7	16.9	14.0	10.6	8.5	12.7
	7.2	8.5	11.0	13.7	14.4	15.8	15.7	16.3	16.9	13.4	10.1	8.9	12.7
1985	9.0	10.2	10.9	12.5	16.3	19.0	19.6	17.6	16.1	12.9	10.8	10.2	13.8
	9.2	8.6	11.2	11.2	13.9	18.3	20.2	18.8	16.1	13.8	10.5	7.8	13.3
	7.0	8.4	10.5	14.3	14.8	17.1	19.3	17.4	15.7	14.0	10.5	8.1	13.1
	8.1	10.2	11.0	13.5	15.1	17.8	18.1	19.5	16.4	12.7	11.3	9.9	13.6
	9.1	9.1	11.8	14.8	16.1	17.8	19.0	18.2	17.1	13.3	11.9	9.4	14.0
1990	6.7	9.3	11.8	14.5	16.0	16.0	18.9	19.7	17.9	14.7	10.7	8.7	13.7
	8.1	10.1	9.9	13.8	15.5	18.3	19.4	18.9	16.5	12.7	10.5	8.5	13.5
	7.6	9.8	9.6	12.6	12.9	16.5	18.1	18.9	14.5	11.1	8.8	8.3	12.4
Average	7.9	8.9	10.7	13.0	14.7	16.7	18.2	17.9	16.4	13.4	10.4	8.4	13.0

Year	July	August	September	October	November	December	January	February	March	April	May	June	Total
				Napier bright snshine hours for year of harvest (July - June)									
1970	166	174	188	265	221	202	263	161	193	207	154	108	2302
	170	111	150	192	217	216	159	161	195	154	93	121	1939
	126	121	183	205	252	209	229	201	188	201	198	144	2257
	147	191	239	265	197	236	270	240	170	121	172	132	2380
	116	116	158	192	198	254	229	172	181	95	172	127	2010
1975	135	138	134	214	239	246	227	209	177	156	108	135	2118
	184	148	178	175	211	239	179	191	193	137	189	126	2150
	179	132	164	187	180	198	259	220	187	177	151	98	2132
	132	125	142	210	250	219	272	211	256	150	115	87	2169
	137	193	142	192	265	252	292	159	140	146	141	104	2163
1980	125	156	135	197	232	248	223	197	156	160	142	94	2065
	138	167	204	233	249	152	232	168	180	211	135	64	2133
	130	119	185	196	196	209	288	177	165	125	188	83	2061
	149	195	123	197	211	237	288	215	241	138	156	139	2289
	106	138	182	114	156	207	246	185	145	179	154	154	1966
1985	138	132	139	253	219	216	272	236	179	139	123	102	2148
	125	160	203	205	205	225	218	170	212	237	147	144	2251
	156	131	166	186	210	220	267	231	190	163	168	161	2249
	143	183	209	215	173	265	273	183	195	157	172	140	2308
	140	195	177	256	205	237	197	202	221	202	118	114	2264
1990	134	146	132	178	215	225	219	234		187	212	135	2017
	128	141		180		306	277	241	196	187	168		1824
				202	199	226	227	201	250	169	116	140	1730
Average	137	149	168	199	218	226	243	203	196	169	151	121	2157

Havelock North mean maximum monthly temperatures for year of harvest (July - June)													
Year	July	August	September	October	November	December	January	February	March	April	May	June	Average
1790	12.4	14.8	17.6	18.3	20.5	23.6	25.8	23.1	23.1	20.9	15.2	14.3	19.1
	15.1	14.1	17.4	19.8	20.5	23.0	22.4	23.6	21.3	19.4	16.6	16.1	19.1
	13.2	15.3	16.8	19.0	20.1	21.5	23.2	22.1	22.9	20.5	16.7	12.4	18.6
	14.2	13.6	18.3	20.3	22.6	21.4	24.8	24.4	22.5	19.5	18.4	15.0	19.6
	12.6	14.1	17.3	19.4	22.5	21.8	23.0	24.7	19.6	18.9	17.1	13.7	18.7
1975	14.4	13.5	16.6	18.7	20.4	23.0	24.0	25.3	23.3	20.8	17.6	13.3	19.2
	13.8	14.8	16.4	18.6	19.6	23.5	22.8	21.1	21.3	18.6	16.5	13.8	18.4
	14.1	14.5	14.8	17.3	17.9	21.9	23.4	23.0	22.5	19.0	14.7	13.6	18.1
	13.2	13.9	13.9	17.7	20.0	21.5	24.1	24.1	23.8	20.5	15.7	12.7	18.4
	13.9	14.8	15.7	17.0	20.9	22.5	26.1	23.4	22.0	19.0	16.1	14.5	18.8
1980	13.8	14.0	16.8	18.3	21.1	23.6	24.5	23.8	20.7	18.6	16.7	13.2	18.8
	13.1	14.6	17.9	19.6	20.6	21.0	24.3	23.3	23.1	20.9	16.1	14.9	19.1
	13.7	12.8	16.6	18.5	19.4	23.6	25.0	24.6	21.4	17.2	17.0	12.7	18.5
	12.8	14.4	15.2	17.1	23.5	22.5	24.0	23.2	24.4	19.6	17.2	14.0	19.0
	12.7	14.6	17.3	18.1	19.4	21.5	22.5	21.5	21.8	19.7	16.4	16.0	18.5
1985	14.4	15.2	15.4	19.0	22.7	24.8	25.9	24.0	21.5	18.8	15.9	15.3	19.4
	14.9	14.4	16.9	17.6	20.3	23.9	25.7	24.8	22.3	21.9	17.5	15.2	19.6
	13.4	13.3	16.1	19.8	20.9	22.7	25.8	24.4	21.3	19.4	17.4	14.9	19.1
	13.8	16.6	17.3	19.7	19.9	23.6	24.5	24.5	21.7	18.4	17.7	15.6	19.4
	15.0	15.8	19.1	22.4	22.6	24.2	23.8	23.7	24.1	21.1	17.0	14.8	20.3
1990	12.7	13.9	16.1	19.2	21.4	22.3	24.6	26.1	23.8	21.2	18.9	14.6	19.6
	14.4	15.2	16.4	19.0	21.1	24.8	26.5	25.6	21.7	19.3	17.2	13.2	19.5
	13.7	16.2	17.3	18.5	18.5	22.3	23.9	23.5	22.1	17.2	14.4	13.6	18.4
Average	19.0	19.5	19.8	20.2	20.3	20.3	20.0	19.3	18.4	17.4	16.6	13.8	19.0

Appendix 6. Derivation of the 'preferred' varieties price

Year	Supply of preferred varieties (thousands of tce's)	Associated weight belonging to variety (proportion of total supply of preferred varieties).					Derived price for export fruit ($/tce)					Derived weighted price ($/tce)
		Braeburn	Cox's	Fuji	Gala	R.Gala	Braeburn	Cox's	Fuji	Gala	R.Gala	
1975	96.4	0.01	0.66	0.00	0.33	0.00	2.23	2.94		3.07		2.98
	130.9	0.01	0.56	0.00	0.43	0.00	2.40	3.06		3.23		3.13
	108.6	0.01	0.45	0.00	0.54	0.00	2.79	3.23		3.14		3.18
	191.3	0.00	0.43	0.00	0.56	0.00	8.54	3.55		3.67		3.64
	229.1	0.01	0.28	0.00	0.71	0.00	3.98	4.25		3.64		3.82
1980	323.6	0.01	0.30	0.00	0.69	0.00	4.52	4.57		4.45	4.62	4.49
	452.7	0.01	0.22	0.00	0.77	0.00	6.25	6.25		5.87	6.12	5.96
	447.4	0.03	0.23	0.00	0.74	0.00	7.14	6.74		7.81	7.18	7.54
	506.4	0.04	0.24	0.00	0.66	0.05	7.51	8.28		6.94	7.40	7.31
	697.0	0.13	0.20	0.00	0.59	0.09	8.00	8.67		7.30	7.53	7.68
1985	1071.7	0.14	0.23	0.00	0.46	0.16	8.69	10.10	7.67	8.88	8.37	9.06
	1510.3	0.26	0.16	0.00	0.35	0.24	10.07	10.42	8.54	9.51	9.45	9.78
	1758.1	0.25	0.20	0.00	0.28	0.27	11.47	11.62	10.53	11.45	10.58	11.25
	2428.3	0.31	0.16	0.02	0.21	0.30	13.8	11.80	14.70	11.98	11.87	12.53
	2629.0	0.29	0.16	0.02	0.19	0.34	18.05	14.41	18.63	12.81	13.84	15.04
1990	3554.2	0.33	0.13	0.04	0.15	0.35	18.04	15.11	18.90	14.23	14.67	15.97
	4715.3	0.36	0.10	0.06	0.12	0.36	21.89	18.30	23.18	12.33	16.15	18.42
	5478.8	0.38	0.07	0.11	0.09	0.35	23.82	24.76	29.88	17.80	21.28	23.09

REFERENCES

Almon, S. (1965). The distributed lag between capital appropriations and expenditures. Econometrica, **33**, (1), 176-196.

Albisu, L.M. and Blandford, D. (1983). An area response model for perennial plants and its application to Spanish oranges and mandarins. European Review of Agricultural Economics, **10**, (2), 175-184.

Alston, J.M.; Freebain, J.W. and Quilkey, J.J. (1980). A model of supply response in the Australian orange growing industry. Australian Journal of Agricultural Economics, **24**, (3), 248-267.

Anderson, K. (1974). Distributed lags and barley acreage response analysis. Australian Journal of Agricultural Economics, **18**, 119-132.

Askari, H. and Cummings, J.T. (1976). Agricultural Supply Response: A Survey of the Econometric Evidence. New York, Praeger Publishers.

Baritelle, J.L. and Price, D.W. (1974). Supply response and marketing strategies for deciduous crops. American Journal of Agricultural Economics, **56**, (2), 245-253.

Bateman, M.J. (1965). Aggregate and regional supply functions for Ghanian cocoa, 1946-1962. Journal of Farm Economics, **47**, 384-401.

Baumol, W.J. and Blinder A.S. (1985). Economics: Principles and Policies (Third edition). New York, Harcourt Brace Jovanovich.

Behrman, J.R. (1968). Monopolistic cocoa pricing. American Journal of Agricultural Economics, **50**, (3), 702-719.

Boyd, M.B. (1984). City of the Plains: A History of Hastings. Christchurch, Victoria University Press.

Braulke, M. (1982). A note on the Nerlove model of agricultural supply response. International Economic Review, **23**, (1), 241-244.

Bruhn, M.K. (1992). Attributes and Use of Pipfruit Industry Standard Data. B.Hort.Sc. Dissertation. Department of Agricultural and Horticultural Systems Management, Massey University.

Bultitude, J. (1983). Apples - A Guide to the Identification of International Varieties. London, The MacMillian Press Ltd.

Chen, D.; Courtney, R. and Schmitz, A. (1972). A polynomial lag formulation of milk production response. American Journal of Agricultural Economics, **54**, (1), 77-83.

Coase, R.H. (1937). The nature of the firm. Econometrica, **4**, (16), 386-405.

Kotler, P. and Armstrong, G. (1991). Principles of Marketing (Fifth edition). Englewood Cliffs, Prentice-Hall.

Dalzeil, P. and Lattimore R. (1991). A Briefing on the New Zealand Macro-economy 1960-1990. Auckland, Oxford University Press.

Dennis, F.G. (1979). Factors affecting yield in apple, with emphasis on Delicious. Horticultural Reviews, **1**, 395-422.

Dowling, J.M. (1979). The supply response of rubber in Thailand. Southern Economics Journal, **45**, (3), 795-805.

Ferguson, C.E. and Maurice, S.C. (1970). Economic Analysis. Homewood, Irwin Inc.

French, B.C. and Bressler R.G. (1962). The lemon cycle. American Journal of Agricultural Economics, **44**, (5), 1021-1036.

French, B.C. and Matthews, J.L. (1971). A supply response model for perennial crops. American Journal of Agricultural Economics, **53**, (3), 478-490.

French, B.C.; King, G.A. and Minami, D.D. (1985). Planting and removal relationships for perennial crops: Application to Cling peaches. American Journal of Agricultural Economics, **67**, (1), 215-223.

Goodwin, R.M. (1947). Dynamical coupling with especial reference to markets having production lags. Econometrica, **15**, 181-204.

Gujarati, D.N. (1988). Basic Econometrics (Second Edition). Singapore, McGraw-Hill International.

Hartley, M.J.; Nerlove, M. and Peters, R.K. (1987). An analysis of rubber supply in Sri Lanka. American Journal of Agricultural Economics, **69**, (4), 755-761.

Jackson, D. (1986). Temperate and Subtropical Fruit Production. Wellington, Butterworths.

Johnson, G.L. (1960). The state of agricultural supply economics. Journal of Farm Economics, **42**, (2), 435-452.

Janick, J. and Moore, J.N. (1975). Advances in Fruit Breeding. West Lafayette, Indiana, Purdue University Press.

Kalaitzandonakes, N.G. and Shonkwiler, J.S. (1992). A state-space approach to perennial crop analysis. American Journal of Agricultural Economics. **74**, (2), 343-352.

Koyck, L.M. (1954). Distributed Lags and Investment Analysis. Amsterdam, North-Holland.

Lockhart, J.C. (1990). The Financial Systems Used on Three Important Farm Types in New Zealand. M.Ag.Sc. Thesis, Department of Agricultural and Horticultural Systems Management, Massey University.

MAF (1980). Matching Horticultural Crops to the Lower North Island. Wellington, Ministry of Agriculture and Fisheries.

Malinvaud, E. (1966). Statistical Methods of Econometrics. Chicago, Rand McNally & Co.

Minami, D.D.; French, B.C. and King G.A. (1979). An Economic Analysis of Market Control in the California Cling Peach Industry. Davis, Giannini Foundation Monograph No.39, University of California.

Moore J.N. and Ballington J.R. (1990). Genetic Resources of Temperate Fruit and Nut Crops. International Society for Horticultural Science. Wageningen, The Netherlands.

Nadda, A.L. (1987). Supply response of perennial crops - A study of Himachal apples. Indian Journal of Agricultural Economics. 43, (3), 446-455.

Nerlove, M. (1958). The Dynamics of Supply: Estimation of Farmers' Response to Price. Baltimore, John Hopkins University Press.

NZAPMB, (1965-1993). New Zealand Apple and Pear Marketing Board Annual Reports. The New Zealand Apple and Pear Marketing Board, Wellington.

NZAPMB, (1975-1993). Price List and Terms of Supply. The New Zealand Apple and Pear Marketing Board, Wellington.

NZAPMB, (1990). New Zealand Apple and Pear Marketing Board 42nd Annual Report. The New Zealand Apple and Pear Marketing Board, Wellington.

NZAPMB, (1992a). New Zealand Apple and Pear Marketing Board Annual Report. The New Zealand Apple and Pear Marketing Board, Wellington.

NZAPMB, (1992b). New Zealand Apple and Pear Marketing Board Annual Report Tree Population Statistics - Tree numbers and hectares by variety within region. Unpublished data, The New Zealand Apple and Pear Marketing Board, Hastings Office.

NZDS, (1982-1996). Export Statistics, Item by country of desination.New Zealand Department of Statistics, Wellington.

NZDS, (1987-1992). Export Statistics, External trade - H.S. Item by country of desination. New Zealand Department of Statistics, Wellington.

NZMS, (1960-1988). Meterological Observations. New Zealand Meterological Service, Wellington, Government Printer.

Petersen, G. (1990). Enterprise choice selection on pipfruit orchards: A case study. B.Hort.Sc. Dissertation. Department of Agricultural and Horticultural Systems Management, Massey University.

Pope, C.J. (1989). In defense of the Board. Horticulture News, **10**, (12), pp 2.

Rae, A.N. and Carman, H.F. (1975). A model of New Zealand apple supply response to technological change. Australian Journal of Agricultural Economics, **19**, (5), 39-51.

Robinson, B.R. and Reynolds, R.G. (1989). Measures of and trends in agricultural competitiveness in New Zealand. Proceedings of NZ Branch Australian Agricultural Economics Society Conference. Discussion Paper 125(2), Agribusiness and Economics Research Unit, Lincoln College, Canterbury. pp. 227-260.

Robinson, K.L. (1989). Farm and Food Policies and their Consequences. New Jersey, Prentice-Hall.

SAS Institute Inc. (1988). SAS User's Guide Basics (Version 5 Edition). Cary, NC: SAS Institute Inc.

Tomek, W.G. and Robinson, K.L. (1981). Agricultural Product Prices (Second edition). Cornell University Press.

Vernon, R. (1966). International investment and international trade in the product cycle. Quarterly Journal of Economics, **80**, (2), 190-207.

Wickens, M.R. and Greenfield, J.N. (1973). The econometrics of agricultural supply: An application to the world coffee market. Review of Economics and Statistics, **55**, (4), 433-440.

Wilton, W.J.W. (1989a). Industry takes huge strides in 40 years. The Orchardist, **62**, (1), 10-11.

Wilton, W.J.W. (1989b). Orchard renovations - which varieties? The Orchardist, **62**, (2), 12-13.

Zhang, J. and Theile, G.F. (1993). The Dynamic Apple Tree System: Pomological and Climate Relationships. Unpublished. Department of Horticulture, Lincoln University.