



## **THE EVALUATION OF ORCHARD ADJUSTMENT STRATEGIES: A Linear Programming Approach to the Development of Rural Policy in the SME Sector**

*A paper for the Small Enterprise Association of Australia and New Zealand 16<sup>th</sup> Annual  
Conference, Ballarat, 28 Sept-1 Oct, 2003.*

Dr Peter P. Oppenheim  
Senior Lecturer  
University of Ballarat  
Australia

### **Abstract**

Fruit production typically involves a period of investment and developmental expenditure which continues until the orchard is fully productive. During this period cash flows are negative. Once the orchard bears fruit, positive cash flows can result. In time, as the orchard trees age and yields decline or new varieties replace the existing varieties, negative cash flows reappear. The duration of this cycle can vary and periods of time ranging from ten to fifty or sixty years would not be uncommon. This study focuses on the Moutere Hill apple and pear fruit in the Nelson Province in the South Island of New Zealand during a recent period when the region as a whole experienced a severe decline in orchard incomes as a result of the failure of orchardists to adjust to changing economic and technological conditions which in turn resulted in orchards consisting of a large number of old trees with a high percentage of less preferred varieties.

In order to derive feasible adjustment strategies a ten year intertemporal linear programming model was constructed. This model was based on an orchard representative of those exhibiting adjustment problems. The model allowed for the adoption of new enterprises in addition to a variety pomological technologies such as replanting, reworking, inter-planting and removal activities. The results obtained from model simulation included optimal patterns of tree replacement and intertemporal cash flows. These results indicated that the financial position of Moutere Hill apple and pear fruit producers would continue to deteriorate over the following decade with considerable borrowing being required to finance maintenance and/or developmental expenditure. Positive cash flows could be expected towards the end of the decade after which the benefits of orchard restructuring would continue to accrue.

While it was shown that considerable potential existed for increased incomes to be generated from Moutere Hill orchards it was recognized that the extent of the delay in instigating adjustment strategies might necessitate a withdrawal from the industry of

those growers who could not, or did not, wish to persevere with fruit growing. Accordingly, two new policies were suggested as possible measures which could supplement existing rural policy in order to alleviate problems of poverty on the Moutere Hills.

**THE EVALUATION OF ORCHARD ADJUSTMENT STRATEGIES:  
A Linear Programming Approach to the  
Development of Rural Policy in the SME Sector**

## **1. Introduction**

The Nelson province consists of two counties, Waimea (753,000 ha) and Golden Bay (260,000 ha) located in a central position at the Northern end of the South Island of New Zealand. Apple and pear fruit production is centered about three major regions which are defined on the basis of soil type and topography as:

- (a) Nelson - the Waimea Plains between Nelson and Appleby
- (b) Mapua - the Moutere Hills between Appleby and Motueka and
- (c) Motueka - the flood plains and terrace soils of Motueka and Riwaka.

Although the soils of Motueka are the most suitable for apple and pear fruit production fruit growing tended to develop on the Moutere Hills.

In 1910 as a result of the government's support for an export trade<sup>1</sup>, a planting boom began on the Moutere Hills. This boom was stimulated by various syndicates which were interested in the subdivision of the Moutere Hill lands. The most notable of these syndicates was Tasman Fruit Lands Ltd; a company floated by Mr. A. McKee in 1911 which acquired 810 hectares at Tasman for the purpose of subdivision. A large amount of publicity was given to the potential for apple production in Nelson by newspapers, the government, and 'experts'. A booklet, "*Apples for Export*" published by A. McKee in December 1910, popularized the export trade and its potential thus encouraging investment in the industry. The booklet consisted of a series of photographs and newspaper articles about the Moutere Hills which proclaimed that the cheaper lands of the hills were better for apples than the richer soils elsewhere. There were also assurances that little knowledge or capital was needed to successfully grow apples:

*... The Moutere particularly offers facilities to the man of small capital to make a start in what is admitted to be one of the healthiest and most profitable industries that the 'simple life' affords ...*

*...It is a mistake to suppose that a man needs special scientific knowledge to commence fruit growing ...*

*... (with) the enjoyment of vigorous health consequent on a busy outdoor life and the sight of a constantly improving asset the months soon slip by and the orchard is in bearing before one realises that the necessary years have actually passed*

(McKee, p 32)

With the onset of the first World War the planting boom subsided. It has been calculated that 2,830 hectares in total were planted on the Moutere Hills during the years 1910-1916 compared with an area of 575 hectares planted to apple and pear fruit in 1973. During the 1950s horticultural advisers in the Department of Agriculture started to advocate a systematic program of tree replacement for trees older than 45 years. However a majority of growers failed to respond to the Department's timely advice and by the time that this study was undertaken the orchards on the Moutere Hills contained high percentages of old, low-valued less preferred varieties with 44 per cent of growers at Mapua failing to achieve positive net farm incomes.

In general when farm profitability declines and debts are significant, any short term adverse factors such as hail or drought are more difficult to cope with. Where the safety margin between incomes and debt servicing is small and declining productivity is significant, extreme financial difficulty may result. This precisely was the situation that faced many producers of apples and pears on the Moutere Hills near Nelson.

To gain an insight into optimal adjustment strategies for Moutere Hill apple and pear producers and to provide a basis for policy recommendations an intertemporal linear programming (I.L.P.) model of orchard adjustment was formulated. This model is

---

<sup>1</sup> To encourage export the government guaranteed a return of one penny per pound on all fruit sold in Europe



$x_j^t$  = the level at which activity  $x_j$  is initiated in period  $t$

$a_{ij}^t$  = the per unit requirement of activity  $x_j$  for resource  $b_i$  in period  $t$ .

$b_i^t$  = the supply of resource  $i$  in period  $t$ .

In essence the model consists of two major sets of activities:

- (a) A set of activities to model the existing orchard activities and cash flows; and
- (b) A set of "adjustment" activities to allow for the adoption of new enterprises.

The entire matrix consisted of over 500 row vectors and 1200 column vectors. The flow of cash through the model, the objective function and the length of the planning horizon are issues of particular importance to an understanding of the model. Therefore a discussion of these features will precede an examination of the various activities and constraints included in the model.

**Cash flow in the model.** Cash transferred from the end of the previous year is made available for use at the start of year  $t$ . From this amount the model deducts the fixed costs such as mortgage and interest repayments, fixed insurance costs and a specified amount for personal consumption to cover such expenses as food and clothing. Having deducted the fixed costs the variable costs of production for the year  $t$  are calculated. Borrowing on mortgage overdraft rates is permitted to overcome cash infeasibilities should cash be limiting. Under circumstances of cash surplus, the cash not required for farm production or reinvestment may be invested off the farm at a specified interest rate. At the end of the year the tax deductible costs incurred during the year are summed i.e. the portion of fixed costs that were tax deductible, the variable production costs and the interest paid on monies borrowed. The total tax deductions are then subtracted from the total income earned during the year to arrive at the taxable income for year  $t$ . The amount of tax payable on the taxable income is calculated and deducted from the taxable income to give the after-tax cash. Appropriate adjustments are then made for the principal components of monies either borrowed in year  $t$  or invested off the farm. The residual then gives the amount of cash available at the start of year  $t + 1$ .

**The objective function and the length of the planning horizon.** The I.L.P. model made use of an objective function which maximized the weighted sum of individual goals

at the end of the planning period. As the "well-being" of farm families can be measured as some combination of annual income and asset accumulation it was decided that a suitable objective to maximize would be the sum of after tax cash and the value of assets the end of the planning horizon subject to a given level of personal drawings each year. Accordingly, only two non-zero values, appear in the objective function<sup>2</sup> namely, the weights attached to the final cash and final assets activities.

In considering the length of the planning horizon it was recognized that with the average age of fruit producers on the Moutere Hills being 40 years a maximum planning horizon of 20 years would meet the needs of these decision makers, even though this period would probably fall short of the time required to reach a new equilibrium situation. Accordingly, a model with such a planning horizon was constructed and solved for a benchmark situation. However the model became too large and expensive to use when augmented with various adjustment activities. Therefore, the planning horizon in the model discussed in this paper was reduced to a ten year period. This was regarded as a compromise between two requirements:

- (a) a period long enough to allow the study of the adjustment process; and
- (b) a period which is sufficiently short to allow the model to be handled without too much difficulty.

**The Constraints** The major constraints included in the model may be grouped as follows: labour

- Existing tree number constraints
- Land constraints
- Labour constraints
- Financial constraints
- Variety limitation constraints
- Accounting constraints
- Final cash and asset constraints

*Existing tree number constraints.*

A set of constraints corresponding to the existing tree activities were formulated in order to limit reworking and inter-planting to no more than the initial tree number.

*The land constraints.*

A single constraint in each year of the planning period constrained total land utilization to no more than the area available.

*Labour constraints.*

A set of labour constraints were included in the formulation of the model. The year was first divided into three periods to reflect the major periods of orchard activity, i.e. the dormant period, the growing season and the harvest period. In view of the importance of labour employment throughout the harvest, this period was further subdivided into nine fortnightly periods in order to provide a second set of constraints that would determine labour requirements and picking costs throughout the harvest period.

*Financial constraints.*

Three financial constraints were set up to facilitate cash flow accounting and the determination of taxation. The first cash constraint limits total expenditure to no more than the cash available at the beginning of the year plus borrowings. The second restraint allows the amount of tax payable in a year to be determined. The final cash restraint permits the income earned to be divided into:

- (a) a proportion covered by tax deductible costs, i.e. tax free and therefore income which is available at the start of year  $t + 1$  (as costs are all paid at the start of each year);
- (b) a proportion to be taxed (the after tax cash component is then also made available in year  $(t + 1)$ ).

*Variety limitation constraints.*

In order to overcome the problem of labour bottlenecks at harvest time, a number of varieties of perennial crops are usually grown to provide an even supply of fruit throughout the harvest period. To constrain the model from choosing the most profitable variety for orchard reconstruction a set of constraints were included to restrain the proportion of the various varieties of perennial crops grown to a maximum percentage of

---

<sup>2</sup> . the value of Final Assets was defined as the present value of future net revenues 'of perennial crops, in existence at the end of the planning horizon, discounted from infinity to the end of the planning horizon, with crop replacement at the optimum time.

total tree numbers.<sup>3</sup>

*Accounting constraints.*

"Non computational" constraints may be used for accounting purposes. The I.L.P. model used such a constraint to determine the total quantity of fruit harvested each year.

*Final asset and cash constraints.*

The final asset and cash constraints appear only once, in the final year of the model.

These constraints were used to determine:

- (a) the final asset value of all perennial plantings at the end of the planning period; and
- (b) the final after tax cash position at the end of the planning period.

The resultant values were then transferred to the objective function of the model.

**The Activities** The activities included in the I.L.P. matrix and repeated in each year of the planning horizon can be divided into the following categories:

- existing orchard plantings
- tree removal activities
- new plantings of perennials
- inter-planting and reworking activities
- annual activities
- activities to hire labour
- financial and taxation activities
- final cash and asset transfer activities.

*Existing orchard plantings.*

The existing plantings of perennial crops were aggregated into 30 activities on the basis of variety, age and density of planting. The added detail to be derived from such a grouping as opposed to a grouping on the basis of variety alone was intended in order to answer questions relating to the optimum replacement of selected age groups of trees.

---

<sup>3</sup> Constraining varieties on the basis of tree numbers as opposed to the quantity of fruit harvested in each fortnightly sub period of the model is preferred as the former method takes into account the problem of harvest periods beyond the planning horizon. Limiting varieties on the basis of fruit production on the other hand, would not necessarily ensure a desired distribution of fruit throughout the harvest period as new plantings may not come into full production during the planning horizon.

*Tree removal activities.*

Because of the cost and/or labour time involved in the removal of existing trees, a set of tree removal activities were incorporated. While these activities may appear superfluous in reconciling tree numbers their inclusion was intended to allow greater accuracy in the estimation of labour times and costs, both of which are seen as critical factors in orchard production.

*New plantings of perennials.*

To facilitate the restructuring of orchards a number of activities were included to allow for the planting of new or additional varieties of perennial crops. In order to limit the size of the matrix only the most likely candidates were included, selection being made on the basis of the net present value of the variety.

*Inter-planting and reworking activities.*

A second set of orchard adjustment activities permitted existing trees the option of being inter-planted or reworked to other varieties. As the existing tree activity could be reworked or inter-planting with any of a number of varieties in any year of the planning horizon, it was again necessary to restrict the number of options available to the most likely candidates in order to limit matrix size<sup>4</sup>.

*Annual activities.*

The inclusion of a number of activities such as off farm work and cattle fattening on an annual basis without provision for herd replacement etc., provided a further set of adjustment activities.

*Activities to hire labour.*

Two sets of activities were included to provide for additional labour to be hired for seasonal work and/or fruit picking. Differential rates of pay were invoked for the two classes of labour which supplemented the owner operator's contribution.

*(vii) Financial and taxation activities.*

To facilitate the cash flow accounting previously described, the following activities were repeated in each year of the I.L.P. model: cash borrowing on either mortgage or overdrafts rates, cash saving in the form of off-farm investment, taxation activities to calculate tax payable, and a tax deduction transfer activity.

---

<sup>4</sup> For example, 30 existing tree activities given the option of being inter-planted or reworked to any 6 new varieties in any year of a 10 year planning horizon implies 3600 activities.

Since all tax deductible expenditures must be subtracted from income earned before taxation is calculated the tax deductions transfer activity allows a sum equal to the tax deductible expenditures of that year to be subtracted from the pre tax income and transferred to the supply of cash available at the beginning of the next year.

*Final cash and assets transfer activities.*

This set of activities, unlike other activities, appears only once in the final year and acts to transfer the value of final assets and cash to the objective function.

### **3. Implications for Rural Policy**

The results obtained from the linear programming model suggested that a further decline in the welfare of Moutere Hill apple and pear producers would occur over the following decade. Regardless of whether or not growers decide to undertake a development program aimed at restructuring their orchards, it is likely that considerable loan finance will be required. Although the financial prospects for the short and medium term indicate a period of severe financial difficulty, the prospects for the long term appear quite favorable. The results also showed that considerable financial gain can be expected when replanted perennial crops reached full bearing. In order to evaluate the various plans that were derived a number of criteria were used. These criteria included the rate of return on capital, the pattern of loan requirements, the present value of expected income, etc. If producers were operating in an environment of certainty, the task of drawing conclusions from the results of the L.P. analysis would have been relatively simple. The potential increase in income noted in the adjustment model over that indicated by the benchmark model would suggest that considerable potential exists for increasing income and if possible, growers should be encouraged to maintain and develop their properties.

However, fruit growers do not operate in an environment of complete certainty so the fact that expected benefits do not begin to accrue for at least ten years, leaves an extensive period of time during which the factors responsible for uncertainty could affect the

---

original assumptions upon which the I.L.P. models were based. In addition, the added indebtedness demanded by persevering with fruit growing on the Moutere Hills is likely to be unacceptable to a number of growers, regardless of the potential return from borrowing. This fact high-lights the major problem facing Moutere Hill apple and pear fruit growers, i.e. *adjustment has been delayed for too long*.

As this study has shown that the potential for increased incomes does exist the question that needs to be answered is whether or not it is too late to rectify the errors of judgment that have been made in the past. In some cases it will be obvious that no alternative exists and growers will be forced to withdraw from the industry. In other cases, where growers are able and willing to borrow amounts as indicated, orchard restructuring could still occur. The problem that remains is to ensure that adequate measures exist to alleviate the rural poverty on the Moutere Hills. The conclusions which have been drawn from the study indicate a need for measures which will assist two classes of growers:

- (a) those growers who are able to demonstrate the potential viability of their holdings, but are in need of temporary finance to continue to develop or maintain their properties, and
- (b) those growers who cannot demonstrate viability, or who wish to withdraw from the industry with a minimum of social dislocation.

At the time that this project was undertaken the New Zealand government provided a range of measures aimed at assisting primary producers. All of those measures had been designed with a view to promoting production by encouraging investment and alleviating the burden of fluctuating farm incomes. Rural policy in New Zealand therefore appeared quite adequate in providing measures to assist those growers who opted to remain on their properties. However, government policy did not cater for the adjustment situation where a withdrawal from the industry was desired. In view of this; two alternative schemes were proposed as solutions to those Moutere Hill apple and pear growers who might decide to leave their holdings.

### **Subdivision of Land**

An amendment to the appropriate legislation pertaining to the subdivision and sale of Moutere Hills orchards into 2., 4 and 8 hectare lots would permit orchardists to reduce their indebtedness and invest the surplus proceeds off the farm. The adoption of such a

policy would meet the growing demand for farms for commercial, semi-commercial and non-commercial purposes. It would reduce the production of apple and pear fruit on the Moutere Hills and stimulate an influx of people into the district. Low income apple and pear producers would be able to remain in the district in their own homes, thus avoiding the social dislocation which often arises when farm adjustment measures are implemented. A second method whereby the desired orchard adjustment may be effected is via the implementation of an Annuity Scheme.

### **Annuity scheme**

Annuity schemes are essentially devices for converting stocks of wealth into income flows. Farm families frequently receive incomes which are significantly below those of non-farm families and yet may hold substantially greater stocks of wealth. This net worth/farm incomes anomaly is often referred to as the "live poor, die rich" paradox of rural poverty where farmers live poor in cash, but die rich in assets. A number of schemes for converting farmers' wealth into income flows operate in several European countries. One of the most commonly cited schemes involves a forward sales contract arrangement under which the farmer mortgages their property in exchange for an annuity based on the net worth of the property with the mortgagee assuming title to the property only after the death of the farmer.

The advantage of such a scheme lies in the fact that the primary producer is able to remain, work on their property, and receive the income from it, in addition to an annuity payment representing part of their net worth. On the death of the grower, an agency would be required to realize the asset by placing the property before a public auction. The agency would be allowed to subdivide before the realization occurred, provided that the entire lot was liquidated within a set time limit following acquisition. Such a scheme would have the advantage of producing higher current consumption levels (including non-pecuniary income gained from remaining in a familiar environment) but at the same time have the disadvantage of creating losses for the farmer's heirs.

Neither of these policies would depend upon a subsidy of any kind and in time could alleviate the problems of rural poverty on the Moutere Hills. It was recognized that in the

course of such adjustment processes the regional economy of the Nelson province would suffer the loss of that farm income generated by the low income sector of the apple and pear fruit industry. Although it was beyond the scope of this study to estimate the net effect of such an adjustment on the regional economy, it is not expected that the loss in export receipts would exceed the cost of supporting the industry particularly in view of the loan requirements specified by the I.L.P. analysis.

In this study it has been shown that the failure of farmers to adjust to a changing environment can lead to problems of regional resource allocation. This failure to adjust at an adequate rate can lead to costly and often unfortunate situations, as in the case of the Moutere Hills. At this stage we could do well to heed the advice of William Shakespeare who when contemplating change suggests:

*"If it were done when 'tis done, then 't were well  
It were done quickly".*

Shakespeare, Macbeth, (I, vii).