Optimisation of a Buyer's Sourcing Strategy in the Mixed Auction/Direct Supply of New Zealand Wool

A thesis submitted in partial fulfilment

of the requirements for the Degree of

Doctor of Philosophy

in

Optimization and Systems Modelling

at

Lincoln University

by

Jagannath Aryal

Lincoln University

2009

Abstract

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The New Zealand Wool Industry (NZWI), an iconic national industry, remains of great value to the New Zealand economy, contributing more than a billion dollars a year to gross output. However, this industry is at a crossroads and the incumbent practitioners are looking for ways to increase the value of the New Zealand wool clip. The value of the industry to the economy is directly related to the price which buyers are prepared to pay for wool. The price is formed primarily as a result of the marketing approaches used as well as intra and inter-fibre competition. The real inflation adjusted price has steadily decreased over recent years and understanding of its dynamics is a fundamental problem for the stakeholders. Among the stakeholders, buyers / exporters are heavily involved in the process of price formation. Buyers / exporters are currently facing a real time problem of sourcing strong wool from two parallel but different marketing systems which are operated simultaneously – *auction* and direct supply. In this context, we have investigated a novel model that optimizes a buyer / exporter's average cost of wool (c/kg) irrespective of the marketing approaches adopted by sellers.

The study required confidential access to highly confidential and commercially sensitive information. Because of this, one particular company who agreed to provide information under conditions of privilege was used to typify the issues confronting a buyer. If the thesis appears to be overly focussed on the interests of this one player, then this is the reason. However it was felt better to fully engage with this one cooperating company – New Zealand Wool Services International (NZWSI) – rather than proceed with a more academic exercise based on general postulates with the risks of loss of commercial relevance.

In the first part of the study, two systems models were developed to chacterize the two main sourcing options available. These were respectively for auction and direct supply.

These models consider the price formation factors for the New Zealand wool clip, from a buyer / exporter's perspective. The constituent factors that determine the cost to the buyer in an *auction* are investigated, as the *auction* cost is also a reference for direct supply. In any auction, there are many types of wool available ($i = 1.....n$). The *auction* cost for a single wool of type i is (x_i) which is the product of the relative price of that particular type and the market average price.

The relative price of a particular wool type is a function of physical properties such as diameter, colour, bulk, medulla, vegetable matter and staple length. Relative prices of different wool types were studied using analytical approaches for the database available from a local *auction* centre. It was found that among the physical properties, diameter had the most significant role in the formation of relative price. As anticipated, this finding matched studies conducted by (G.A. Carnaby, Maddever, Ford, & Stanley-Boden, 1988; Maddever, 1989; I.P. Stanley-Boden, 1985; I.P. Stanley-Boden, Carnaby, & Ross, 1986). On the other hand, the market average price depends on global supply- and - demand and is a function of aspects such as house starts, overall quality of wool and time lags (Philpott, 1955; Wiggins & Beggs, 1980). Average market prices for wool are freely available after each sale. The average cost at auction for type i is $\overline{x}_i$ which is the average of several lots of wool of type i. Thus, the first part of this study concludes with the determination of the average cost to the buyer in an *auction* ($\overline{x}_i$) of any particular type of wool (say i).

In the second part of the study, an analysis was made of the associated extra cost, risk, margin and cost of risk in both marketing systems, from a buyer's perspective. Since these costs differ the total extra cost (due to transport, storage etc.) of type i to a buyer depends on the proportions bought at auction (suppose y) and directly (1-y). Let the total additional cost to the buyer at auction and direct supply be $a(y)$ and $b(y)$ respectively. We assume for reasons elaborated in the thesis that $a(y)$ and $b(y)$ are independent of wool types bought. The total additional cost to the buyer in both marketing systems [$a(y)$ and $b(y)$] for a hypothetical auction cost is calculated using data provided by the wool buying company consulted. Similarly, the cost of risk associated with auction $A(y)$ and the cost of risk associated with direct supply $B(y)$ is also calculated.

In the third part of the study, an investigation was conducted to predict the average cost in c/kg to the buyer for wool type i (say, Z_i) by formulating an *optimization* model. This *optimization* model aims to minimize Z_i as a function of y and takes into account average cost ($\overline{x}_i$) for type i at *auction*, proportion of wool bought at auction (y), total additional cost at auction $a(y)$, cost of risk associated with auction $A(y)$, proportion of wool bought at direct supply $(1-y)$, the total additional cost at direct supply $b(y)$ and the cost of risk associated with direct supply $B(y)$. Further, the loyalty rebate to the growers (θ) is also taken into account. Thus, this *optimization* model predicts the value of "Z_i" where

$$Z_i = y.\big(a(y) + A(y)\big) + (1-y)\big(b(\theta, y) + B(y)\big) + \overline{x}_i$$

for all $\bar{x}_i$ we minimize Z_i as a function of y.

Accordingly, an optimization model for the total cost is developed considering the associated risks, the loyalty rebate and the proportion of wool in the two pathways, auction and direct supply. This optimization model considers the factored cost of risk in two pathways, and optimizes the buyer's behaviour in terms of both the rebate offered and the percentage desired to be purchased via direct supply. By relating this to the quantity growers wish to supply for any given level of the rebate it is shown that the rebate can be varied by the buyer to minimize his total cost. In the case of the real world example used in this thesis it is calculated that the buyer should use the rebate more aggressively than presently to attract grower suppliers to a new marketing channel.

In summary, this study extends the available analysis of the cost to a buyer of the wool he/she purchases. Whilst the determinants of market average prices have been widely studied previously and are well understood, the relative prices of different types have been less intensively investigated. The analyses conducted in this thesis supported findings from earlier work in general but updated them using a contemporary data base. However this study developed system models for price formation in both auction and direct supply sourcing and an associated *optimization* model for the buyer / exporter of the New Zealand wool clip. All three of these models were original and none appear to have been described previously. It is hoped that these three models will be of quite general utility and also be useful therefore for other agricultural commodities that are traded simultaneously via *auction* and direct supply. The average price for a given wool type Z_i, which is the output from this new modelling exercise is precisely what is required as input data for solving the minimization problem in wool blending models.

Although it was found that this optimization could be usefully applied and interpreted in relation to solving the issue of what proportion, the buyer should purchase from direct supply, it was also found that grower inertia and loyalty to the traditional auction system was limiting the amount of wool available to the buyer in practice. This situation prevailed despite the buyer passing back all the savings of direct supply sourcing to the growers via a rebate. It was realised therefore that the rebate itself could and should be modelled as a second degree of freedom in the optimization of buyer's behaviour.

The total cost Z_{Total} for many lots of wool can be computed once we predict Z_i. The task of assembling such a processing parcel has been comprehensively studied previously (G.A. Carnaby, 1983). In fact most processing lots are blends of different wool types. The formulation problem is essentially a linear programming optimization which is described in more detail in the thesis.

My deepest gratitude belongs to my dad,

I dedicate this thesis to you.

Acknowledgements

A number of people have made this project possible and have contributed to its completion.

Jagannath Aryal

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2009

Table of Contents

List of Tables

List of Figures

Abbreviations

CEO	Chief Executive Officer
CV	Common Value
GUI	Graphic User Interface
IID	Identically and Independently Distributed
IP	Integer Programming
IPV	Independent Private Value
IWS	International Wool Secretariat
IWTO	International Wool Trade Organisation
LP	Linear Programming
MLR	Multiple Linear Regression
MWNZ	Meat and Wool New Zealand
NZWB	New Zealand Wool Board
NZWI	New Zealand Wool Industry
NZWSI	New Zealand Wool Services International
OECD	Organisation for Economic Co-operation and Development
PCA	Principal Component Analysis
PDE	Partial Differential Equation
PGGW	New Zealand's largest – and only nationwide – provider to the agricultural sector (http://www.pggwrightson.co.nz/company_profile.html).
RET	Revenue Equivalence Theorem
WIN	Wool Industry Network
WPIL	Wool Partners International Limited
WRT	With respect to
WRONZ	Wool Research Organisation of New Zealand

Publications and Presentations

Referred Journal Papers

- **Aryal J**., Kulasiri D., and Carnaby G.A. (2008). Auction theory: bidder's perspective in a public out-cry English auction. *International Journal of Computer and Information Science and Engineering*, 2 (3), pp.143-147

- **Aryal J**., Carnaby G.A., Kulasiri D., and Samarsinghe S. (2010). Optimising Buyers sourcing strategy in agri-commodity sourcing – a case study from New Zealand wool industry (In Preparation).

Proceedings / Conferences Papers

- **Aryal, J**., Kulasiri, D., Carnaby, G.A., Samarsinghe, S. (2009). Investigating the price of New Zealand wool clip using modelling approaches. In Anderssen, R.S., R.D. Braddock and L.T.H. Newham (eds) 18th World IMACS Congress and MODSIM09 International Congress on Modelling and Simulation. Modelling and Simulation Society of Australia and New Zealand and International Association for Mathematics and Computers in Simulation, July 2009, pp. 727-733. ISBN: 978-0-9758400-7-8. http://www.mssanz.org.au/modsim09/C1/aryal.pdf

- **Aryal, J**., Kulasiri, D., Carnaby, G.A. (2007). Auction Theory: Bidder's Perspective in an English Auction Environment. In Proceedings of World Academy of Science, Engineering and Technology, Volume 26: pp 535-539, ISSN: 1307-6884.

Presentations:

- MODSIM, 2009. Investigating the price of New Zealand wool clip using modelling approaches. In 18th World IMACS Congress and MODSIM09 International Congress on Modelling and Simulation. Modelling and Simulation Society of Australia and New Zealand and International Association for Mathematics and Computers in Simulation, Cairns, Australia.

- MWNZ, 2008. Buyer's perspective in simultaneous sourcing pathways of New Zealand wool. In a workshop organised by Meat and Wool New Zealand (MWNZ) for Scholarship Students Orientation, Lincoln, New Zealand.

- AMNA, 2007. Auction Theory: Bidder's Perspective in an English Auction Environment. In Applied Mathematics and Numerical Analysis (AMNA) conference, Bangkok, Thailand.

- LU, 2007. An integrative system model development for a New Zealand wool buyer. In a PhD proposal seminar presentation, Lincoln University, Agriculture and Life Sciences Division, Lincoln, New Zealand.

- MWNZ, 2007. Systems model for New Zealand wool auction. In a workshop organised by Meat and Wool New Zealand (MWNZ) for Scholarship Students Orientation, Wellington, New Zealand.

- NZWSI, 2007. Wool appraisal data analysis using statistical methods. In a seminar organised by New Zealand Wool Services International (NZWSI), Christchurch, New Zealand.

Part One:

This part of the thesis is focused on the development of systems models for auction and direct supply and the determination of the average cost to the buyer in an *auction* $\bar{x}_i$ of any particular type of wool (say i).

This part includes chapter one, two, three and four.

Chapter 1
NEW ZEALAND WOOL INDUSTRY:
SUPPLY CHAIN OF WOOL CLIP: AND
MATHEMATICAL MODELLING

This chapter begins with an introduction to the New Zealand Wool Industry and its price dynamics. Mathematical modelling, and in particular optimization techniques are then examined in relation to sourcing agricultural commodities. The motivation of the study is then introduced. Consideration is given to the parallel sourcing options for the New Zealand wool clip and the buyer's decision making supported by mathematical models. The structure of the thesis as well as the research objectives are presented.

1.1 New Zealand Wool Industry

The New Zealand Wool Industry is of significant value to the New Zealand economy, contributing more than a billion New Zealand dollars a year (Mallard, 2006). This iconic industry is at a cross roads due to the steady decrease of the value (unit price) of the New Zealand wool clip over the years. The unit price of New Zealand wool depends on various factors affecting overall supply and demand. These factors are beyond the control of an individual buyer / exporter. Accordingly, our focus is mainly on two major factors namely the physical properties and the marketing approaches. The physical properties of the wool clip are diameter, colour, length, vegetable matter, bulk, and medulla (G.A. Carnaby, 1983). These physical properties vary due to the genetics of the sheep, the location of the wool on the sheep's body, the weather and various farming practices by the growers. Variation in the physical properties leads to more than 3000 different types of wool in the market. This indicates that New Zealand wool is a complex fibre which therefore makes it harder for practitioners to estimate its price.

The price of the wool also depends on the marketing approaches used to move the wool from the farm gate to the end user. Primarily, the New Zealand wool clip is marketed via three different methods (i) auction, (ii) direct supply from growers and (iii) buying from private merchants. The auction system is based on the English open out-cry public auction which has been operating for the last 150 years in New Zealand. This system is the principal wool marketing approach and accounts for 45% of the trading of New Zealand wool (WIN, 2007).

The key players of the auction (buyers, brokers and growers) as well as the New Zealand government are trying to understand the reasons behind the strong decrease in the price of New Zealand wool. It has been speculated that one of the factors underlying the decrease in price is the inherent instability in the auction system. Further, the incumbent practitioners are questioning the auction system and are looking at alternate methods such as direct supply of wool from the growers. All the players are facing a challenge in

understanding the wool price dynamics and are in a dilemma in choosing the optimal marketing approach.

In this study, our emphasis is on the buyers who export the wool overseas. For a buyer, determining the price of individual wool lots is challenging and complex. In this situation, buyers are simultaneously operating in more than one marketing approach to meet their wool requirements. They are not sure of always adopting the best approach, either auction or direct supply that might fulfil their wool requirements and position themselves in the most profitable situation. Buyers are seeking an optimal sourcing model that can fulfil their wool requirements.

An optimal sourcing model is a key factor in the business of wool buyers. With such a sourcing model, they can increase the profitability in their respective businesses and the New Zealand wool clip will be delivered most cost effectively to overseas manufacturers. Within this complex setting, the immediate players as well as the New Zealand government are considering reforms to the sourcing systems for New Zealand wool. In light of the focus given by the buyers / exporters and the government, research which can address the issue of an optimal sourcing model for wool buyers could make a contribution to the New Zealand wool industry.

The nature of the underlying problem stated above is not only important in the context of the New Zealand wool clip but also in the marketing of numerous agricultural commodities, many of which, from tea to seeds, are auctioned and blended before export. Hence this rather narrowly focused study is likely to apply to agricultural commodities traded elsewhere via auction and direct supply. Agricultural commodities have a high importance for the New Zealand economy, in terms of generating export revenue. The importance of agricultural commodities in New Zealand can be observed from its unique position among the 30 members of the OECD[1] countries, while other OECD countries have industry-based economies; New Zealand's economy is agri-based.

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[1] Organisation for Economic Co-operation and Development is an international organisation of 30 developed countries that accept the principles of representative democracy and free market economy.

In this setting, the New Zealand wool industry, price formation dynamics and the consideration of alternate sourcing options are the main areas where this study focuses. These are all necessary considerations if we are to achieve an optimal solution for the buyer – that is the principal over-arching focus of this study. Hence, a brief overview of past research in relation to the New Zealand wool industry and price formation is presented next.

1.1.1 The New Zealand Wool Industry: Past, Present and Future

The New Zealand wool industry has played an active role in the global wool business and in research and development for wool. For more than 50 years the New Zealand wool industry participated in the International Wool Secretariat (IWS[2]) as a founding partner. This global organisation promoted wool and provided industry infrastructure all underpinned by the woolmark certification brand (Carter & MacGibbon, 2003). In 1996, New Zealand left the IWS (Parliament of Australia, 2000) to set up its own brand and promotional body, Wools of New Zealand.

The New Zealand wool industry also created research facilities at the Wool Research Organisation of New Zealand (WRONZ) and this created a flow of technologies commercialized worldwide (G.A. Carnaby, 2005).

Various attempts have been made to develop other strategies for the betterment of the New Zealand wool industry. Reviews and a range of proposals have been put forward for different industry models. Among the reviews and proposals, The Battelle Report (1971), The Acquisition Debate (1972-77), the Arthur D Little Report (1992) and the McKinsey Report (2000) were considered as major proposals designed to energize the New Zealand wool industry. Summarising the main points of these reports, the Acquisition Debate hinged on a single desk for all New Zealand wool sales. The Arthur D Little Report

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[2] In 1937, a non-profit organisation was formed internationally with the establishment of the International Wool Publicity and Research Secretariat, later known as the International Wool Secretariat (IWS).

proposed New Zealand Wool Board (NZWB)[3] marketing of a small number of uniform blends (NZWSI[4] does this nowadays). The McKinsey Report called for a strong wools marketing company.

Despite these recommendations and initiatives the New Zealand wool industry has undergone further significant decline and is, once again, at the cross roads.

Recently, in 2007, yet another initiative was taken to form the Wool Industry Network (WIN). It is claimed that the WIN's role is to revitalise New Zealand's $1-billion wool industry with a market-led approach to maintain and grow wool's profitability for the benefit of all sub-sectors from farm to retail. This strategy and its implementation have been unfolding in real time during the course of the research described in this thesis. Some of the resulting issues are described in Chapter 4 (Instability of the auction system).

Among the many issues raised by the previous proposals (submitted for industry reforms), a change in the wool selling system is a hardy perennial. Proposals recommended that direct linkages between growers and the market may correct the market disconnection inherent to the long established auction system. However, there has been and is now no consensus on the optimal sourcing options for the New Zealand wool clip.

As well as the recommendations for industry reform, studies have been carried out to understand the relative price behaviour of the New Zealand wool clip (G.A. Carnaby et al., 1988; Maddever, 1989; I.P. Stanley-Boden, 1985; I.P. Stanley-Boden et al., 1986). Apart from studies into the price of wool as a commodity (Philpott, McKenzie, & Wood, 1969; Wiggins & Beggs, 1980), previous studies also attempted to address relative price issues by taking into consideration wool properties. However, the price dynamics issue still remains poorly understood.

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[3] NZWB is a body corporate established under the Wool Board Act 1997. It holds assets on behalf of wool growers.

[4] New Zealand Wool Services International, a Christchurch based wool exporting company (http://www.nzwsi.co.nz/).

In this context there is a need for an optimization model for the wool requirements of the buyers / exporters. Mathematical models and their role in better understanding the sourcing options are presented next.

1.2 Mathematical Modelling in Sourcing Agri – products

Generally, models are used to describe how objects of interest behave in the system under study (Dym, 2007; Fishwick, 2007). These are helpful in visualising behaviour that cannot be directly observed (Fishwick, 2007) and are considered to be an abstraction of reality. In general, the modelling approach to problem solving consists of five steps; (i) asking the question, (ii) selecting the modelling approach, (iii) formulating the model, (iv) solving the model and (v) answering the question (Meerschaert, 2007). We will cover these five steps in this study.

A system involved in sourcing agricultural commodities can be considered as complex and is characterised by having multiple input variables of unknown or chaotic behaviour (Vohnout, 2003). Such a system can be represented by any mathematical modelling technique. Mathematical modelling in agricultural research is essentially an empirical process with only a few feasible theoretical considerations. In this context, a free choice of mathematical models of agricultural systems is possible (Vohnout, 2003). In a real application to an agricultural system, like alternate sourcing options, the system is considered to follow a particular mathematical structure having many variables. The variables (one or more) can be controlled to produce the best outcome in some other variable, subject in most cases to a variety of practical constraints on the control variables. Optimization models can be designed to determine the values of the control variables which lead to the optimal outcome, given the constraints of the problem. The techniques and the modelled system are helpful to commercial enterprises and systems managers in their decision making. Generally, optimization studies involve: (i) a model of the system of interest, (ii) an objective function, (iii) input parameters, and (iv) an algorithm for the process (Mayer, Kinghorn, & Archer, 2005). In our context, the optimization strategy for

a buyer/exporter is a model of the system of interest, the price is an objective function, input parameters include the decision of a buyer including the loyalty rebate to growers and we develop the algorithm for the optimization strategy.

A brief overview of application of optimization techniques and agri-products sourcing is presented next.

1.2.1 Optimization Techniques in Agri- product Sourcing

Optimization problems arise in many real-life applications and are intensively studied in different areas. Producing an optimized model of real-world problems is complex and challenging (Hart, Larcombe, Sherlock, & Smith, 1998). Numerical optimization techniques are increasingly being used to identify the best solution for modelled systems (Fu, 1994).

In the broader context of agricultural research, many studies have used optimization techniques for example in the dairy industry (Hart et al., 1998; Mayer et al., 2005); agricultural facilities design (Yi, Kim, & Lee, 1998); water distribution to the farm (Heinemann, Hoogenboom, Georgiev, de Faria, & Frizzone, 1999; Kodal, Martin, Yildirim, Selenay, & Sonmez, 1997), pasture system (Zhai, Mohtar, Chen, & Engel, 1999) and liquid manure injection (Ren & Chen, 1999). However, in the areas of agri-product sourcing and negotiations between buyer and supplier very limited research has used optimization techniques (Talluri, Vickery, & Narayanan, 2008). This latter study categorized suppliers into efficient and inefficient performers and identified effective negotiation strategies with respect to cost, quality and delivery performance. However, this study did not address the development of an optimal solution to the issue of having parallel sourcing options.

In the New Zealand wool sourcing context, the development of an optimization strategy is a novel approach and one which does not appear to have been studied previously in any other agri-business context. An optimization strategy would enable integration of translated subjective systems together with objective systems in better understanding the price dynamics of the New Zealand wool clip. The abstraction of price behaviour can be visualised by developing models that represent the decision making process of a wool buyer in two different marketing systems – auction and direct supply.

The need for a quantitative strategy for a wool buyer in the New Zealand system and the gap in the scientific literature helped motivate this study.

1.3 Motivation of the Study in the Thesis

Among the diverse aspects of the New Zealand wool industry, the sourcing choice as seen from a buyer's perspective is a major aspect. The players involved in the chain of wool supply have different roles. The incumbent practitioners are practicing wool marketing based on their own experiences instead of using any underlying mathematical model. Among the practitioners, wool buyers / exporters are facing challenges in understanding the price dynamics of the wool clip. Further, the buyers / exporters do not know how to develop a model of the system that can optimize the risk of adopting the different marketing strategies. The current practices of buyers / exporters primarily revolve around the overall trends in average market price compounded by the relative price of different wool types based on their physical characteristics. Understanding the price dynamics of different wool types over time is of crucial concern to the stakeholders and formed the starting point for this study. As the New Zealand wool clip is highly variable (Taylor, 1985), volatility[5] in its price is high over time (Wood, 2003). This complexity is one of the challenges in understanding the price dynamics of the New Zealand wool clip.

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[5] Volatility refers to the rate of change in price over a given period of time. High volatility refers to rapid price change.

However as the study developed, the auction system, which had been the principal selling method for over 150 years came under new pressure from various direct sourcing options. This compounded the optimization problem for the buyer (as discussed below) since the risk of supply availability began to influence behaviour. This in turn led to the inclusion of these parallel sourcing options, and the dynamics of supply volumes in them, as part of the optimization.

To the best of our knowledge the field has not been studied elsewhere even though it is likely to be of broad applicability to the marketing of many different farm products and commodities undergoing similar supply chain change. In this setting, this thesis is focused on developing an optimization strategy for a buyer in a mixed auction / direct supply system for New Zealand wool. Considering the contribution of the study specifically, it will help a buyer who is facing the problem of sourcing optimal quantities of wool in parallel sourcing options. In general, the optimization strategy should be helpful to the sourcing of other agricultural commodities that are traded simultaneously via auction and direct supply systems.

Primarily, the exploration and the study involves the *auction system, parallel sourcing options* and *buyer's decision making supported by mathematical models.* We explain the reasons for choosing these aspects as follows.

1.3.1 Parallel Sourcing Options for the New Zealand Wool Clip

In a supply-chain of any agricultural commodity, various sourcing options exist. The sourcing options help commodities to reach the end user from the farm gate. These sourcing options are chosen considering the benefits to the stakeholders involved in the trading of the commodities. While choosing the sourcing options, the stakeholders take into account the associated costs, risk, profitability, competition and other factors of the business. Despite the fact that the stakeholders take into account these factors, it is

unlikely that there is a consensus for a sourcing option among the players of any dynamical system. Whatever the sourcing option for a commodity may be, the stakeholders are always concerned for the value of the commodity, good industry practice and the profitability.

In the context of the strong wools[6] of New Zealand, two main sourcing options are in practice namely, auction and the direct supply system.

An auction system is a transaction between the broker and buyer / bidder where both parties agree to sell and to buy the product for a competitive dynamic price. In the case of the New Zealand wool clip, the auctioneer (the broker) sells the various types of wool on behalf of growers to the buyers. The ownership of the item changes from growers to buyers based on the price in an auction. The price which decides the ownership to the winning bidder is a function of various factors. Further, the uncertainty of the price of a particular wool type is the part of the competition as not all information is known equally by all participating bidders / buyers. This real auction uncertainty is guided by some common knowledge available to all buyers and some private information unique to each bidder. This common knowledge and private information leads to a competition among the bidders and a stage is reached where the ownership of the wool type goes to the winning bidder.

Recently, a new approach - the direct supply of strong wool - has been launched by the largest wool exporter of New Zealand - New Zealand Wool Services International (NZWSI). This approach was developed in consultation with farmer groups and representatives (NZWSI, 2007). The claimed objective of this initiative is to raise the price of New Zealand wool to a sustainable level by ensuring certainty of supply to the exporter through guaranteed commitments from woolgrowers. At the same time the WIN initiative promises to produce a second direct supply route managed by New Zealand's largest broker, PGGW[7].

A key question now for existing buyers is whether the auction system or their own new direct supply initiative controlled by the exporter in question is more beneficial to that

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[6] New Zealand wool clip is mainly categorized into three types of wool; merino, mid-micron and strong wool. Strong wool constitutes 89% of New Zealand wool clip. This research is limited to the study of strong wool.

[7] PGG Wrightson is New Zealand's largest – and only nationwide – provider to the agricultural sector (http://www.pggwrightson.co.nz/company_profile.html).

exporter. It is unlikely that an exporter will have any access to direct supply arrangements controlled by a broker or a competitor. A comparative study will answer questions on the pros and cons of both systems in relation to New Zealand wool exporters and the price dynamics. Comparative models of the two different marketing approaches will be of bottom line significance to an individual large exporting company. If spread across several leading firms, the benefit to the New Zealand economy of greater precision could be several millions of dollars per annum.

1.3.2 Buyer's Decision Making Supported by Mathematical Models

The decision making of a buyer of New Zealand wool is primarily affected by the different sourcing options. Buyers are unsure of securing the optimal proportion of wool from any sourcing option. They are seeking solutions for effective decision making. To make efficient and effective decisions a quantitative model could help. Such a model would help them to understand what is going on in their decision making. A mathematical model would serve as a quantitative model for the extraction of the information that would help to better understand the decision making process and the result of the decision making of buyers. In the context of the New Zealand wool industry, no study has yet been done in developing a model that would optimize the buyer's strategy in sourcing the wool from various sourcing options. In this setting, the study is certainly novel as no such exercise has been described previously.

In sourcing wool via different means, buyers use their past experience only. Exporters or buyers are not reviewing quantitatively the sourcing options and the price formation of the New Zealand wool in these pathways. Further, due to various dynamic factors, there is no consensus between the players of the wool industry as to which will be the win-win situation for growers, brokers and buyers.

Studying the optimization of a buyer's strategy would help in our understanding of the price formation of the New Zealand wool clip. In particular, buyers are the major key players who have good business networks with customers within the country (mills,

manufacturers) and overseas. Extraction of underlying information in sourcing the wool from farm gate to the exporter is important and can be accomplished by developing a mathematical model taking into account the buyers' perspective. Such a mathematical model would facilitate the decision making of a buyer.

A system model that takes into account the factors that are used by the bidders during the auction environment would help to better understand the price of the wool types in an auction system. Within the framework of the system model, sub-models involving theoretical as well as practical models can be developed based on the nature of the factors (quantitative or qualitative). Factors like physical properties of the wool, currency movements, and competition between wool buyers can be used to visualise the system model. Existing auction theory is being used to provide a conceptual framework within which all the factors both quantitative and qualitative must be integrated by the buyer to make a bid in any auction.

The proposed optimization strategy takes into account the governing principles of mathematics which are used by the incumbent practitioners of the wool industry but poorly understood by them. The governing principles of mathematics are applied to the price formation behaviour of the New Zealand wool clip. The price formation dynamics is observed with established mathematical / statistical price prediction techniques. The risk factors associated with these two different marketing systems will be studied. During this optimization model development exercise, the analysis will take into account the auction and direct supply marketing system and determine the optimal use the buyer should make of each system.

Even if, for example, direct supply has a lower base cost structure, an exporter will not use that system to source 100% of his fibre needs. This is because direct supply locks in volume which increases risk in the event of a market downturn. A novel optimization issue to be examined for the first time in this study is the trade off between these two parallel sourcing options together with the "cost of risk" to the exporter as the proportion sourced via each option changes.

In light of such motivations, challenges and possibilities the objectives are presented next.

1.4 Objectives

The study will deal with the development of a model of the optimization problem faced by a buyer in a mixed auction / direct supply situation. To the author's knowledge this optimization problem has never been previously described or studied in the academic literature. Nonetheless, it is likely to be a problem of quite universal generality in relation to the supply of agricultural commodities and other products which are auctioned. Some of these other applications will be researched and described. Further, the optimization strategy will be supported by first developing models of price formation based on the auction system because the auction system is the principal price setting mechanism for both sources of supply. An exploration will be made on the analysis of the trade off between the two supply systems (auction and direct supply) in relation to optimizing the exporters risk/return position.

More specifically, this project will aim to accomplish the following five main objectives:

- *To develop a system model based on a public out-cry English auction (New Zealand wool auction).*
- *To develop a system model of a direct supply initiative (New Zealand wool).*
- *To apply analytical (established mathematical / statistical) methods in developing the price prediction models to better understand the price formation process in auctions of the New Zealand wool clip.*
- *To study the trade off between price and cost in the two supply systems so as to optimize the exporters risk / return position in using both simultaneously to source wool for export.*
- *To formulate mathematical (optimization) models taking into account the associated risk, cost of risk and rebate from buyer's and grower's perspective.*

To fulfil the above objectives an attempt will be made to answer the following research questions.

- Which physical parameters have a significant role in the relative price formation of the New Zealand wool clip?

- What are the major constituents in an open out-cry English auction that define a bidder's perspective as a system model?

- What are the major constituents in direct supply sourcing that define a bidder's perspective as a system model?

- What are the factors that govern the price formation procedure of agri-products in different sourcing options? In particular, for the New Zealand wool clip what factors play an important role in the price formation of it?

- What are the roles of associated cost, risk and margin in the parallel sourcing options of agri-products needed to develop an optimization strategy for a buyer?

- How can a mathematical (optimization) model be helpful for the decision making of a buyer in a mixed sourcing option of agri-products?

- What sort of underlying information can be extracted in terms of parameters from the developed mathematical model?

1.5 Overview of Chapters

The thesis is presented in seven chapters. In the current chapter, an introduction is provided to the New Zealand Wool Industry, mathematical modelling in sourcing agri-products and more specifically an overview on buyer's decision making in sourcing New Zealand wool in the parallel sourcing options, is presented.

Chapter 2 describes price formation in the marketing of New Zealand wool from the system modelling perspective.

Chapter 3 discusses analytical approaches to understand the price dynamics of the New Zealand Wool clip.

Chapter 4 discusses the instability of the auction system – a traditional sourcing option for New Zealand wool.

Chapter 5 presents the development of an initial optimization model and hypotheses for New Zealand wool.

Chapter 6 describes the formulation and generalization of an optimization model for mixed sourcing of agri-products taking into account the rebate decision of buyer as a variable.

Chapter 7 presents the conclusions and recommendation of this study.

Chapter 2

THE MARKETING OF NEW ZEALAND WOOL AND THE PRICE FORMATION PROCESS: A SYSTEM MODEL APPROACH

We presented a big picture of this study in the previous chapter. In this chapter, we attempt to cover a marketing overview, the price formation process and the marketing approaches of the New Zealand wool clip from system model perspectives. To do so, we structure this chapter into five main sections. The first section begins with a marketing overview where we cover production, export and use of the New Zealand wool clip in various applications. In the following section, the price formation process and the constituent physical properties of the New Zealand wool clip are presented. We conceptualise the marketing approaches namely auction and direct supply and present them from a system modelling perspective in the third section. We include an analytical treatment of English auction principles relevant to the New Zealand wool auction. The fourth section is a discussion and the final section provides a brief summary of this chapter.

2.1 The New Zealand Wool Clip: a Marketing Overview

2.1.1 Production, Export and Use of the New Zealand Wool Clip

Wool is New Zealand's ninth largest export earner earning about $1 billion per annum (WIN, 2007). There are three main, widely recognised categories of wool separated according to, fibre diameter – fine, mid-micron and strong. Strong wool accounts for 89% of New Zealand's wool production, fine wool 5% and mid-micron 6%. In this study, we focus on the supply-chain of strong wool. Strong wool is mainly used for floorcovering – carpets and rugs. Approximately 90% of all wool grown in New Zealand is exported. To be more specific, New Zealand produces 14% of world wool production clean equivalent (Table 2.1) and it provides 20 % of the supply to the export market worldwide (Table 2.2).

The New Zealand wool clip is exported mainly to China (25%), UK (13%), India (10%) and smaller amounts to other countries (Table 2.3). The New Zealand wool clip is primarily used for interior textiles (68%), apparel (30%) and other uses (2%). Figure 2.1 shows the use of the New Zealand wool clip in different products.

Table 2.1   World wool production clean equivalent, 2005

Country	Percentage
Australia	28
Others	28
China	14
New Zealand	14
Argentina	3
India	3
Iran	2
South Africa	2
Turkey	2
UK	2
Uruguay	2

Source: IWTO % volume

Table 2.2   World wool exports

Country	Percentage
Australia	52
New Zealand	20
Others	7
Germany	5
China	4
UK	4
Argentina	2
Uruguay	2
Spain	2
France	1
Belgium	1

Source: (Global Trade Information Services, 2007), % volume, year ending 30 June 2006

Table 2.3   Top ten export destinations of New Zealand wool clip

Country	Percentage
China	25
UK	13
India	10
Italy	9
Belgium	8
Germany	6
Australia	5
Japan	4
Turkey	3
USA	3

Source: Meat and wool New Zealand, % volume, year ending September 2006
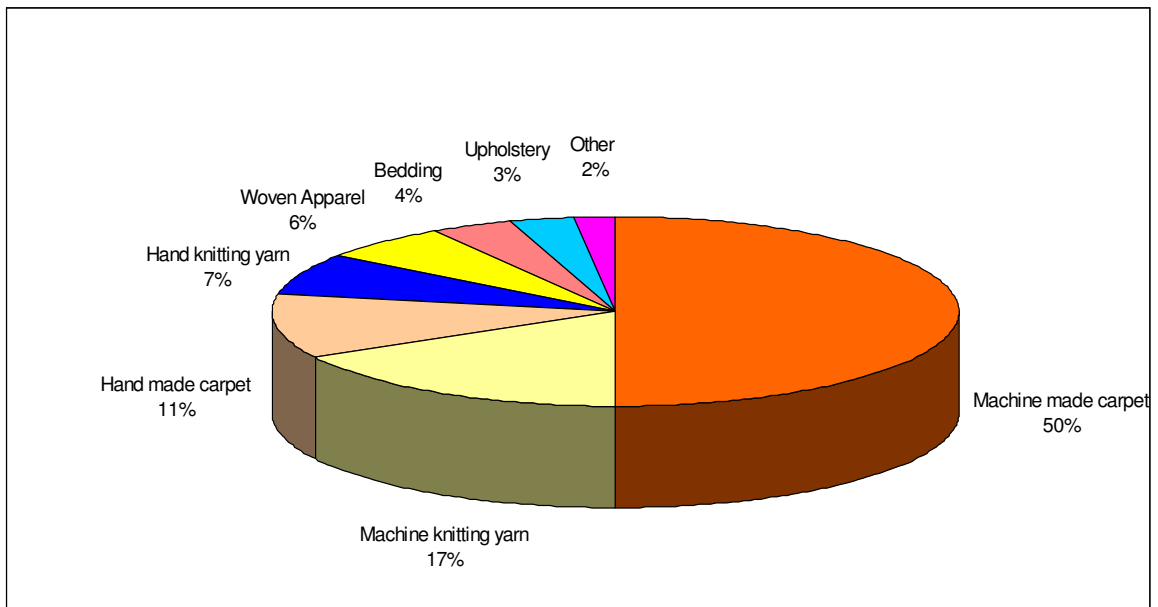
Figure 2.1 Use of the New Zealand wool clip in different products - adapted and modified from WIN (2007).

The quantitative information that we presented in the above Tables (Table 2.1, Table 2.2 and Table 2.3) and depicted in Figure 2.1 help us to understand New Zealand's position and contribution in global wool marketing. Such marketing follows certain pathways from farm gate to the end user.

2.1.2 Pathways of New Zealand Wool Marketing

There are established pathways for New Zealand wool marketing. Like the marketing of any other agricultural commodity wool has to travel a path from its origin to reach the end user. Such pathways of wool marketing involve different stages and different roles of various players. The pipeline of wool supplying the industry consists of the following stages (Wood, 2006):

- sheep growing
- wool harvesting
- sampling and storage in a wool broker's store
- pre-sale testing of individual lots
- sale to an exporter at auction / or by private treaty from a wool merchant
- wool blending & scouring
- post sale testing of amalgamated lines ready for export
- shipping to mill (New Zealand or overseas or merchant for further blending)
- spinning into yarns
- weaving, knitting or tufting into products.

Various players are involved in performing the above tasks. Generally, growers, brokers, private merchants, auction centres and exporters / buyers are the key players of the wool pathways (Refer to Figure 2.2).
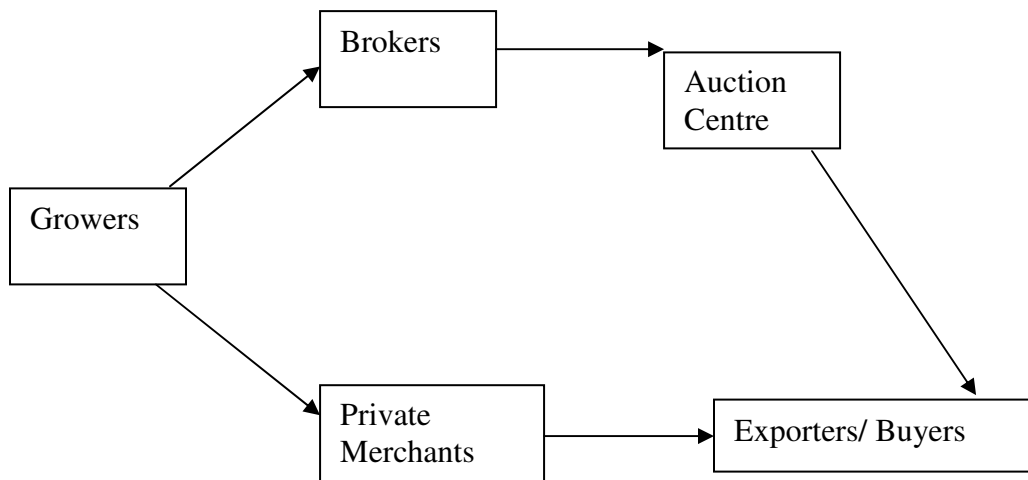
Figure 2.2 Wool pathways from farm gate (growers) to exporters / buyers: an overview of the key players.

Among the key players, the brokers' and buyers' task is important in relation to price formation. Brokers facilitate the sale of growers' wool through the auction system and more specifically, they:

- receive wool from the grower
- provide technical and financial services to the grower
- arrange the auction
- store wool until sold
- assemble bales into lots, each lot averaging from six to seven bales and typically ranging between three and nineteen bales
- arrange for raw wool testing
- appraise the wool subjectively
- sell wool on behalf of the grower and invoice the buyer
- provide feedback to the grower on the quality of the wool and a market appraisal
- may store wool after sale at a cost to the buyer
- deliver wool to the dump or the local processor
- guarantee payment.

(Champion & Fearne, 2001; McKinsey & Company, 2000)

On the other side of the transaction, wool buyers act on behalf of the processing / exporting sector. Buyers receive orders for types of wool (very often a blend of several individual growers' lots) of a particular specification from a processor and agree to supply the wool for a certain price. Buyers buy wool mostly at auction; however, they also try to find wool at the lowest price so that they can increase their own margin irrespective of the trading system. The trading system could be an auction or other means for example private merchant or direct contract to the growers. On top of that, the buyers perform the following functions (Dolling, 2000):

- accumulate wools to fill a processing consignment
- combine wools to meet specification
- guarantee the quality of the wool with the carriage of risk

- arrange for testing of scoured parcels of wool

- arrange for transport and handling

- organise or provide financial facilities such as credit, part- and extended payment

- arrange international trading contracts

- hedge interest rates and currency associated with international transactions

- sell scoured wool blends rather than individual grower lots (most exporters do this).

The brokers / auction centre / exporters route plays a key role in price formation since it is a public process with open flow of price information. The private merchants often rely on auction prices to set their purchase price to the grower.

New Zealand wool marketing has been running for many years with the process mentioned above, however, there are challenges in wool marketing which are presented next.

2.1.3 Challenges in Wool Marketing

Marketing of any agricultural commodity faces challenges and of course there are opportunities for new marketing strategies. In the context of the wool industry, the challenges faced are:

- decreasing numbers of sheep due to competing land uses

- other fibre alternatives

- mixed subjective classification / objective specifications of wool

- over servicing at each stage – too many players

- decreasing use of wool as a global commodity.

On top of the above issues, there are some fundamental issues like whether wool should be marketed as a commodity[8] or as a niche product[9] (Champion & Fearne, 2001; Dolling, 2000) ? What would be the optimal way to market wool? To answer some of these questions, initiatives at a policy level have been started.

We presented an overview of marketing of the wool clip and it's pathways, the players' role and the challenges in wool marketing. These all lead us to further understand the price formation procedure for the New Zealand wool clip. This is presented next.

2.2 Price Formation: Physical Properties of the New Zealand Wool Clip, Growers and Buyers' Perspectives

Primarily the relative price of the differing New Zealand wool type depends on the physical properties of it (wool quality factors). On top of that, growers' perspectives as well as buyers' perspectives towards the New Zealand wool do matter.

2.2.1 Physical Properties of Wool

Wool has a number of physical properties, also called quality factors, that determine its commercial value as a textile fibre, the ease with which it can be processed into yarn and the products into which it can be converted (Angel, Beare, & Zwart, 1990; G.A. Carnaby, 1983; G.A. Carnaby, Corrigan, Agar, Elliott, & Maddever, 1983; Wood, 2003, 2006).

These properties vary for wools obtained from different:
• parts of the body of a sheep
• individual sheep in the same flock
• strains of sheep within a breed

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[8] a commodity is traded in its original form without processing or adding value
[9] a niche product is traded after processing i.e. after adding value on it

• ages of sheep within a breed

• breeds

• environments (*i.e*. climate, terrain, pasture etc.)

• farming properties

• shearing regimes (timing, frequency, preparation procedures)

• geographic regions

• seasons of the year

The physical properties which are considered to be the major determinants in price formation of the wool are colour, diameter, vegetable matter, length, bulk, and medulla. These properties are "necessary and sufficient" in defining the vector space of wool properties (G.A. Carnaby, 1983). In the case of the New Zealand wool clip, objective measurements of the physical properties can be obtained from testing houses. There are two testing houses (SGS[10] and NZWTA[11]) in New Zealand which can carry out such tests for greasy wool as well as scoured wool and issue test certificates. The tests are based on the specifications set out by the International Wool Trade Organisation (IWTO[12]).

2.2.1.1   Colour

Among the physical properties of wool, colour can be described using three parameters, namely; X, Y, and Z. This trio of measurements are referred to as the tristimulus values, a common term used in colour science. From the wool trade's perspective two derivative parameters are significant (Y and Y-Z). Y is brightness (i.e. reflectance) and Y-Z is used to characterize yellowness. In general, the whiter (brighter) the wool, the better price it will demand and the more yellow the wool, the less will be the price in the market. Figure 2.3 below illustrates the different colour of wools and their reaction towards white light.

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[10] SGS Wool Testing Services (http://www.wooltesting.sgs.com) based in Wellington, New Zealand

[11] New Zealand Wool Testing Authority Limited (http://www.nzwta.co.nz) based in Napier, New Zealand

[12] IWTO (http://www.iwto.org) is the international body representing the interests of the world's wool-textile trade and industry.

When white light shines on wool, certain amounts of red green and blue are absorbed, depending on the colour of the wool

A yellow wool absorbs more blue than red and green

$X \sim Y > Z$

A dull grey wool absorbs similar amounts of red, green and blue

$X \sim Y \sim Z$ (all low)

A white wool absorbs only a small amount of red, green, blue

$X \sim Y \sim Z$ (all high)
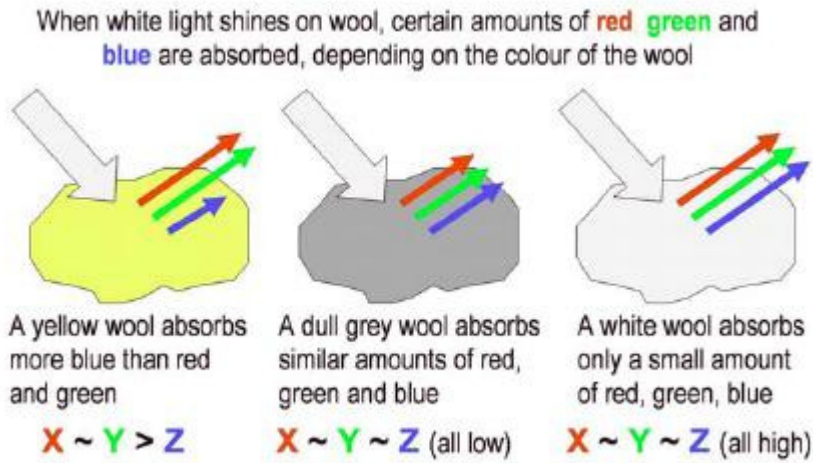
Figure 2.3 Different colour of wool and their reaction to white light (adapted and modified from Wood, 2003).

2.2.1.2   Diameter

Fibre diameter is possibly the most important property of wool since it determines its suitability for certain end-uses (Angel et al., 1990; Teasdale, 1995; Wood, 2003, 2006). Fibre diameter is also called micron in day to day use language. However, micron is the unit for fibre diameter, where 1 micron = 1 millionth of a metre (or one thousandth of a millimetre). The finer the micron, the higher the price in the market and *vice versa*. For example; merino (finer wool) gets better prices in the market than strong wools (coarser wool). The micron of the wool depends to a large extent on what breed the wool came from. Because of the inherent variability of wool, any sample of fibres will have a range of diameters (from 10 – 70 microns for individual fibres). On the other hand, finer wools are weaker and generally more difficult to spin than coarser wools (Wood, 2003).

The price diameter curve is not linear. For strong wools, often used in carpets, (35 – 50 microns) diameter is not a major factor in price formation. But, in apparel, micron affects softness and price increases dramatically as the micron reduces below 25. Between 25 and 35 microns the fibre is used in a variety of products with increasing premiums for fineness as the micron decreases.

2.2.1.3   Vegetable Matter

Vegetable matter (VM) in wool is indicative of contamination of the wool. It consists of burrs, grass seeds, thistles, hard heads, straw, chaff and twigs that stick to the fleece when the sheep is grazing (Teasdale, 1995). Procedures used to achieve complete removal of VM from the wool depend on the type of matter in the wool. Some types of VM are more problematical than others, in terms of (a) the difficulty of removing them during processing and (b) their potential impact on the quality of the finished product. The presence of certain types or quantities of VM may require carbonising of the wool (in rare cases in New Zealand wools), in which case the wool becomes downgraded in value

and is only suitable for woollen processing. Very slight levels of VM can sometimes be tolerated in carpet manufacture.

2.2.1.4   Length

Length largely determines the processing system by which the wool will be manufactured, and the properties of the resulting yarn. Rather than measuring individual fibres, the fibre length and strength of fleeces can be determined by measuring the average length and strength of a representative set of staples (Wood, 2003). Two methods are used for this. One is *staple length and strength* (mainly used for fine wools) and the other is *length after carding* (mainly used for strong wools).

Length after carding measures the fibre length distribution in a sliver after simulated carding. This test was developed in New Zealand specifically for strong wools. Fibres break in carding especially if they have a weak region known as a "break" in the staple. A break is usually associated with a period of nutrition stress such as occurs in winter or during lambing.

Fibre diameter is the most important characteristic in fine wools, while the length is of equal importance in coarser wools (Teasdale, 1995)

2.2.1.5   Bulk

The bulk, or bulkiness, of wool is related to its crimp characteristics and is a measure of its ability to fill space and have a springy handle (Wood, 2006). Bulk is a particularly important property in selecting wools for knitwear and for machine-made carpets. Bulk is closely associated with wool lustre (or shine), generally, the higher the lustre, the lower the bulk of the wool. Lustrous wools are undesirable in most types of machine-made carpets, but are acceptable or even preferred in hand-made rugs.

2.2.1.6 Medulla

Wool fibres having hollow cells which are not composed of solid keratin are said to be medullated (Wood, 2003). The degree of medullation in wool can vary, with *kemps* being the most medullated fibres (Wood, 2006). Medullation is generally unwanted from a processing point of view. Because of the relatively stiff nature of medullated wool fibres when bent, and the low tensile strength, they tend to break more readily in carding, with their fragments being lost as waste. Medullated fibres also have a lower apparent colour yield and show up as relatively whiter fibres after dyeing. Although exploited in some products e.g., Harris Tweed, this affect is generally regarded as undesirable. For these reasons, medullation has been eliminated from most sheep breeds by selective breeding over many years (Wood, 2003).

2.2.2 Growers' Pricing Perspective

The importance of the physical properties of wool in relation to price of one wool versus another, i.e. "relative price" is highly significant from the growers' perspective. The formed price is a function of these physical properties. Generally, the formed price is expressed in terms of relative price. This is a ratio between the price to the mean price of all wools sold at a particular time.

Relative price of the wool = f (physical properties of wool clip).

To get a high relative value of the wool, growers can control some of the physical properties. Properties like length, vegetable matter and colour can be controlled via management while diameter, bulk and medulla can be controlled by genetic breeding. The growers try to produce the wool clip of their choice by controlling these factors. However, these controls on sheep are also dependent on geographical location and other farming factors.

2.2.3 Buyers' Pricing Strategy

The pricing strategy of buyers depends on the physical properties of wool. These physical properties are taken into account by the bidders or buyers in any of the wool trading systems (auction or direct supply).

In the case of auction bidding, the bidders have most of the quantitative information of the wool clip before going to the auction. These quantitative numbers of the physical properties such as diameter, colour, vegetable matter and length help the bidder to figure out the specific types of the wool and hence the valuation for each type.

Different physical properties have different important characteristics in different types of wool. The wool types are treated differently for different ranges of values for colour, vegetable matter and length. For example, fibre diameter is the most important characteristic in fine wools, while the length is of equal importance in coarser wools (Teasdale, 1995).

On top of these issues, the pricing perspective of buyer or bidders is guided by the orders received from the overseas customers and the manufacturing mills within the country. The pricing is thus to some extent controlled by wool trading (marketing) which is described in detail in the next section.

2.3 Marketing Approaches: Auction and Direct Supply

2.3.1 New Zealand Wool Auction: an English Open Out-cry Auction

The New Zealand wool auction is a public open out-cry auction which has been running for the last 150 years. A total of 45% of New Zealand wool clip is currently traded via

auction (WIN, 2007). The auction runs using English auction principles. The procedure of auction operation and participation of the bidder is similar to an online English auction. However, the difference is that the bidders are physically present there to make a bid for the particular New Zealand wool types of interest to their business. Wool is available from over 3000 types of wool produced in New Zealand. This broad range of wool types reflects the different breeds, age, and place of origin on the sheep's body. Further, wool is separated and differentiated by various types of possible contamination from vegetable matter to cotts. It is also produced at different locations throughout the country. From the broad range and the production in different locations is derived the diversity inherent in the New Zealand wool clip. Such diversity resembles a complex system. The bidders in the wool auction follow the traditional ways of the bidding system. Though the bidding procedure is traditional, the live nature of the New Zealand wool auction allows the bidders to get real time feedback via their offices on some major factors like currency fluctuations as the auction is in progress.

As can be seen from the Christchurch wool auction centre, the only centre in the South Island of New Zealand, there are around forty bidders registered for bidding purposes. However, not all of the registered bidders are actively involved in buying a particular lot of wool via auction. The number of bidders during auction hours is uncertain and hence it follows the "independent –private- value" (IPV) model and "common value" (CV) model as in other English auction environments (Klemperer, 2004; R.P. McAfee, 2002; R. Preston McAfee & McMillan, 1987). In practice, the wool market is controlled by quite a small number of exporters.

Considering the mathematical assumptions in any auction environment, the Revenue Equivalence Theorem (RET)[13] has a significant role. The RET, in general, predicts that the seller can expect equal profits on average from all the standard as well as non-standard types of auctions (Klemperer, 2004; P. Milgrom, 2004). As the RET is a

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[13]The first real revenue equivalence theorem is due to Riley and Samuelson (1981) and Myerson (1981). One of the major findings of Auction Theory is the Revenue Equivalence Theorem, which states that any allocation mechanism/auction in which (i) the bidder with the highest type/signal/value always wins, (ii) the bidder with the lowest possible type/value/signal expects zero surplus, (iii) all bidders are risk neutral and (iv) all bidders are drawn from a strictly increasing and atomless distribution will lead to the same revenue for the seller (and player i of type v can expect the same surplus across auction types).

fundamental basis for auction theory, it can be assumed that if the bidders are risk neutral the seller would not benefit from such risk neutral bidders. However, on the other hand, if the bidders are risk averse the seller would expect more benefit from such bidders. The risk averse bidders are more volatile than the risk neutral bidders. Further, as discussed above, every bidder may have to follow two models (IPV and CV) simultaneously during the time of bidding.

2.3.2 Mathematical Assumptions Associated with New Zealand Wool Auction

We consider the New Zealand wool auction from the bidder's / buyer's perspective and relate it to the existing mathematical formulation of the English auction principles. We follow as closely as possible the standard notation of auction theory papers without loss of generality while developing this formulation. The formulation considers two assumptions which are relevant to the New Zealand wool auction. The first one is whether RET holds true in the case of the uncertain number of bidders in an English auction environment. And, secondly, what would be the expected price of the bidder in any English auction environment?

The suitability of RET in the case of uncertain numbers of bidders relevant to the New Zealand wool auction is presented.

We follow the proof based on Krishna (2002)[14].

Let $\mathbb{N} = \{1, 2, ..., N\}$ denote the set of potential bidders and let $A \subseteq \mathbb{N}$ be the set of actual bidders. Let us consider that an actual bidder $i \in A$ and let p_n denote the probability that any participating bidder assigns to the event that he is facing n other bidders. Thus, bidder i assigns probability p_n that the number of actual bidder is $n+1$. The

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[14] The detailed background on order statistics is presented in Appendix A.

probabilities p_n do not depend on the identity of the bidder or on his value. It is also important that the set of actual bidders does not depend on the realized values (Krishna, 2003). As long as bidders hold the same beliefs about the likelihood of meeting different numbers of rivals in an auction environment, the proposition holds that the expected payment of a bidder with value zero is zero, and yields the same expected revenue to the seller provided the values drawn are *iid* -independently and identically distributed.

Let us consider a standard auction a and a symmetric and increasing equilibrium β of the auction. It should be noted here that the bidders are unsure about the number of rivals they have to face, β does not depend on n. Let us assume that the expected payoff of a bidder with value x who bids $\beta(z)$ -strategic bid- instead of the equilibrium bid $\beta(x)$. The probability that he faces n other bidders is p_n. In this case, the bidder wins if $Y_1^{(n)}$, the highest of n values drawn from F, is less than z and the probability of this event is $G^{(n)}(z) = F(z)^n$. The overall probability that he will win when he bids $\beta(z)$ is therefore,

$$G(z) = \sum_{n=0}^{N-1} p_n G^{(n)}(z) \qquad\qquad \textbf{2.1}$$

His expected payoff from bidding $\beta(z)$ when his value is x is then

$$\prod{}^a (z,x) = G(z)x - m^a(z) \qquad\qquad \textbf{2.2}$$

This shows that in the situation of uncertain number of bidders RET also holds true.

Now, we present the expected price of the bidder in an English auction environment. Let us take a case of three bidders having actual private types, $x_1 = a, x_2 = b, x_3 = c,$ respectively with $a < b < c$, after (Menezes & Monteiro, 2005). The implicit assumption is that the price starts at zero and rises continuously. The first player to drop out is player 1 at price p_1 such that:

$$E[V_1 | x_1 = a = X_2 = X_3] = p_1 \qquad \textbf{2.3}$$

Prior to bidder 1 dropping out, the expected values of bidders 2 and 3 were given, respectively, by:

$$E[V_2 | x_2 = b = X_1 = X_3] \qquad \textbf{2.4}$$

and

$$E[V_3 | x_3 = c = X_1 = X_2]. \qquad \textbf{2.5}$$

After bidder 1 drops out, these expected values are revised in the following way:

$$E[V_2 | x_2 = b, E[V_2 | X_1 = X_2 = X_3 = a] = p_1] \qquad \textbf{2.6}$$

and

$$E[V_3 | x_3 = c, E[V_3 | X_1 = X_2 = X_3 = a] = p_1] \qquad \textbf{2.7}$$

The price keeps rising until the final price p_2 and the winner is determined as follows:

$$E[V_2 | x_2 = b = X_3, p_1] = p_2 \qquad \textbf{2.8}$$

The value of the object to player 3 prior to knowing p_2 is

$$E[V_3 | x_3 = c = X_2, p_1]. \qquad \textbf{2.9}$$

Bidder 3 wins the auction at price p_2.

If we generalize for n players, the expected price in an English auction environment is,

$$P^E = E[E[V_1 | X_1 = y_1 = Y_2, Y_3, ..., Y_n] | X_1 = x > Y_1] \qquad \textbf{2.10}$$

The above formulation shows that established assumptions of English auction environment are true for New Zealand wool auction. Now, we present next a system model perspective of buyer.

2.3.3 Wool Auction from the Buyer's (Bidder) Perspective: a System Model

A system model can provide insights which would be difficult or impossible to obtain by other means, and it provides the capability of exploring relationships that cannot be explored in any other way (Schwarzenbach & Gill, 1984). To present New Zealand wool auction in a systemic view from a buyers' perspective an overall model and supporting sub-models are conceptualised (Figure 2.4).

The integration of the overall model and segmented sub-model (as shown in Figure 2.4) helps to better understand the price dynamics of the New Zealand wool clip. The overall model presented in Figure 2.4 is flexible enough to accommodate the decision making behaviours of a bidder in any New Zealand wool auction. Two stages of the model can be categorized: *prior to auction* and *during and after auction.*
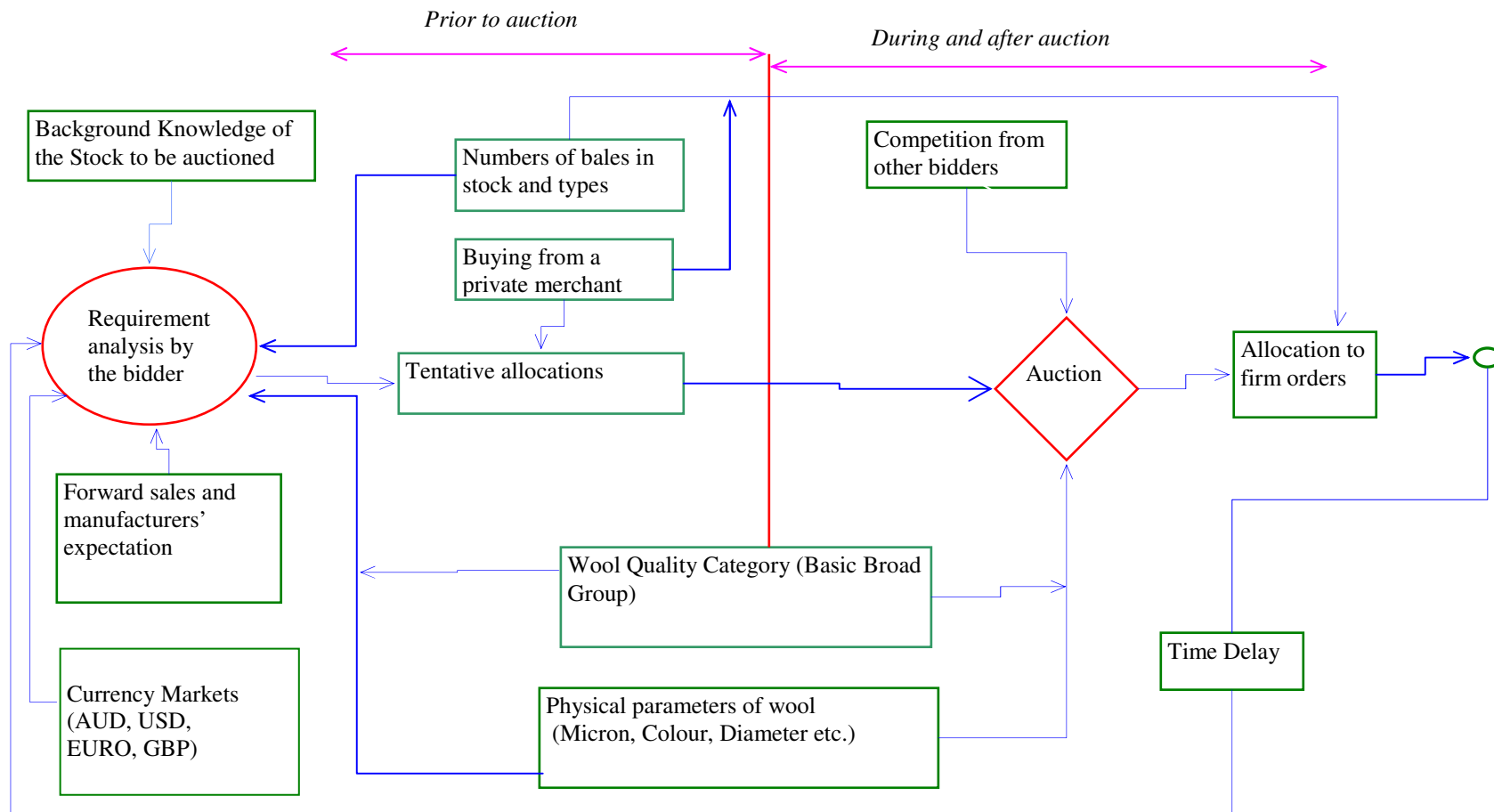
Figure 2.4 An overall model showing the decision making behaviours of a bidder in the New Zealand wool auction environment: a systemic view.

As explained in Milgrom and Weber (1982), the English auction has many variants. In particular, three types of English auctions: the ascending-price English auction, *the English open out-cry auction* and the Japanese button auction are in use (Steiglitz, 2007). The New Zealand wool auction is the *English open out-cry auction* where jump bids – bids above the level being solicited by the auctioneer – are allowed. The New Zealand wool auction is idealized as follows: prior to auction day, the bidders are given the opportunity to inspect a sample of the wool lots going to be auctioned. Further, the bidders are provided with catalogues of wool to be auctioned. In the catalogues, information such as wool quality factors (diameter, colour, vegetable matter, length of the wool staple) is provided. Prior observation helps to achieve the requirement analysis for the bidder. Prior to auction, the bidders take into account many factors. Likewise, during and after auction the bidders take into consideration the same factors. Three major factors play a role in both situations: 'physical parameters of wool', 'wool quality category' and 'number of bales in stock and types'. These factors are common to the bidders in competition. The model generated from these factors is common to all bidders. In auction theory terms, the distribution generated by such common factors is a common value model. From Figure 2.4, it can be seen that the bidder with a requirement analysis in his mind competes in the auction. This leads to the assumption that like other English auction types, the bidders have common values for the wool types they are going to buy. With their common values, they compete in the auction environment and the bidder chooses whether to be active at the start price (p_0).

From the modelling perspective, the New Zealand wool auction can be modelled as a continuous process in which each successive bid is an arbitrarily small increment above the previous bid (Klemperer, 2004; P. Milgrom, 2004). Further, jump bidding is allowed in the auction and hence a stochastic process (for example, a Markov process) in continuous time can be applied to characterize the price behaviour of wool buyers (Chou, Lin, Chen, Ho, & Hsieh, 2007).

In addition to this, particularly for the wool auction, five specific factors, which are independent to the bidders, determine the price of the wool in an auction (Aryal, Kulasiri,

& Carnaby, 2008). The five factors are different to all the bidders and not known to each other. In other words, the price of the wool in an auction is a function of these five factors:

Price of the wool in any auction = f (Stock held, forward sales position, available wool types in specific auction, currency factor, seasonality of supply).

These five factors are the major constituents that contribute to make the independent-private-value model different for each bidder. With the independent-private-value model and common value model in their minds, bidders participate in the auction environment. These two models are simultaneously used by the respective participating bidders. As the auctioneer raises the price, bidders drop out one by one. However, any bidder can come back in up to the final knock of the hammer, finalising the sale.

As said before, the independence of these five factors contributes to setting the price of each wool type in the auction. The rate of change of price with respect to these five independent variables can be categorised as follows:

Let us suppose,

the resulting price $=u$, stock held $= sh$, forward sales position $= fsp$, available wool types in specific auction $= (w_1,......w_n)$, currency factor $= c$ and seasonality of supply $= ss$, then,

$$u = f(sh, fsp, w_1,...w_n, c, ss)$$

$$du = \left(\frac{\partial f}{\partial sh}\right) d_{sh} + ... + \left(\frac{\partial f}{\partial ss}\right) d_{ss}$$

$$u = \int \left(\frac{\partial f}{\partial sh}\right) d_{sh} + ... + \int \left(\frac{\partial f}{\partial ss}\right) d_{ss}$$

2.11

The above equation **2.11** describes the rate of change of price during the auction hours from the perspective of participating bidders.

Further, we can think of the individual effect / relationship of five independent variables to the price at the auction (*u*) as;

- If *sh* is more then *u* is less

- If *fsp* is more then *u* is more (buyer tempted to buy more wool to fulfil *fsp*)

- If wool types are many then *u* is less (it depends on the quantity – more quantity – more price)

- If *c* (NZD high against USD), then *u* is less

- If *ss* is high then *u* is less.

Each box shown above (in Figure 2.4) can be treated as a sub-model of this system model development exercise. All the boxes are explained briefly as follows:

2.3.3.1   Physical Parameters of the Wool

The physical parameters of the wool have a major role in determining the price. These physical parameters are taken into account by the buyers / bidders in any of the wool trading systems. In the case of auction bidding, the bidders have most of the quantitative information before going to the auction. These quantitative numbers of the physical properties help the bidder to figure out the specific types of the wool and hence the valuation for each type. For example, if diameter is less than 22.5 micron then the wool might be categorised as merino, if diameter $\geq$ 22.6 to 31.5 micron then it might be categorised as mid-micron, if diameter $\geq$ 31.6 to 35.0 micron then the type might be described as fine crossbreed and if diameter $\geq$ 35.1 micron then the type might be categorised as coarse crossbreed. Similarly, the wool types are treated differently for different range of values for colour, vegetable matter and length.

In addition to the quantitative information, some qualitative factors which are not known by the bidders beforehand will also have role in determining the price of the wool types in any auction. For example: "Faults" are detrimental to price and reflect VM, cottedness or other features which involve extra processing costs. However, some other factors for example, style[15] (not one of the 6 necessary and sufficient properties but a characteristic dependent upon them) are related to value and act positively via these independent variables to increase the price of the wool.

2.3.3.2 Wool Quality Category (Basic Broad Groups)

The differentiation of the wool into a basic broad group helps the bidder to think about the end use of it and hence the value for it. Generally, from the various wool types the three basic broad groups used are Merino, Mid-micron and Cross-bred. This differentiation helps the bidder to do their requirement analysis and come up with some bidding values in the auction environment for each broad group. For example, Merino wool is mostly used for apparel and has a high price. The Mid-micron group is used for apparel as well as upholstery whereas cross-bred is widely used for carpet manufacturing. The basic broad groups have effects on requirement analysis as well as at auction (G.A. Carnaby et al., 1988; Maddever, 1989; I.P. Stanley-Boden, 1985; I.P. Stanley-Boden et al., 1986).

2.3.3.3 Currency Markets

Another major factor in determining the price of the wool in the auction is the currency market. Four major currencies (Australian Dollars, US Dollars, Euro & Great Britain Pound) are being compared against the New Zealand dollar by the bidder. During the auction day, the fluctuations in the currency market are taken into

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[15] Style is not independent. It is made up of bulk (crimp), colour, diameter etc.

account by the buyers. The buyers update the conversion rate in real time via their contacts (in office).

As the auction is conducted in New Zealand dollars the bidder does a requirement analysis keeping in mind that the stronger the New Zealand dollar the dearer it is for the customer overseas. A rising New Zealand dollar leads directly to lower bids.

To see the effect of different currencies in the price of a particular type of wool, a trend between the currencies and price of the particular type of wool can be observed for a certain period. The trend would help a better understanding of the relationship between the price of certain wool types and the currency. The general trend will be that the higher the New Zealand currency the lower will be the price of the wool. However, it might not be the case at a certain point of time and hence the price may also increase with an increasing the currency which is against the theoretical condition. These points may be helpful in an investigation where there is influence of other factors like demand, supply and many others on top of the currency factors.

But all other things being equal, the price a buyer is prepared to pay rises and falls in direct proportion to the currency movements.

2.3.3.4 Forward Sales and Manufacturers' Expectation

An important factor which plays a significant role in determining the price of the wool in any auction is 'the forward sales and manufacturers' expectation' as held by the buyer. This depends on the following three major factors:

- customers' requirements
- seasonality of wool availability
- current position limitations

These three factors are not available in a quantitative format and hence a theoretical model will better represent the price of the wool in any auction due to these factors.

2.3.3.5 Background Knowledge of the Stock to be Auctioned

To have background knowledge of the stock to be auctioned bidders need to be aware of the following two things:

- seasonality of availability
- Roster set up time and wool availability

In different seasons different wool types are available. For example, Merino wool is mainly available from July to October. Mid-micron wool is mainly available from May to August and the Cross-bred wool mostly all year around. This availability information for corresponding seasons provides background knowledge of the stock to be auctioned to the bidders. Further, Roster set up time and wool availability also helps in figuring out background knowledge of the stock to be auctioned. For example, the roster is set up early in the season by the broker and exporter- July to June (Season).

2.3.3.6 Buying from a Private Merchant

As explained in section 2.1.2, buying wool from a private merchant is an alternative physical pathway of wool from the farm gate to buyer. In this system, the wool goes from growers to buyers via a private merchant. No brokers' involvement exists here. Once a buyer buys same wool from a private merchant, the purchasing of wool via auction will be affected and hence the price of the wool going to be bid for by such buyers will be affected. In addition to that, all the buyers keep in mind how much stock they have in their store and what is the forward sales position. Both the stocks and forward sales position affect auction purchase volume and types.

2.3.3.7 Numbers of Bales in Stock and Types

The quantity of wool and the types held in a buyer's stock help determine their purchasing requirement analysis and possible allocation to firm orders, balanced against what is the forward sales position. Both the stocks and forward sales position affect the volume and types of wool for purchase by individual companies.

2.3.3.8 Tentative Allocations

Tentative allocation by buyer is like a split function, where after doing all the requirement analysis in his/her head, the buyer with his position in mind participates in the auction. Basically, stock and forward sales position are considered by the buyer while analyzing the tentative allocation.

2.3.3.9 Competition from Other Buyers

There are altogether 37 buyers listed in the auction centre in Christchurch, South Island, New Zealand. Not all listed buyers in the auction centre are active. Almost 80% of the wool clip is exported by six active buyers. The remaining 20% of the clip is basically traded by 31 buyers (Ching, 2007). There are currently six to nine main buyers. A sample market report presented in Appendix C shows the nine main buyers in Christchurch auction centre for a specific auction day. These main buyers are:

- New Zealand Wool Services International Ltd
- J.S. Brooksbank & Co Australasia Ltd
- Dawsons
- Segard Masurel (NZ) Ltd
- G. Modiano (NZ) Ltd
- Bloch & Behrens Wool (NZ) Ltd
- Fuhrmann NZ (1983) Ltd
- J Marshall

- G Modiano

Competition among the active buyers is increased by uncertainty of each others position and their respective contact with customers.

2.3.3.10 Allocations to Firm Orders

After buying the wool from auction and private merchants the buyer will make a decision when allocating to firm orders. The number of bales in stock and types will be taken into account when allocating to firm orders. The export of the New Zealand wool clip is to over thirty countries and hundreds of clients.

A system model and the respective sub-models from a buyer's perspective in an auction environment leads to the alternate marketing approach – direct supply initiative – which is presented in the next section.

2.3.4 Direct Supply Initiative (Forward Contract)

In the direct supply initiative, the parties involved in supplying and receiving the product make an agreement to buy or sell the product (which can be of any kind) at a pre-agreed future point in time. Among the many supply-chain methods, direct supply is used in practice for various commodities (Banker & Mitra, 2007; Jackson, Quaddus, Islam, & Stanton, 2006; Shi, Irwin, Good, & Dietz, 2005; Shi, Irwin, Good, & Hagedorn, 2004; Townsend & Brorsen, 1997). Townsend and Brorsen (1997) studied cost of forward contracting in hard red winter wheat and concluded that forward contracting is more costly than many people realise. Similarly, Shi et al. (2004) reported the cost of forward contracting of corn in the USA. The result from this study showed that the cost could vary across regions. In another study by Shi et al. (2005) a risk premium analysis of the forward contract was observed for wheat in the USA. It was observed that the estimation

of risk premium is dependent on forward basis. The forward basis is the difference between the implied forward price and the settlement of the nearby futures contract (Shi et al., 2004).

In the case of wool, practices of direct supply in the UK are reported in Bell, Brooks et al.(2007). The study even documented the existence of forward contracts for the sale of wool in medieval England around 700 years ago. Jackson et al.(2006) presented a result from a study in the case of Australian wool. The study found that producers are willing to try selling methods that shorten the wool supply-chain and they also favoured relationship-based systems.

In the New Zealand context, although isolated instances have always occurred, the forward contract supply-chain was adopted in areas of merino wool marketing on a wide scale following the release of the McKinsey report. However, in the areas of strong wool, it has only recently been introduced on a significant scale by NZWSI in the market (Ching, 2007; NZWSI, 2007). The WIN initiative is also likely to produce a competing direct supply channel focussed on the leading broker PGGW.

2.3.5 Direct Supply from the Buyer's Perspective: a System Model

A direct supply initiative in the area of strong wool – " the Purelana concept" - has been developed by NZWSI to initiate direct supply from New Zealand woolgrowers to the market (NZWSI, 2007). NZWSI has stated that they wanted to differentiate the wool supplied through this initiative from wool sourced through all other channels. The Purelana brand which is a registered trade mark has been developed exclusively by NZWSI to provide New Zealand scoured wool product with a clear point of difference in export markets. With a three year exclusive supply contract, woolgrowers who are signed up to Purelana will receive an annual forward market price, a premium pool payment and a loyalty rebate. Farmers can thus accurately budget their net wool returns. NZWSI have expressed the hope that the initiative will result in better long term returns for growers. According to NZWSI (2007) the principles claimed for the Purelana concept are:

- to market New Zealand wool to the highest quality standards, processed in the most modern wool scouring plants, which are 100 percent owned by NZWSI
- to produce a product that adheres to the strictest environmental requirements
- to investigate a supply and marketing process that will deliver sustainable advantages and returns to all participants
- consistency of delivery quality to specifications

A second integrative system model (the first one is about auction in the previous section) is presented which contains the overall model of the direct supply initiative marketing system. The integration of different parts of the model will lead to an integrative system model which will help a better understanding of the price dynamics of the New Zealand wool clip in the direct supply initiative marketing system. While analysing different parts of the model, costs are calculated in each part of the pathway (a detailed comparison of costs will be presented in Chapter 5.

As presented in Figure 2.5 the market price of a certain wool type is determined by two factors; the auction, and buying from a private merchant. Having knowledge of the auction price of the certain type of wool, the buyer approaches a service provider (Private merchant or Broker). The service provider communicates with the growers and the buyers (two way communication). Thus, a decision to contract the wool is completed. The physical pathway of wool follows from two sides. Farmer or grower and service provider both send the wool direct to the wool scour storage. The wool in the scour storage then goes direct to washing and is then linked with client marketing initiated by NZWSI. The scoured wool product goes to three major types of clients; overseas middle men who trade parcels of wool in different territories, yarn manufacturers, and vertical mills which make both the yarn and carpet within their own organisation.
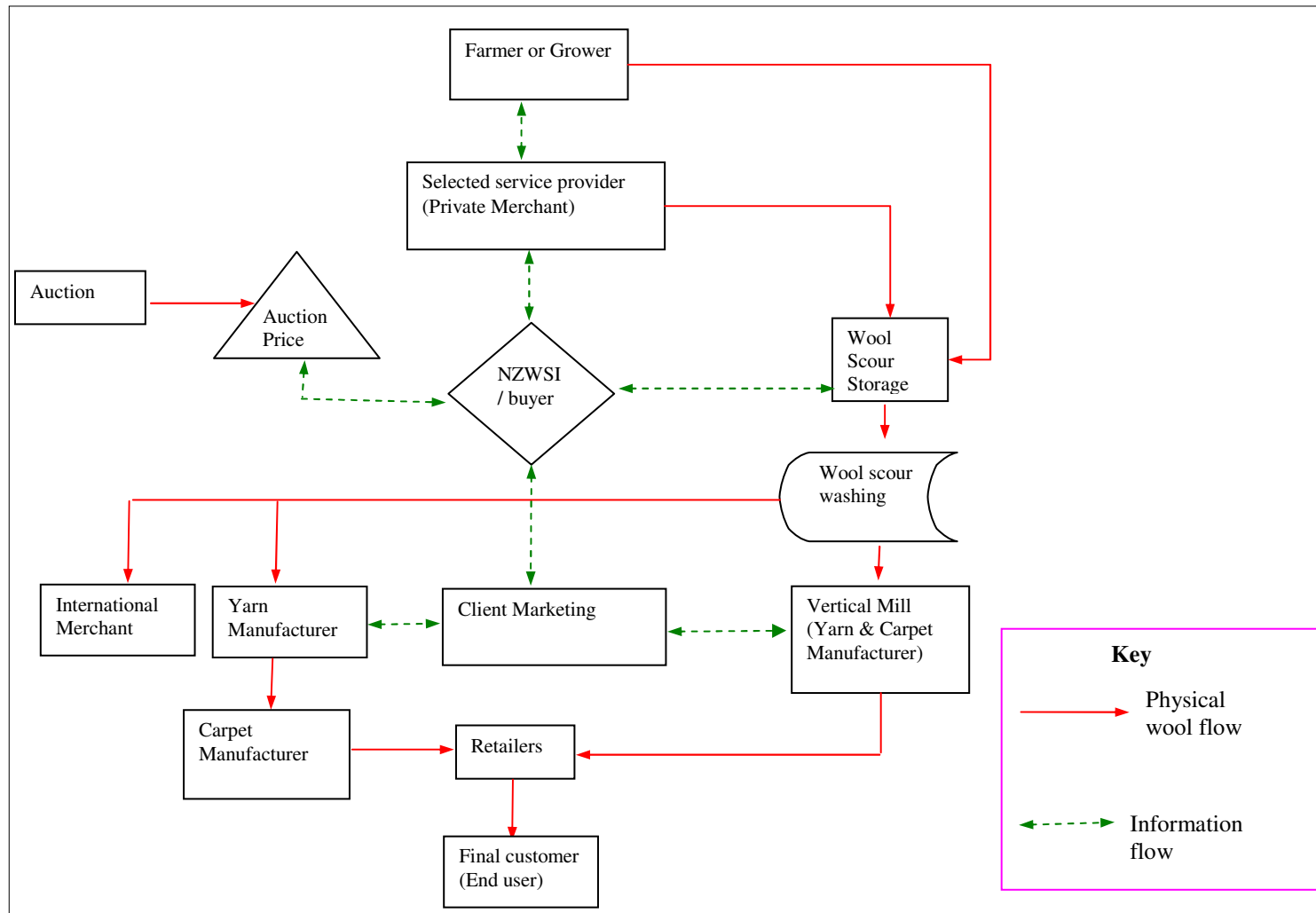
Figure 2.5 Information pathway and physical pathway of New Zealand wool clip in direct supply initiative: a schematic view.

2.4 Discussions

This marketing overview of the New Zealand wool clip shows that New Zealand's position in wool trading is significant in comparison with other countries. Within the New Zealand agricultural sector, generating more than a billion New Zealand dollars per annum, New Zealand wool is positioned as the ninth largest contributor to the New Zealand export economy. The revenue is primarily generated due to the export of the wool clip overseas and to the local mills. Such export activities are performed by buyers / exporters. Their perspectives on the price formation process have a significant role. The price thus formed can be characterized in terms of systems modelling. The systems models thus formed in both auction and direct supply method consider the constituent factors of price formation. For buyers participating in both routes, auction price for a certain type of wool is important as this price is considered as a reference in the direct supply initiative too.

The participating buyers determine the cost of i-type (let's say, x_i) of wool as a product of its relative price and the average market price. The relative price, as we discussed in the section 2.2.2, is a function of physical properties whereas average market prices for wool are freely available after each auction sale. Once we determine the cost (x_i) for a particular type of wool, the average cost at auction for type i is $\bar{x}_i$ which is the average of several similar i types of wool. The system models facilitate the calculation of this quantity $\bar{x}_i$ which we will use in the optimization model (in Chapter 6).

2.5 Summary

In this chapter, we have presented a marketing overview of the New Zealand wool clip. The price formation process in auction and direct supply is presented from a buyers' perspective. This is depicted in two systems models, auction and direct supply. As the

auction price is also the reference for price formation in direct supply, a detailed analysis of price formation in the wool auction environment is presented. We stated earlier that 45% of New Zealand wool is traded via auction, this shows that auction is still a major wool trading avenue; therefore, we present a sample of historical auction data analysis using mathematical / statistical approaches in the next chapter.

Chapter 3

ANALYSIS OF HISTORICAL AUCTION DATA IN RELATION TO PRICE FORMATION (IN BOTH SUPPLY ROUTES)

We will not complete a full analytical treatment of the model presented in Figure 2.4. However, some of the sub-units are readily modelled. For example, there is ample data relating the physical properties of wool to the price received in a single auction. The auction data are the result of the competition between many bidders and are a rich source of information for understanding the price dynamics of the wool clip; therefore, our analysis focuses on the database available from a local wool auction centre. We begin with an overview of price formation and the available wool price database. Cleaning and preparation of the database with calculations of Bulk and Medulla by developing approximation equations is then presented. The data base with a full set of necessary and sufficient conditions is then examined and tested using mathematical /statistical methods. A discussion is made for the results achieved from different methods and the chapter is summarised.

3.1 Price Formation and the Data

3.1.1 Wool Appraisal Data

Wool appraisal data are produced for the auction. An auction is the selling avenue for 45% of New Zealand greasy wool[16] (WIN, 2007). We, in this section, focus on the development and testing of analytical models (mathematical / statistical) based on the wool appraisal data of two years from one major auction centre. In particular, the appraisal data have been collected from the auction centre in Christchurch located in Canterbury, South Island of New Zealand. The auction centre in Christchurch is the South Island's only centre for wool marketing (Figure 3.1). This centre deals with 40% of total wool trading in New Zealand. Further, Canterbury is New Zealand's largest and most diverse wool production region (WIN, 2007). Many of the country's most significant wool enterprises are based in Canterbury. There are 7.5 million sheep (20 per cent of the national flock) in the Canterbury region (WIN, 2007). The commercial base of the New Zealand wool industry is in Canterbury.

It is highly likely that models developed from the analysis of the data from the Christchurch auction centre would broadly represent the whole New Zealand wool clip. The data contains the following attributes:

- physical parameters of the wool: [(diameter, colour (Y, Y-Z), length, VM, yield)
- market indicators (auction price per kg for greasy wool of certain type)
- quantity of wool traded at the auction
- auction date, broker and warehouse

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[16] Raw wool from the farm.

- wool types[17]

Looking at the data, diameter, colour (Y, Y-Z), and vegetable matter content only are in quantitative forms. The other three parameters (Length, Bulk and Medulla) are included under wool types and descriptor headings and not necessarily shown by numerical numbers. The diameter ranges from 16.9 micron to 42.7 micron. The "Y" ranges from 0 to 70.1, "Y-Z" ranges from -2.2 to 12.4 and VM ranges from 0 to 7.6.

The length was represented in code which would normally take into account the staple length and is expressed in inches. As an example, "d" equals 4/6 inches, but it has an inherent barbe length which alters depending on tenderness. There are variations in different exporters in terms of how they compile and utilise the data particularly in relation to style and length. This compilation would be influenced by their clientele requirements. In a wider perspective, the length code would normally take into account the staple length described in inches or millimetres or barbe or a combination of these factors which are also dependent on the degree of tenderness fault.

As stated above, in the database, we do not have bulk and medulla in quantitative form. These are independent parameters from a processing perspective i.e. they result in unique processing or product effects. Bulk is denoted in the database by the descriptor "X" and medullation is denoted by "S". High bulk factor can influence prices, usually with some sort of premium and conversely high degree of medullation can create a discount when contained in fleece wools. It usually has little impact on other categories as they often contain medullated fibres and are used in products accordingly.

The wool types available in the database are represented by the combination of letters and numbers having unique meaning. The detailed valuing code for wool types is presented in Appendix B. As for an example, a wool type "F4D, H, 1F, 3T" provides a lot of information about that particular wool type. The first letter represents the category – from which part of the sheep's body the wool is from. F implies the wool is 'main body' wool. The number after the letter represents colour code. Here 4 refers to a poor colour. The

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[17] Various types of wool coded with symbols that represent in order category, colour, length (in inches) and descriptors (details of wool valuing codes and types is presented in Appendix B).

letter D refers to the length of the staple and is 4/6 inches. The attributes that come after these first three as explained above, show attributes or faults with an indication of degree of how bad and how good it is. These come from the descriptors group. Generally, descriptors are showing the wool in a negative way.

A basic understanding of the available database leads us to work further into it to extract meaningful information relevant to this study.

Figure 3.1 Wool appraisal data collected from the auction centre in Christchurch, South Island, New Zealand.

3.1.1.1   *Data Cleaning and Preparation*

Prior to testing of quantitative models based on the auction database, we rigorously examined and cleaned the database. The cleaning process includes omitting data having either no auction prices or zero auction prices. The zero auction prices indicate that those lots were not sold at that auction date. Further, data having no parameters values are also excluded in the analysis. For example, data having zero for "Ys" are excluded from the database. We reclassified the data using a filtering technique taking into account the micron as a primary factor.

The reclassification generates groups of the wool types into the classes as shown in Table 3.1. This grouping is a result of the application of a basic filter. The first group consists of micron groups having sub-group Merino (< 23 micron), Mid micron (23.1-31.5 micron), Fine Crossbred (31.6-35 micron) and Coarse Crossbred (>35.1 micron). Each of the sub-group is further grouped into Fleece and Oddments. Other groups covering all microns are in second group having no sub groups. The letter codes in Table 3.1 are representing the wool type in terms of category. The list of code to the corresponding category is based on the convention as shown in Table 3.2. These categories show us from which part of the body the wool is coming from.

Table 3.1 **Grouping of wool types after applying the filtering technique(Ching, 2007; NZWSI, 2007).**

Main Group	Sub-group	Further group
Micron groups	Merino (< 23 micron)	Fleece (F)
		Oddments (everything else)
	Mid micron (23.1-31.5 micron)	Fleece (F, R, V)
		Oddments (B, P, C, E, K, N, Q, S, T, X, Y, Z)
	Fine Crossbred (31.6-35 micron)	Fleece (F)
		Oddments (same as for mid-micron)
	Coarse Crossbred (>35.1 micron)	Fleece (F)
		Oddments (same as for mid-micron)
		Cotts (G, H, W)
Other groups covering all microns	Down Fleece (D)	
	Lambs Fleece (L)	
	Lambs oddments (M)	

Table 3.2   Codes and corresponding wool category and descriptors used to define various wool types (Ching, 2007; NZWSI, 2007).

Code	Category	Code	Descriptors
A	-	A	Autumn (Sound)
B	Bellies	B	Burr
C	Clothing	C	Cotts
D	Down Fleece	D	Skirt / B- or Disc Type
E	Eye Clips	E	Contains bellies
F	Mainbody Wool	F	Felted Wools
G	Soft Cotts	G	Good Side of Type
H	Hard Cotts	H	Shorn Hogget
I		I	Urine Stain
J	Mud / Slipe	J	Mud
K	Crutchings	K	Dusty
L	1st Lambs	L	Treefoil
M	2nd Lambs	M	Pen Stain
N	Necks	N	-
O	Black	O	Dag
P	Pieces	P	Water Stain
Q	Backs	Q	Very Mixed Micron
R	Double Fleece	R	Very Mixed Length
S	Second pieces and Lox	S	Kempy
T	Brands	T	Tender
U	Drysdale	U	Lustre
V	Dead	V	Blacky Fibre
W	Open Cotts	W	Woolly Hogget
X	Dag	X	Bulk
Y	Stain	Y	Thistle
Z	Down Odds	Z	Moit / Seed / Pine

We can criticise the above filtering presented in Table 3.1 on the grounds that any serious results would also need to factor in colour, length and the impact of the descriptors not only the categories (presented in Table 3.2). Each part of the assessment code is at some point critical and determines the end price factor both positively and negatively. However, this filtering would help buyers to come up with a decision on how useful the wool is for processing. This ultimately helps to decide the price of the wool. This filtering is developed taking into account the buyer's decision making behaviour during the auction and direct supply of wool sourcing. We apply this technique to the database and make ready for further treatment.

As we mentioned before, we do not have Bulk and Medulla in our database in quantitative form. These are obtained computationally by developing simple approximation equations based on the lettering codes. The foundation of these approximation equations is the previous study on computer blends by Carnaby (1983). Approximation equations are developed such that we can translate the subjective wool type code into quantitative numbers. To come up with the objective numbers we define the Bulk and Medulla interms of category and descriptors (Table 3.2). Such definitions are translated into the equations.

For Bulk:

Bulk is related to breed characteristics and is a *function* of various categories and descriptors. The categories that help to define the Bulk are [*micron, crutching (K), Down fleece (D), Down oddments (Z). The descriptors that help to define the Bulk are Bulk(X) and lustre (U)*]. The approximation equations are developed to incorporate the function of each category and descriptor.

Let us adopt a standard equation for Bulk viz,

$$Bulk_i = 42 - (12/20) \text{ Micron}$$ **3.1**

The conditional statements are,

If Category = D, then

Bulk = $Bulk_i$ **+ 5**   **3.2**

If Category = Z, then

Bulk = $Bulk_i$ **+ 5**   **3.3**

If Category = K, then

Bulk = $Bulk_i$ **+ 3**   **3.4**

Taking into account the descriptors that help to define the Bulk,

If Descriptor = X, then

Bulk = $Bulk_i$ **+ 3**   **3.5**

If Descriptor = U, then

Bulk = $Bulk_i$ **- 4**   **3.6**

For Medulla:

Medulla is a combination of breed characteristics and also depends on the location of the category on the animal, for example, high medullation is found in Eye-clips, Topknots and Crutchings. Medulla can be defined interms of categories and descriptors. It is a function of the following categories: [*micron, crutching (K), Eye Clips (E), Second pieces & Lox(S), and Drysdale (U)*]. Further, Medulla is a function of the following descriptor: [*Kempy (S)*].

Let us adopt a standard equation for Medulla viz,

$$Medulla_i = [(Micron - 30) * 5/6] \qquad \textbf{3.7}$$

The conditional statements are,

If micron < 30, then

$$Medulla_i = 0 \qquad \textbf{3.8}$$

If micron $\geq$ 30 and $\leq$ 36, then

$$Medulla_i = [(Micron - 30) * 5/6] \qquad \textbf{3.9}$$

If micron >36, then

$$Medulla_i = [5 + (Micron - 36) * 25/10] \qquad \textbf{3.10}$$

If Category = E, then

$$Medulla = Medulla_i + 7 \qquad \textbf{3.11}$$

If Category = K, then

$$Medulla = Medulla_i + 5 \qquad \textbf{3.12}$$

If Category = S, then

$$Medulla = Medulla_i + 3 \qquad \textbf{3.13}$$

If Category = U, then

$$Medulla = Medulla_i + 15 \qquad \textbf{3.14}$$

Now, we take into account the descriptor that helps to define the medulla

If Descriptor = S, then

$$Medulla = Medulla_i + 8 \qquad \textbf{3.15}$$

We can generalise the above equation given the condition that if Category = Either E, or K or S or U and Descriptor = S, then

$$Medulla = Medulla_i + 10$$

3.16

We developed codes in the SPSS (version 15.0)[18] environment to write the above approximation equations (3.1 to 3.16) for the computation of Bulk and Medulla. A sample interface is shown below (Figure 3.2).

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[18] SPSS is a widely used software for data analysis (http://www.spss.com)
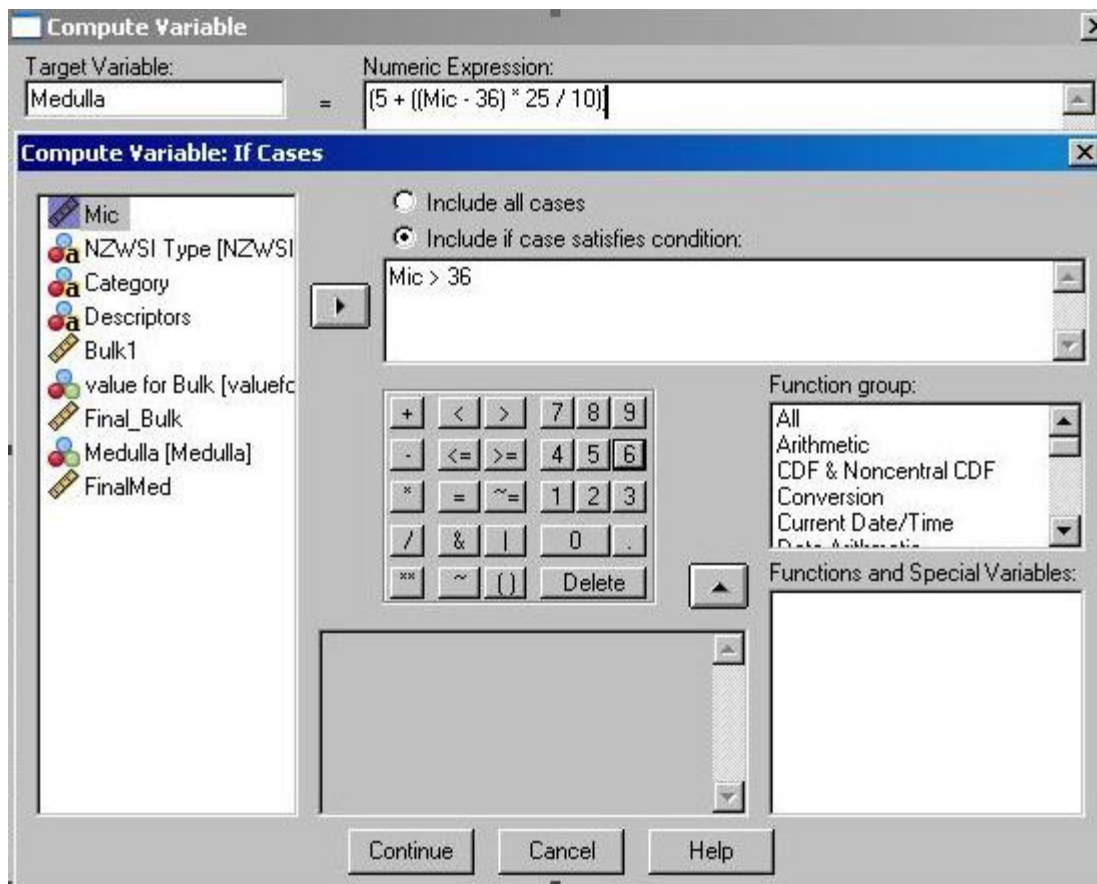
Figure 3.2 A sample interface showing the calculation of Bulk and Medulla by implementing the approximation equation stated above (3.1 to 3.16)

These calculations provide the full set of necessary and sufficient conditions to define the wool space. Once the data base had a full set of parameters (6 necessary and sufficient parameters) and their quantitative measured or estimated value we further tested the database with mathematical / statistical methods. In particular, we used regression and principal component analysis (PCA) methods.

Mathematically speaking, we are aware that these necessary and sufficient parameters are not orthogonal; consider say diameter – as per the approximation equations for bulk and medulla. We now discuss here the acceptability of application of the statistics to non-orthogonal parameters. The next point we like to discuss is the auto correlation (multicollinearity) between parameters. The discussion will centre on the logic of why we still intend to use multivariate analysis like multiple regression and PCA to generate predictive equations for the price of wool type, based on these physical parameters.

Previous studies used regression analysis (G.A. Carnaby, Maddever, & Ford, 1985; Maddever & Cottle, 1999; Maddever, Ford, Bond, & Carnaby, 1984) and principal component analysis (Maddever, 1989; I.P. Stanley-Boden, 1985; I.P. Stanley-Boden et al., 1986) for New Zealand wool appraisal data. These studies produced some insights into the price behaviour of New Zealand wool. Further, wool price was predicted using forecasting methods (Steel, 1999; Steel & Jansen, 1998).

If we look into outside of New Zealand wool, the marketing data set are in most cases are clearly vulnerable to multicollinearity and in such situation as well, meaningful information can be extracted using the established statistical methods (Lafi & Kaneene, 1992; Shipchandler & Moore, 1988; Willett & Whan, 1969). If strong multicollinearity is present, statistical techniques can be used which result in biased estimators. The extent of such biased estimators can be reduced by the associated reduction in the variance of the estimator (Gunst & Mason, 1977; Massy, 1965). To deal with the multicollinearity problems many statistical procedures were proposed and among them PCA is advantageous as it has an exact distribution theory available for the estimates (Gunst & Mason, 1977). A strong recommendation was made for the use of PCA on any data set to

identify the underlying number of axes associated with the independent variables (dimensionality) and to quantify the interdependence that might exist among the independent variables (Carnes & Slade, 1988).

There exists a large body of literature in many scientific studies that have applied multivariate analysis like multiple regression and PCA to develop prediction models. A few representative examples and the area of studies are, in mechanical properties for wool and cotton fibres (Lam & Postle, 2006), in retrieval experiments (Dincer, 2007), in veterinary medicine (Lafi & Kaneene, 1992), in predicting the percentages of ternary mixtures of cow's, ewe's and goat's milk (Rodriguez-Nogales, 2006), in pattern analysis of gene expression of bacteria (Vilain & Brozel, 2006), in analysing the ranking criteria for tier rankings of national universities (Webster, 2001) the use of multivariate statistical analysis is reported.

With the above discussion, we now develop wool price prediction models using regression and PCA for our cleaned database.

3.1.2 Model Based on Regression Analysis

We develop models to perform the analysis based on simple regression and multiple linear regression where auto-correlation effects are ignored in the first instance. Multiple linear regression can be applied once the database is cleaned and it has a full set of necessary and sufficient conditions to define the wool vector space (G.A. Carnaby et al., 1985). Multiple linear regression models give the R-Squared (R^2)[19] value of the model describing the goodness of fit. Further, we observe regression coefficients, scatter plots and the effect of parameters on predicted clean price.

Further, the major contributing parameters in predicting the price of the wool among the physical parameters are observed in this analysis. Models are developed for the prediction

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[19] It is a value generally expressed in percentage which is commonly used to assess the goodness of the model under observation.

of auction price against the six parameters namely; colour (Y, Y – Z), vegetable matter content, length after carding, diameter, bulk, and the medulla.

The simple linear regression model follows the form $\mathbf{Y = b_o + b_1X}$, where $\mathbf{Y}$ is the response (in this case predicted clean price); $\mathbf{X}$ is the predictor (measurement – in this case value of physical parameters of wool); $\mathbf{b_o}$ is the intercept; and $\mathbf{b_1}$ is the coefficient.

The table below (Table 3.3) shows the summary of the simple linear regression models for the clean price against physical properties of wool.

As shown in Table 3.3, the simple regression model developed by using diameter (micron) produces a high R-squared value (63%). To better understand the contribution of diameter in predicting the auction price, an attempt is made in partitioning the data into two groups based on the diameter. The first group contains the data having less than 30 micron diameter and the second group is greater than or equal to 30 micron diameter. These two groups are visualised separately for the linear regression models along with their scatter plots. The results from these two models are presented below (in Figure 3.3 and Figure 3.4).

From Figure 3.3 and Figure 3.4 it is observed that the less the diameter, the higher is the price of the wool in the auction. The R-squared value for < 30 micron group is 69.2% while it is only 5.9% for the >= 30 micron group.

This shows that micron is critically important in apparel and other applications (such as upholstery and knitting yarns). This aligns with past studies which show the key role of diameter in determining both the spinning limit of wool and the softness of the product made from it. In carpets, micron is not particularly significant however.

Table 3.3   Summary of simple linear regression models for the clean price against physical properties of wool.

Physical properties	Regression Fit $Y = b_o + b_1X$	R-Squared value
Colour Y	Y = 7.710 - 0.06503 * ColY	58.1%
Colour (Y-Z)	Y = 4.891 - 0.3224 * ColY-Z	25%
VM	Y =3.736 + 0.9020 * VM	9%
Length after carding	Y = 4.608 - 0.05237* Length (in Cm)	7%
Medulla	Y = 5.045 - 0.1425* Medulla	24.3%
Bulk	Y = - 3.275 + 0.3288* Bulk	56.4%
Diameter (Micron)	Y = 11.07 - 0.2104 * Diameter (Mic)	63%

Table 3.4 Summary of simple linear regression models for the clean price against diameter for the partitioned diameter.

Physical properties	Regression Fit $Y = b_o + b_1X$	R-Squared value
Diameter (< 30 micron)	Y = 16.7 - 0.444 Diameter (< 30 Mic)	69.2%
Diameter (> 30 micron)	Y = 4.81 - 0.0392 Diameter (>=30 Mic)	5.9%
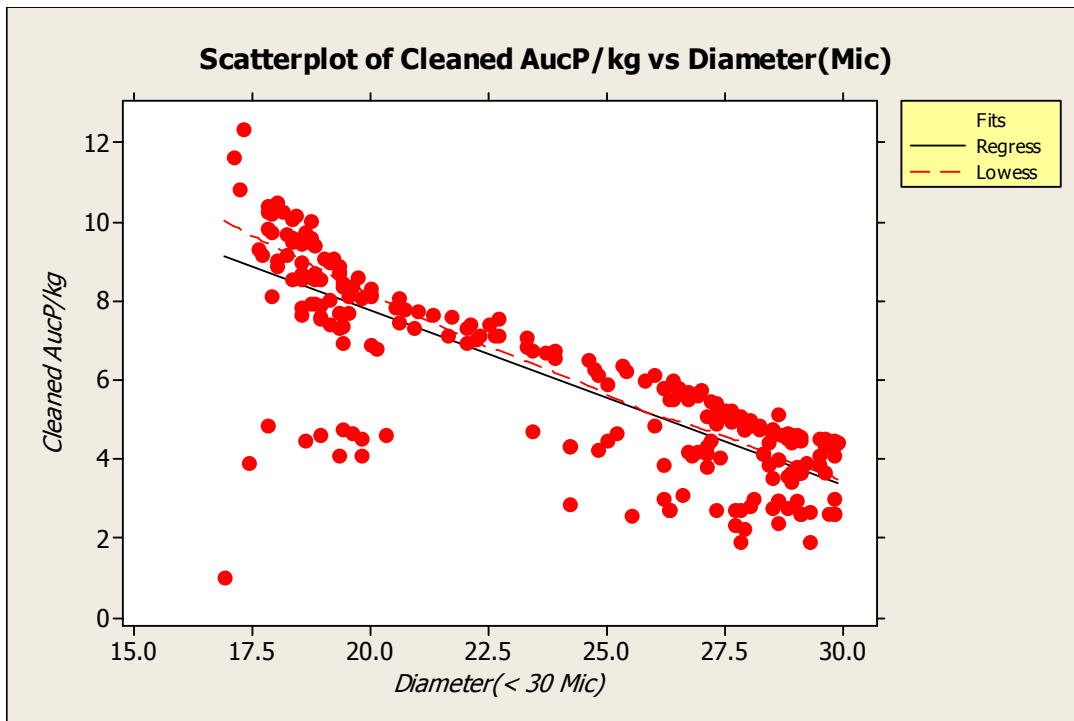
Figure 3.3 Scatterplot developed from a simple linear regression model for diameter (< 30 micron).
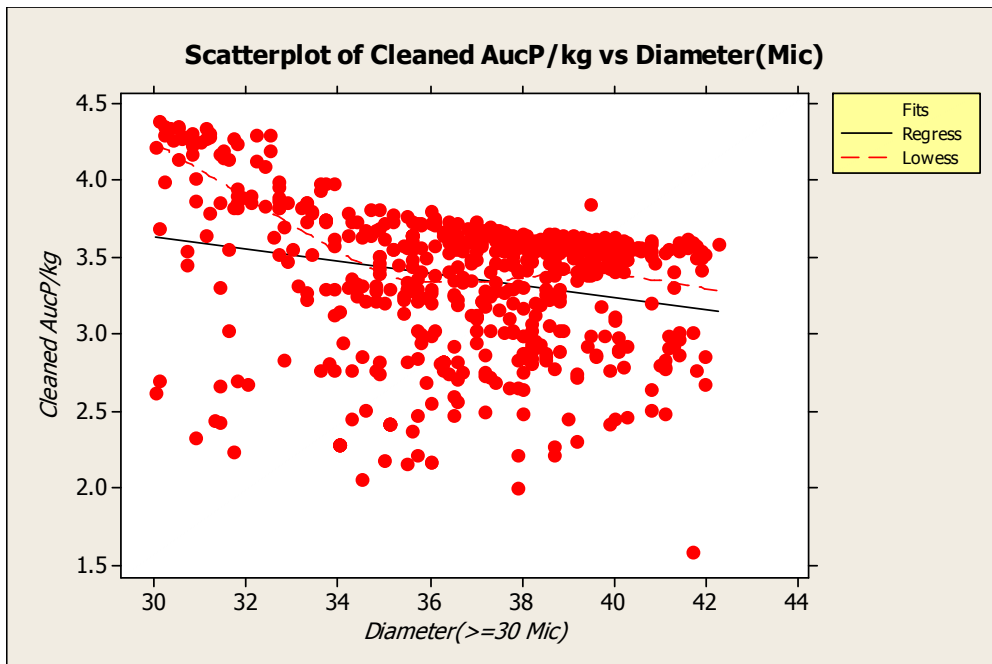
Figure 3.4 Scatter plot developed from a simple linear regression model for diameter (>= 30 micron).

In addition to the simple linear regression models described above, to better understand the combined effect of all the physical parameters a multiple linear regression model is developed. The regression equation developed for this model provides the clean auction price per kg (CAucPkg),

CAucPkg = 8.59 + 0.0352 Y - 0.0628 (Y-Z) - 0.153 VM + 0.342 L - 0.217 D +0.0662M - 0.0551B

From this analysis we observed that the model developed from multiple linear regression analysis produced a good R-square value (84.4%). Still, we believe that there is room to improve the model. The model was improved by excluding the comparatively low number of the wool types having quite unusual faults indicated by the following categories and descriptors:
Categories: G, H, J, O, T, V, W, X, Y (19 ~ 2.51% of total) and Descriptors: F, I, J, K, L, V, Y, Z (127 ~ 16.82% of total).
An analysis is made after the exclusion of these types of wool. Simple linear regression models as well as multiple linear regression models are developed. Partitioning of the database was carried out as previously. Among the models developed, a model based on multiple regressions produced a R-squared value of **92.7%** for a model < 30 micron (before 69.2%). This result signifies that wool types having low quality which have low value and price are playing a major role for the low R-squared value and hence the goodness of the model. This shows that some specialized types of fault cause particular price discounts not predicted by the six key properties.

On the other hand, as the physical parameters are not actually independent, for example as bulk and diameter are not independent, the use of multiple linear regression analysis is not strictly legitimate(Angel et al., 1990; G.A. Carnaby, 2007).

Further exploration was then made using principal component analysis and possible dimensionality reduction.

3.1.3 Principal Component Analysis and Dimensionality Reduction

Principal Component Analysis (PCA) is a method of transforming the original independent variables into new, uncorrelated variables. These new transformed variables are called principal components (Lafi & Kaneene, 1992). Every principal component is a linear combination of all the original independent variables. One major aim of doing PCA is to reduce the number of independent variables without losing much of the information. Such independent variables recover as much variability in the data as possible (Irpino, 2006).

We applied this established method of statistical analysis to the cleaned database that we prepared for the analysis. The result from PCA is presented in Table 3.5.

Table 3.5   Eigen analysis of the correlation matrix

Eigen value	3.6848	0.9978	0.9316	0.6765	0.5890	0.0974	0.0229
Proportion	0.526	0.143	0.133	0.097	0.084	0.014	0.003
Cumulative	0.526	0.669	0.802	0.899	0.983	0.997	1.000
Variable	PC$_1$	PC$_2$	PC$_3$	PC$_4$	PC$_5$	PC$_6$	PC$_7$
ColY	0.389	0.237	-0.169	-0.186	0.738	-0.401	-0.157
Col (Y-Z)	0.219	-0.231	0.843	-0.391	-0.051	-0.172	-0.053
VM	-0.278	0.341	0.500	0.668	0.331	0.014	0.016
Length	0.219	0.818	0.049	-0.116	-0.490	-0.163	-0.024
Diameter	0.511	-0.027	0.023	0.160	0.052	0.169	0.825
Medulla	0.402	-0.322	-0.073	0.558	-0.314	-0.511	-0.241
Bulk	-0.503	-0.034	-0.053	-0.125	-0.047	-0.702	0.482

The first principal component has variance (Eigen value) 3.6848 and accounts for 0.526 which is 52.6% of the total variance (Table 3.5). The coefficients listed under PC_1 show how to calculate the principal component scores:

PC_1 = 0.389 ColY+ 0.219 Col(Y-Z) - 0.278 VM + 0.219 Length + 0.511 Diameter (Mic) + 0.402 Medulla – 0.503 Bulk

The second principal component has variance (Eigen value) 0.9978 and accounts for 14.3% of the total variance. As the interpretation of the principal components is subjective, it is difficult to say which principal component is representing an overall population size. However, from Table 3.5, the first five principal components together represent 98.3% (52.6% + 14.3% + 13.3% + 9.7% + 8.4%) of the total variability. Thus, most of the data structure can be captured in five underlying dimensions. The remaining two principal components account for a very small proportion (1.7%) of the variability. The Scree plot, Score plot and Loading plot in combination provide this information visually in the following Figure 3.5. The figure presented the variance and principal components of seven measurements.
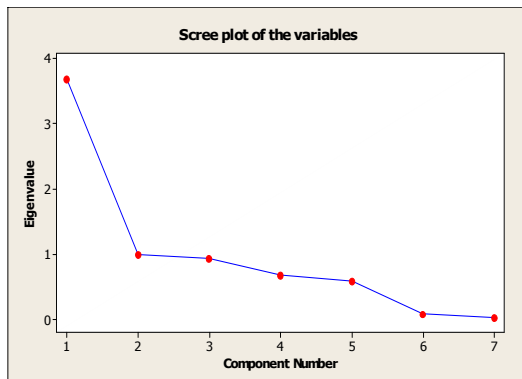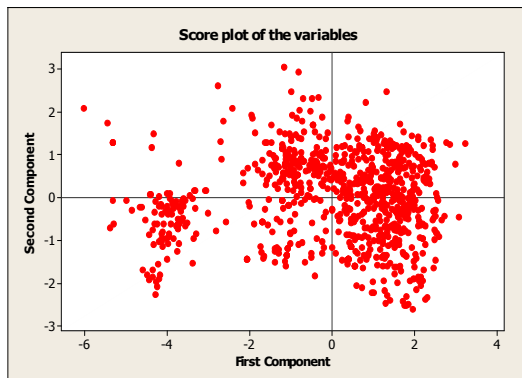
(a) Scree plot
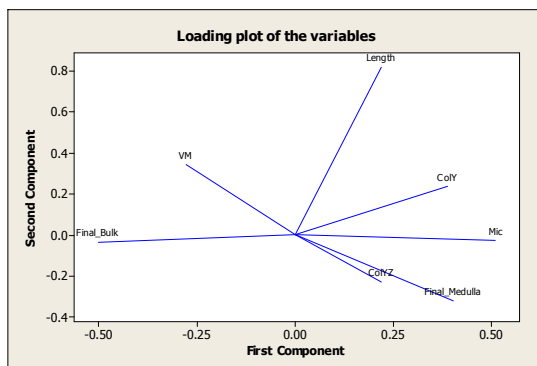
(b) Score plot

(c) Loading plot

Figure 3.5 The variance and principal components of seven measurements (a) scree plot (b) score plot and (c) loading plot showing the variability of the principal components.

3.2 Discussions

As the Canterbury region is an important region for the New Zealand wool industry, a sample data base was chosen from the auction centre in Christchurch. Consistent with previous studies (Maddever, 1989; I.P. Stanley-Boden et al., 1986) the model developed showed that fibre diameter has a significant role in the price formation of the New Zealand wool. However, there is a role played by other physical parameters as well. In this analysis, we calculated two other physical parameters – bulk and medulla - to make a full set of necessary and sufficient processing conditions of the data set. The calculations are made by developing empirical equations using expert knowledge. Further, the principal component analysis showed that five mathematically independent components out of seven are important for the data set under study.

3.3 Summary

To summarise, an analysis of historical auction data showed that diameter has high impact on the price of the wool as expected.

In Chapter 2 and Chapter 3, we mentioned that auction is a major marketing avenue for New Zealand wool. However, there is now big pressure on this system and its future is potentially unstable. The instability of the auction system is discussed in the next chapter.

Chapter 4

INSTABILITY OF THE AUCTION SYSTEM

In the previous chapters we developed systems models of the mechanisms for price formation. The wool price is mainly established via these transparent processes in the auction pathway. The auction price achieved by the broker acting for the grower represents a cost to the buyer / exporter. We now discuss the instability of the auction system in the context of New Zealand wool marketing. This discussion covers stakeholders' satisfaction / dissatisfaction with the auction system, crossover in roles, the New Zealand government's policy in wool trading, alternative wool marketing options and how all these led to the optimization problem which is the centre piece of this thesis. This is followed by a section providing a brief overview of the optimization problem. This covers price, cost and risk in both the auction and direct supply systems. The next section discusses the issues floated in this chapter. The chapter concludes with a brief summary.

4.1 Instability of Auction System

The New Zealand wool auction is the historic marketing approach adopted for the last 150 years by the stakeholders involved in wool trading. At present, this selling method is facing displacement by other alternative methods like the direct supply system and is at the crossroads. Further, the stakeholders involved are not sure of which method to follow for the profitability of themselves and the industry. Some stakeholders argue that an auction system is no longer an appropriate method of selling for a niche product like the wool clip. This argument is supported by the view that the wool clip is traded via auction as a commodity without having any value added by differentiation or relationship selling. A niche product approach rests on added value. Despite the arguments against the auction system, stakeholders have both satisfaction and dissatisfaction with the auction system. Those who prefer the auction system point to its cost effectiveness at establishing the true value of the product. This is presented next.

4.1.1 Stakeholders Satisfaction / Dissatisfaction

The stakeholders' (Growers, brokers and exporters) satisfaction and dissatisfaction with the auction system is described below. Some growers are satisfied as the auction system is convenient. They just send their wool off farm as soon as it is shorn and they are guaranteed prompt payment. Further, growers using it are comfortable that they are getting true market value as the price setting is done publicly. However, some growers are dissatisfied because they prepare wool for auction without knowing the identity of their customers and so cannot seek to meet specific market needs. Therefore, many wool growers now choose to sell wool to private buyers and end – users by passing various fees and costs. Growers are keen to develop direct relationships with processors so they receive information from end users and adjust their wool specifications to market

requirements. Some growers also blame the auction system for the current historically low prices.

When we think of brokers, their satisfaction with the auction system arises because it lets them earn revenue without taking ownership. The auction system leads to other business for them (grain, ram selection, etcetera). On the other hand they are also dissatisfied because it is hard to increase revenue as sheep numbers decline. Similarly, in the auction system from the brokers' perspective the high overhead structure needed to service growers occurs even though wool flows are not guaranteed.

The other stakeholders in the supply chain of wool – exporters – have satisfaction as well as dissatisfaction over the auction system. Some exporters are satisfied with the auction system as this system provides an open market for them, which is easily accessible, involves public competition and has a visible price setting mechanism. Furthermore, historical knowledge of wool selling allows them to match overseas demand. On the other hand, anyone can basically buy and access the wool with no real investment in the industry. Once satisfactory finance lines have been approved by the brokers it is possible to buy and access wool. This leads to a crowd of bidders/exporters who are not real exporters of wool. On the other hand, brokers can manipulate types and volumes available at auction. Similarly, brokers set reserve market levels which often are not relevant to the "real" market. The market information is public and may be used to the disadvantage of growers and exporters by overseas clients.

Overall, the criticism (satisfaction / dissatisfaction) of the auction system in the marketing of New Zealand wool can be broadly summarised in a number of issues, for example; removal of diversity, addition of costs, lack of communication, poor fitness for purpose, price volatility, trading away of premiums and lack of price risk management.

4.1.2 Crossover Between the Exporter and Broker Roles

Although the roles of exporters and brokers are distinctly defined and understood by the stakeholders, at present their roles are crossing over. For example, Wool Partners International Ltd (WPIL[20]) previously largely the broking firm PGGW, now is moving into exporting. Elders (woolbrokers) own JS Brooksbank (exporter). NZWSI (exporter) has setup direct buying from growers. Masurel (exporter) has set up its own auction catalogue. Some private merchants have set up their own auction catalogues. These moves by wool exporters and brokers cross an unwritten demarcation line that has existed between them for decades. Such crossovers change the established wool selling pipeline and lead to market fragmentation. It is not clear yet whether such change and fragmentation will lead to the betterment of the wool industry. Whilst some may consider there is a role for government others do not. In any event, it seems there is a lack of policy from the government's side in wool trading.

4.1.3 New Zealand Government's Lack of Policy in Wool Trading

The New Zealand government has assisted with some limited funding to the Wool Industry Network (WIN) to help investigate opportunities to change the wool industry for the better. They won't step in and directly change or provide large scale financing. Government may assist with human resources if a business case and solid future strategy can be proven to be viable (as Fonterra[21] did) but will not provide cash funding.

They will not step in and make rules/laws to change the industry or restrict entry.

The lack of a policy incorporating some form of direction by government for wool trading and the instability of the wool auction system has pushed the stakeholders to think

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[20] WPIL- Wool Partners International Ltd, initially known by the working title The Wool Company, established by the recommendation of Wool Industry Network (WIN).

[21] A co-operatively owned company by 11,000 New Zealand dairy farmers and having partnership with other leading global companies.

about alternative ways of wool marketing. In the context of strong wool marketing of the New Zealand wool clip, a direct supply initiative has been launched recently by a leading export company NZWSI.

4.1.4 Direct Supply Initiative

For the sourcing of strong wool, this direct supply initiative is arguably the first time in New Zealand that this has been done on such a big scale by the leading wool exporter / buyer. The direct supply initiative comes into effect even though auctions are still running for the marketing of New Zealand wool. The direct supply initiative as explained in Chapter One has a claimed objective of raising the price of New Zealand wool to a sustainable level by ensuring certainty of supply to the exporter through guaranteed commitments from woolgrowers. This scenario shows that buyers are buying wool via two parallel methods of wool sourcing – auction and direct supply. Such simultaneous trading leads to the need to consider optimal decision making if a buyer / exporter is to minimize their total cost of wool. Whilst the auction price controls the cost to the exporter in auction purchases, it is only part of the total cost as the exporter faces other logistical and handling costs for example. These costs differ in direct sourcing.

4.1.5 Leading to the Optimization Problem

Sourcing of wool via auction and direct supply simultaneously leads to an optimization problem for a buyer. Buyers are not sure of the optimal strategy. A cost comparison of the system models between the open out-cry English auction approach and the direct supply approach can answer which is the cheaper marketing strategy in terms of associated direct cost. Simply considering the pathways, the auction system has more direct costs in comparison with the direct supply initiative. Further, the comparison points are based on;

- immediate return to the grower through charges / cost structure / deliberate premiums paid
- interest factors relating to borrowings and length of time incurred
- brokers fees
- testing fees
- storage costs
- handling efficiencies (freight from farm to processor)
- just in time factors (relating to interest storage and raw wool cost)
- forward contract handling cost structure (compared with private merchant / auction)
- competition (comparing ease of access against committed supply)

However when the risks associated with the two different systems are considered, analysed and compared, for e.g., risks on purchase pre-harvest and specifications and more importantly exposing the exporter to an excess stock position in a falling market the relative proportion which should be bought from each route is revealed. The auction system certainly appears to involve less exposure to this principal risk and potentially disastrous financial risk.

Thus the optimization problem to be solved revolves around the cost, risk and margin associated with two systems.

4.2 The Optimization Problem

The optimization problem is concerned with the risk and margin associated with the two main alternative marketing systems of the New Zealand wool clip; the auction marketing system and the direct supply marketing system. The associated risk / return is optimized from the buyer's perspective and takes into account the price formation process described in the earlier auction model.

A conceptual model presented in Figure 4.1 and the description below will show the profit margin and the associated risk in the two different marketing systems.

Grower

Wool Price & costs   *Wool Price & costs*

Auction   Direct supply

Risk   *Risk*

Exporter

Supply

*The volume exported per month will
follow a probability distribution.*

Frequency

Volume offered by
growers per month

Volume demanded
per month
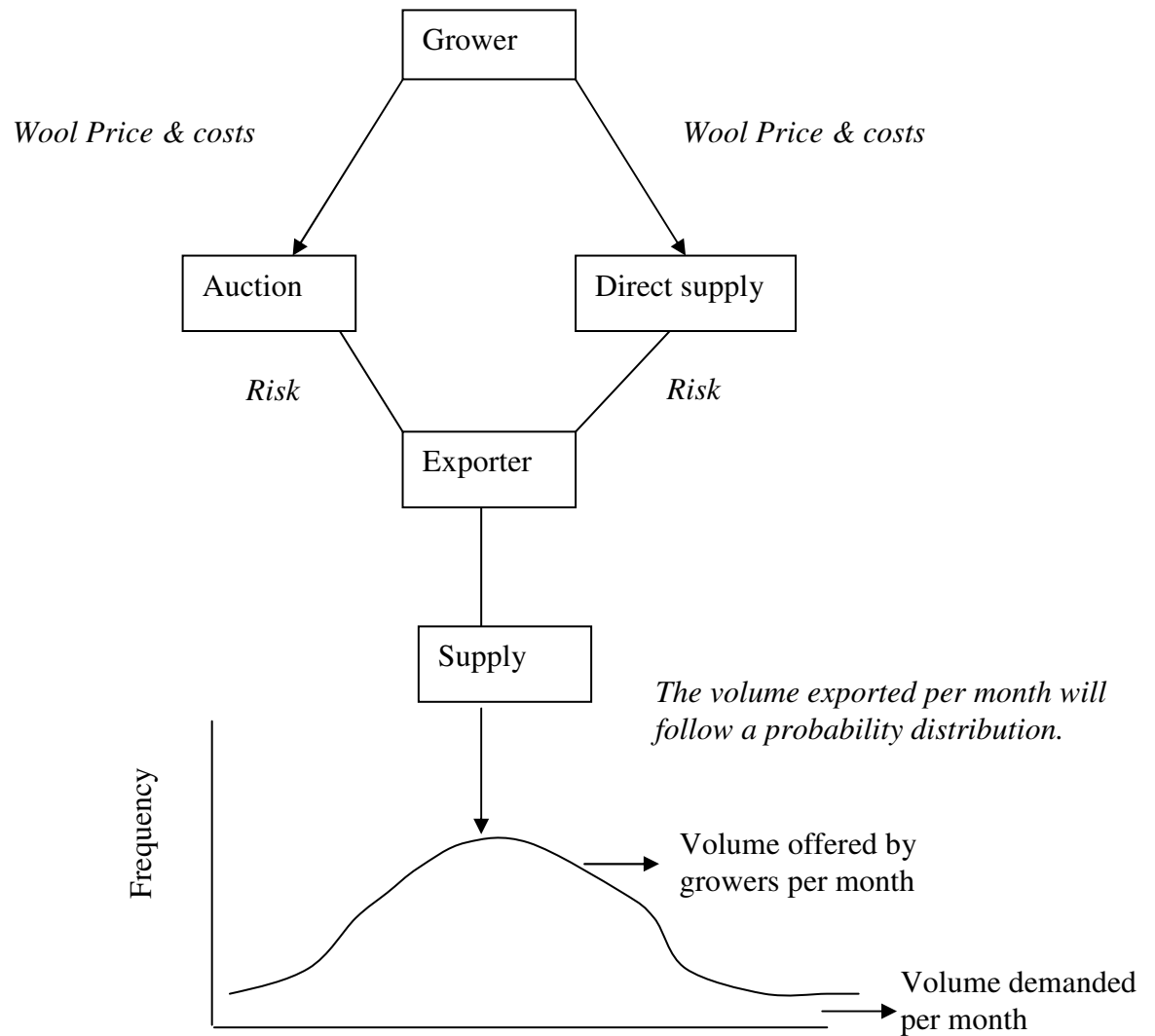
**Figure 4.1 A conceptual model of associated risks in auction and direct
sypply marketing systems for a flow of wool from growers supply to end-
users demand.**

4.2.1 Association of Price, Cost, Risk and Margin

The association of price, cost, risk and margin govern the overall task of the exporter in minimizing total cost of wool purchased. In the business process, price and cost come forward to the surface and are mostly visible, while risk and margin play an important role behind the scenes.

4.2.1.1 Association of Cost and Price in Auction and Direct Supply System

In the business process, there are number of costs involved irrespective of the sourcing option. The price of the wool at auction is a key aspect, the details of which have been described in the system model for auction price formation. The cost of sourcing wool from the two systems is different. Direct sourcing eliminates a number of charges viz;

- brokers commission
- pre sale testing
- brokers storage
- transport to brokers store (the wool moves directly from grower to scour)

Prices are generally set by the auction route. Wools sourced directly are generally paid a premium to ensure grower involvement. However this premium is usually less than the cost saving described above. Therefore on a per lot basis the exporter can save money and increase profit by sourcing directly rather than via auction.

However as an increasing proportion of wool is sourced directly, the exporter becomes locked into fixed volumes of supply. This is dangerous in a situation where global demand can suddenly fall.

The risk associated with the two different marketing systems from the buyers perspective is as follows[22]:

4.2.1.2   Risks Associated with the Auction Marketing System

Among the risks to the buyer / exporter involved in the auction system the exporter can eliminate stockholding risk by withdrawing from purchasing. Nonetheless some residual risks are still there. The residual risks can be listed as follows:

- o   need to take stock of both specific types available seasonally against future contracts as well as unrelated stocks to hedge a forward position
- o   cancellation of contract after buying the wool
- o   uncertainty whether able to purchase the required wools. This uncertainty is due to the following two reasons:
  - ▪   because wool flow and wool types may change seasonally
  - ▪   unknown competitor requirements may create excessive competition forcing prices above the expected market level. This is arguably the dominant risk to the exporter in being overly reliant on auction purchases.
- o   currency fluctuation which has a daily effect
- o   international climate (political or economic of the country) which is completely out of the buyers' control.

There are a few other risks in the auction system for example, immediate / short term shipment against confirmed contract and already covered currency risk[23].

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[22] The uncontrollable and controllable variables in auction and direct supply from buyer's perspective are presented in Appendix D.

[23] A brief list of associated risks and corresponding variable actions in New Zealand wool auction from buyer's perspective is presented in Appendix E.

4.2.1.3 Risks Associated with the Direct Supply System

The main risk with this system is becoming committed to purchase in the event of a sudden drop off in export volumes. Other lesser risks include;

- o large volume of similar types of wool being delivered into NZWSI storage within a very short time frame. e.g., South Island fleece is produced in two very short periods;
  - pre-lamb fleece – July to September
  - post Christmas fleece – January to March
- the associated risks in the direct supply can be categorized as being either minor risks and major risks from the buyer's perspective:
  - o major risks
    - having to store large volumes of wool due to seasonal flow
    - delivery from the grower and commitment by NZWSI if for example, the growers all produce extremely seedy (high vegetable matters) wools because of previous weather patterns.
  - o minor risks
    - spread payment (50% at the time of contract and another 50% after 150 days)
    - targeting pro-active committed large wool growers i.e. inheritenly minimizes the poor preparation risk.
    - ability to manage contracted wool allocations against forward sales
    - minimizing borrowings
    - minimizing stock taking to balance forward position
    - minimizing storage time

Accordingly the exporter / buyer must trade off the cost saving associated with direct purchase against the risk associated with having an increasing proportion sourced this

way. In the model to be developed the costs associated with this risk will be quantified. In practice there will be a range of values for the proportion sourced via each route where the overall profitability of the exporter is maximized after taking both factors into account.[24]

4.3 Discussions

Some stakeholders in the New Zealand Wool Industry have wanted to have a change in the wool marketing system for the betterment of the industry. They are trying to establish new approaches of wool marketing like direct supply instead of the established wool marketing system – auction. However, there is no published study undertaken yet from any stakeholders' perspective relating to which marketing system is beneficial to them. Due to the lack of publicly available research findings, it is very hard for them to come up with a concrete business strategy to be adopted in wool marketing. In this scenario, all the stakeholders are involving themselves in various marketing systems such as auction, direct supply and supply via private merchant etcetera. Stakeholders have their own satisfaction and dissatisfaction with various systems of wool marketing. Due to these, some of them are considering changing their roles and crossing over each others established roles. Among the stakeholders, exporters are in dilemma of choosing the marketing options to be adopted either auction or direct supply in order to minimize their total cost. An optimal decision can be predicted by formulating an optimization problem considering the associated costs and risks in two different method of wool sourcing.

4.4 Summary

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[24] A brief list of associated risks and corresponding variable actions in the direct supply of New Zealand wool from buyer's perspective is presented in Appendix F.

This chapter presented the instability of the wool auction system covering stakeholders' satisfaction / dissatisfaction, crossover of roles, New Zealand government's policy in wool trading and stakeholders interest for alternative wool marketing options. Wool marketing in simultaneously operated systems has led to the optimization problem for wool buyers. The optimization problem can be formulated taking into account the associated cost and risk in systems, auction and direct supply.

The initial optimization model development and hypotheses for New Zealand wool will be presented in the next chapter.

Part Two:

In this second part, an analysis is made of the associated extra cost, risk, margin and cost of risk in both marketing systems, from a buyer's perspective. Since these costs differ the extra cost (due to transport, storage etc.) to a buyer depends on the proportions bought at auction (suppose y) and directly (1-y). Let the total additional cost to the buyer at auction and direct supply be $a(y)$ and $b(y)$ respectively. Further, we factored the cost of risk to the buyer at auction system $A(y)$ and the cost of risk to the buyer at direct supply $B(y)$. We assume for reasons elaborated in the thesis that $a(y)$ and $b(y)$ are independent of wool types bought. The total cost to the buyer in both marketing systems $[a(y)\text{ and }b(y)]$ for a hypothetical auction cost is mathematically determined.

This part includes Chapter Five.

Chapter 5

INITIAL OPTIMIZATION MODEL AND HYPOTHESES

FOR NEW ZEALAND WOOL

Our study of associated cost, risk and margin with the auction and direct supply in Chapter 4 prompted us to further explore the optimization aspect with the establishment of hypotheses. We present a comparative study of cost, risk and cost of risk associated with two different sourcing options of New Zealand wool. In this chapter, an established method of wool sourcing in New Zealand – auction – is compared with a direct supply initiative recently adopted by New Zealand Wool Services International (NZWSI) – Purelana. The association of cost, risk and cost of risk is analysed from both the perspective of NZWSI and the growers in the two different sourcing options. At the outset it was hypothesized that this analysis would lead to the development of an optimization strategy for a buyer so that the optimal use the buyer could make of each of the sourcing options could be determined. However, testing of the hypothesis revealed that there was not necessarily an optimal use of the dual system and that the Purelana initiative was motivated by risk management and strategic competitive factors not suspected or understood at the outset. The chapter therefore proceeds in two parts. In part 1, we explore the hypothesis and the testing of the hypothesis. In part 2, after recognizing that the hypothesis is valid only in terms of short term risk, we describe the competitive landscape and likely longer term strategic positioning factors driving the behaviour of the separate players supporting both the Auction and Purelana options.

5.1 Problem Statement and Hypothesis

After having discussion with the buyer at NZWSI, it was established that quantitative approaches had not been used by the company for the analysis of associated cost, risk and cost of risk before launching the new sourcing option – Purelana. Similarly, quantitative approaches had not applied either for the established wool marketing option – Auction. Decisions on how to source wool had primarily been based on the buyer's experience whatever the sourcing options. Generally speaking, it is highly likely that other wool buyers in the New Zealand wool industry are also making decisions without having any quantification of associated cost, risk and cost of risk irrespective of the sourcing options. In this context, this is an unique problem to be addressed for the decision making of the wool buyer that might help to increase the overall profitability of the New Zealand wool industry. It is hoped that the quantification of the associated cost, risk and cost of risk in two different sourcing options might help the decision making of a wool buyer in choosing the marketing pathways for New Zealand wool. Further, it might help the growers in their selection of wool marketing pathways so that they can increase their profitability.

We cannot always determine our costs and benefits exactly. There is always risk in real world applications. The idea of risk is derived from the concept of uncertainty due to randomness (Galambos & Holmes, 1997; Jablonowski, 2006). In quantifying the risk, we need to take into account the uncertainty of happenings which we call in mathematical terms probability. The probability can be realised by getting the idea of long-run relative frequency of occurrence of risks.

In this study, the investigation is focused from the perspective of NZWSI. It is appreciated that this may result in loss of generality, but on the other hand, NZWSI were prepared to give access to commercially sensitive data under terms of confidentiality. After discussion with NZWSI we postulated that the Purelana route provided cost savings mainly in terms of broker's charges. However as the volume purchased via Purelana increased, the company would face overstocking risks with high penalties associated with this. On top of this we identified that if all wool is purchased at Auction there will be times when wool cannot be obtained (unavailability risk).

Therefore in part 1, the hypotheses to be tested for the study are:

(I)   **Purelana route has a lower (cost at scour) to NZWSI**

(for example, if Auction cost is 'X' c/kg and Purelana cost is 'Y' c/kg then Y < X)
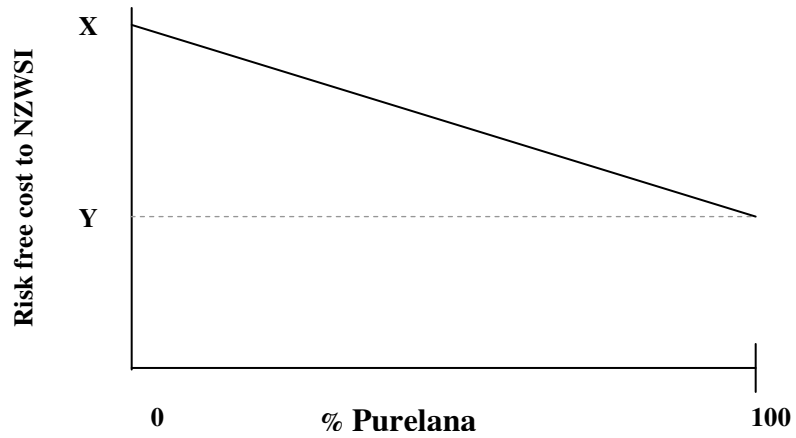
Figure 5.1 A hypothetical graph showing the relationship between risk free cost to NZWSI and % Purelana

(II)   As percentage of Purelana increases overstocking risk escalates

(Purelana risk premium = *function* (proportion of Purelana)
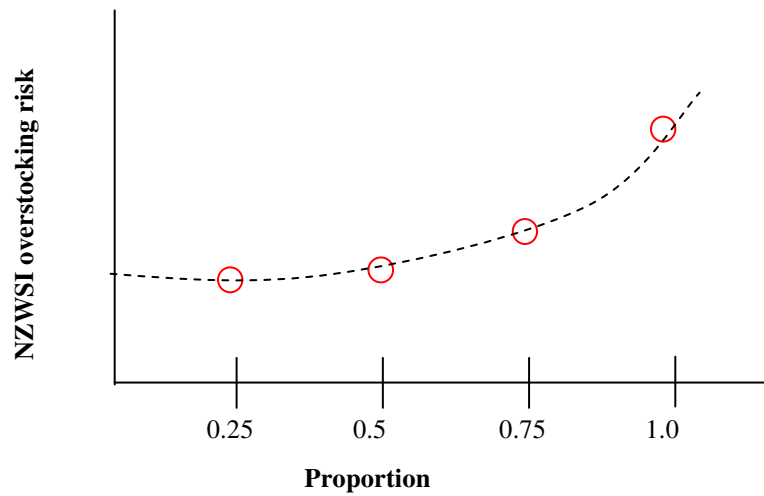
Figure 5.2 A hypothetical graph showing the relationship between NZWSI overstocking risk and proportion of Purelana.

(III) **As percentage of auction increases there will be increased unavailability risk**.
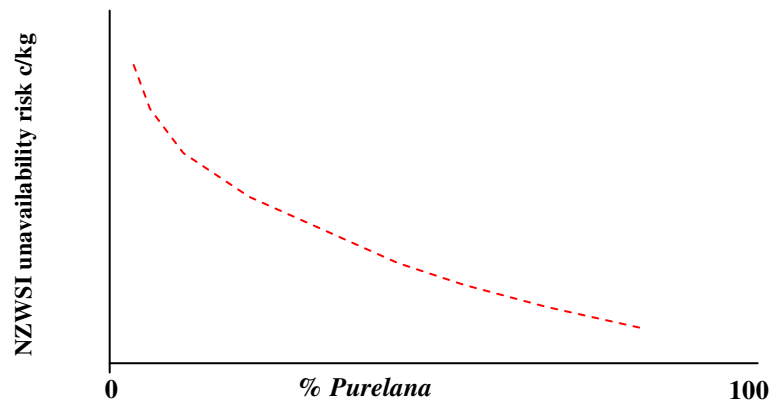
Figure 5.3 A hypothetical graph showing the relationship between NZWSI unavailability risk c/kg against % Purelana

(IV)   Therefore there will be an optimum % of Purelana.
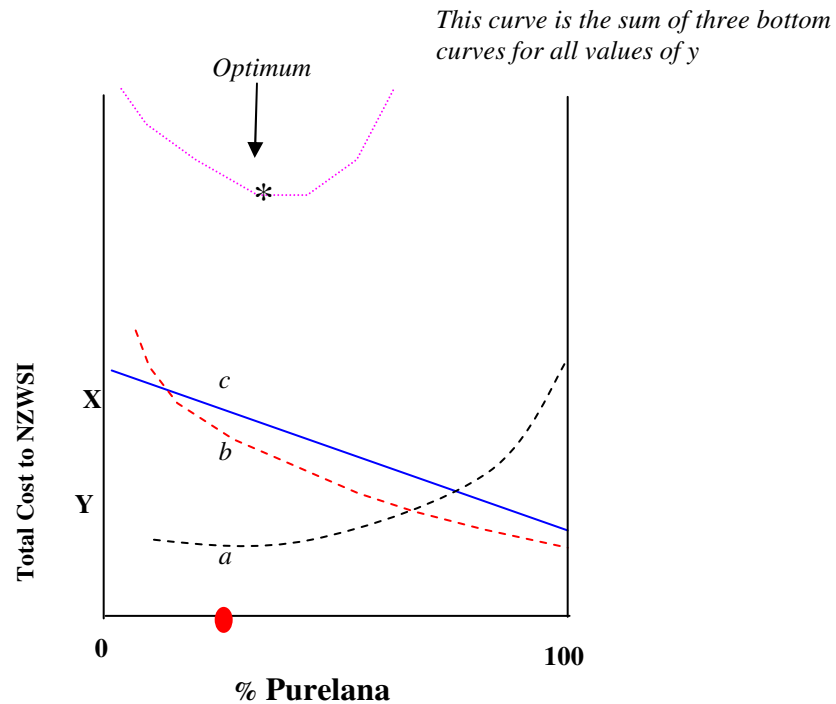
Figure 5.4 A hypothetical graph showing the relationship between the total cost to NZWSI and % Purelana. A conceptual optimum point (*) which is the arithematic sum of the three points *a*, *b* and *c* for all values of % Purelana is shown. Where *a* is the point to the overstocking risk line, *b* is the point to the unavailability risk line and *c* is the point to the risk free line from the line in x-axis which is % Purelana.

As described before, after having carried out an assessment of associated cost, risk and cost of risk the analysis will further be enhanced by formulating an optimization problem. The optimization problem is concerned with the risk and margin associated with the two main alternative marketing systems of New Zealand wool clip; auction marketing system and direct supply marketing system. The associated risk / return will be optimized from the buyer's perspective. A conceptual model presented in Figure 5.5 and the description below will show the profit margin and the associated risk in two different marketing systems.

In the Figure 5.5 we conceptualise the wool production during the different seasons in the New Zealand wool farm (above one) and the volume demand of such wool by the customers of NZWSI (below one). This figure shows that there is a variation in production and supply of wool during the seasons however the demand by the customers is not affected by any season and is constant throughout the year. In this scenario, buyer / exporter (NZWSI) has to maintain the relationship to the growers and customers taking into account the profit and margin.

Grower

AUCTION   **Direct supply**

Exporter

Supply

Volume produced / month on NZ Farms

Curve showing the variation in production and supply of wool during seasons.

Seasons

Volume demanded by customers of NZWSI per month

June   **July**   **Dec**

Seasons
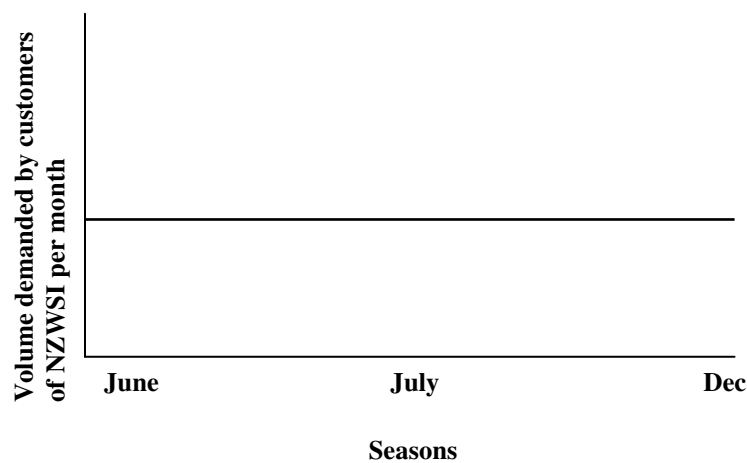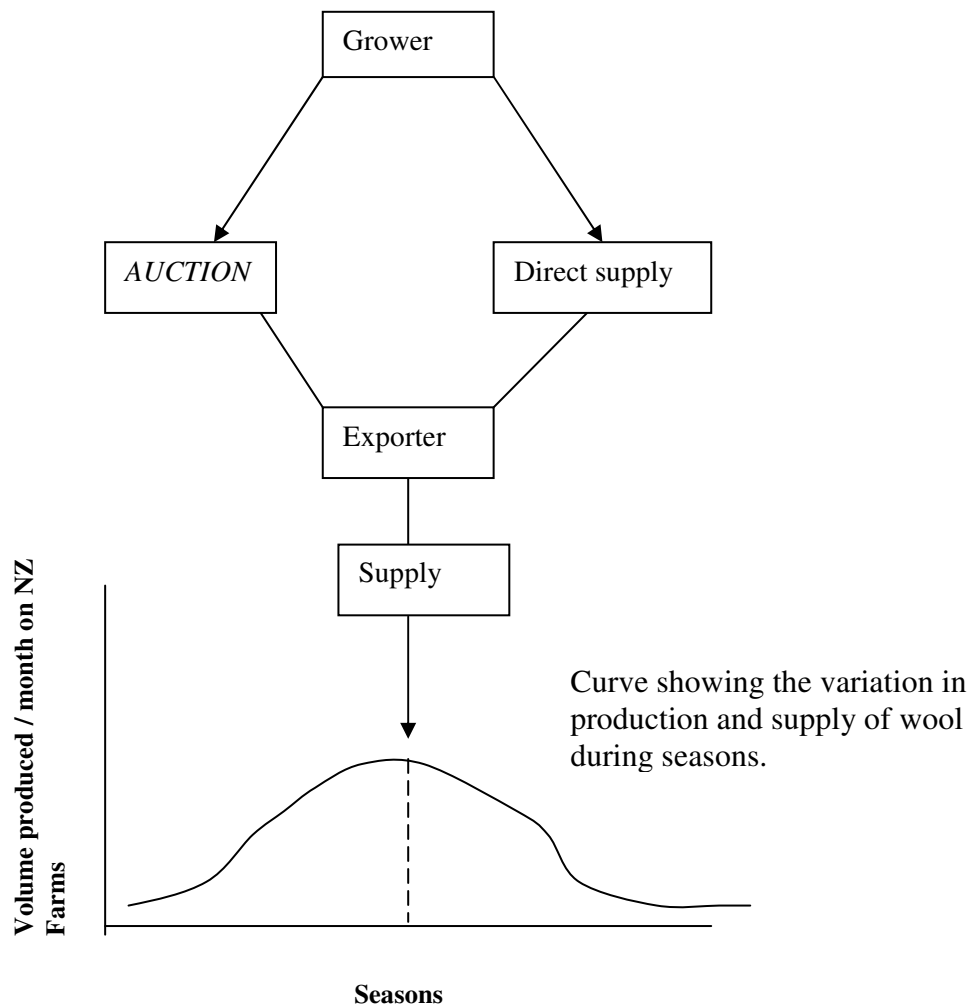
Figure 5.5 The relationship of volume produced /month on NZ farms above and the relationship of volume demanded by consumers of NZWSI per month below.

5.2 Testing of Hypothesis with Real Life Case Study

The hypotheses stated above are tested with a real life case study from NZWSI. A time series for the auction pathway is developed taking into account the delivery days and the actions taken in the course of wool marketing (Figure 5.6). Similarly, another time series is developed for the direct supply initiative - Purelana (Figure 5.7). Both time series are used in quantifying the associated cost, risk and cost of risk in each sourcing option. The comparisons are summarised and presented in tabular formats.

5.2.1 Time Series for Auction Pathway

The movement of wool during the auction can be depicted in a time series. From the NZWSI perspective, in the auction pathway, the time series cycle starts from when an order for wool is confirmed. From this point until the correct wool type can be bought at auction there are numerous risks to be covered. This is usually done by purchasing physical stock of a different type and holding this until the correct type can be bought at auction. We call this "hedging". There will according to NZWSI be on average 60 days hedging period until the auction date where the bidders' place bids for the wool clip. During this hedge period, the shearing of the wool is accomplished on average 10 days prior to the auction date. Within 11 days from the date of auction the payment is made by NZWSI and after payment there will be a 30 days period on average for the transportation of purchased wool clip to scour and until it enters the blending line for processing at the scour.
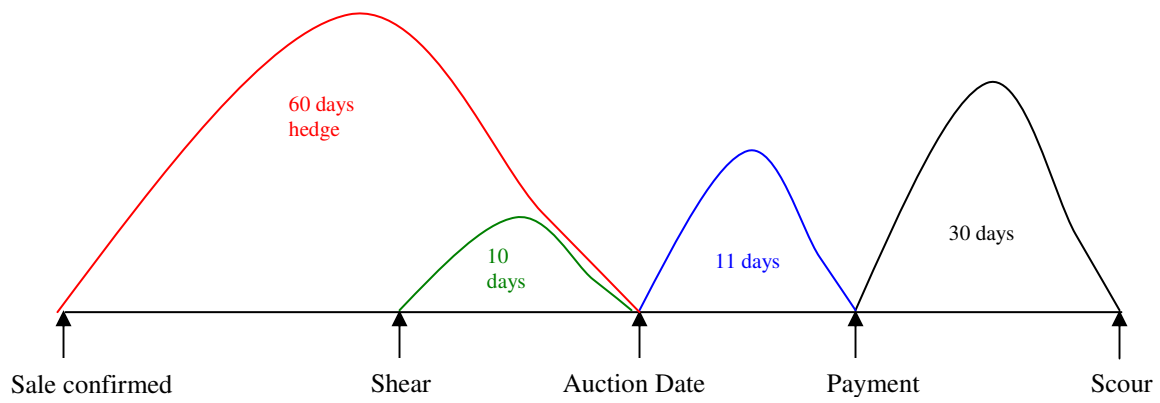
Figure 5.6 Time series for auction pathway showing the duration and corresponding actions.

5.2.2 Time Series for Direct Supply Pathway

The movement of wool in the Purelana system can be depicted in a time series as shown in Figure 5.7. As in the Auction system, in the Purelana pathway, the time series cycle starts from the date of confirmation of the order from an NZWSI customer. There is no market risk to hedge from order date till the time the grower contacts the service provider as the grower commits at the auction price prior to the order being taken. As explained in the documentation of Purelana, the payment procedure is made in two different instalments (NZWSI, 2007). The first 50% payment is after 21 days from when grower contacts service provider and the second 50% payment is after 150 days after the first 50% payment. After the first 50% payment wool will be in the scour on average in 30 days.
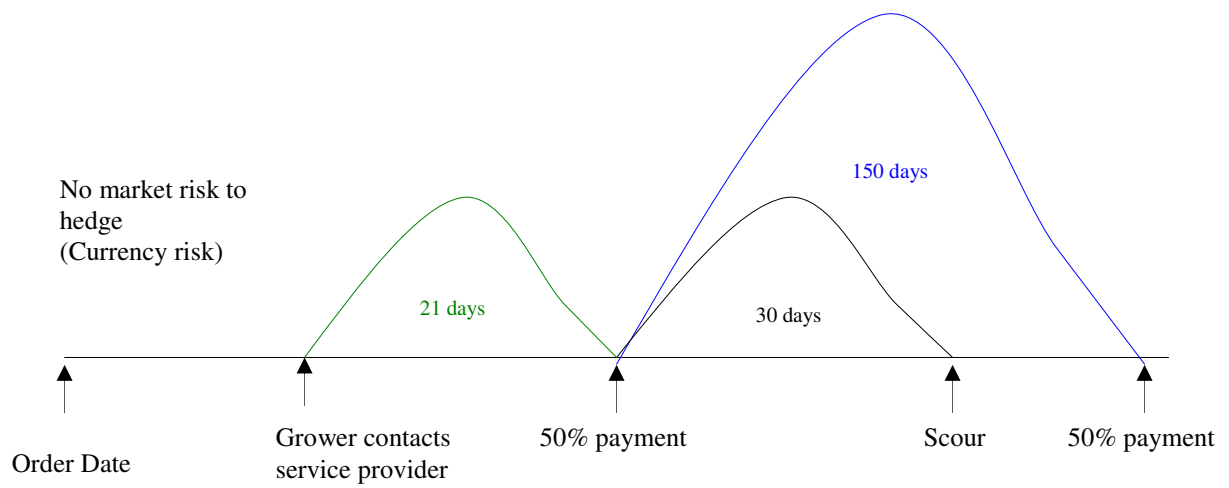
Figure 5.7 Time series for Purelana pathway showing the average durations and actions.

5.3 Calculation of Risk Free Cost and Cost of Risk

5.3.1 Auction Versus Direct Supply

Let us consider that the transfer price at auction is a typical value of, say, 350 cents per kg clean. There are various costs associated with the wool clip from sale confirmation to scour in the auction system. As mentioned earlier, the associated costs are calculated from the buyer's perspective. The time series shown in Figure 5.6 is a guideline for the calculation of associated costs in the Auction system. While calculating the associated cost a flat interest rate of 9.5% pa. is used. An additional administrative charge of 5% over and above the use of money charge also applies. The actual costs like storage cost, scour testing cost, broker delivery charge and transportation to scour are calculated and summed up to get the value at scour.

As shown in Table 5.1 the total cost to the buyer at the scour from Auction route is 381.6 c/kg. The difference between this total cost and the auction price of 350 c/kg is 31.6 c/kg is the cost $a(y)$ that we are going to use in Chapter 6 while formulating the optimization model. Strictly speaking $a(y)$ is dependent on the auction price $\overline{x}_i$ but to first approximation we will ignore this for the purpose of model development.

Similarly, the same auction transfer price is considered for the direct supply initiative i.e. 350 cents per kg clean. The costs associated with this sourcing option are calculated based on the time series shown in Figure 5.7. The interest rate is considered 9.5% pa. In this direct supply initiative, a guaranteed premium of 5% will be added to the base market price and paid to the growers after 150 days. Similarly, a loyalty rebate of $ 2.50 per bale at the end of each year and a pool payment (in the first year, the targeted pool payment is 5%) will be added as cost to NZWSI. All the associated costs are quantified (Table 5.1) and summed up to get the cost to NZWSI at the scour. As shown in Table 5.1 the total cost to NZWSI at the scour from Purelana route is 379.8 c/kg with zero pool payments.

The pool payment varies from 0 to 17.5 c/kg (5% of the base contract price 350 c/kg clean and if paid will add to both the NZWSI cost and to net grower returns). The total cost from direct supply route, 29.8 c/kg (the difference between 379.8 c/kg and 350 c/kg), is the cost $b(y)$ that we are going to use in Chapter 6 while formulating the optimization model. Likewise for $a(y)$, the same comments regarding $b(y)$ and $\overline{x}_i$ apply here too.

Table 5.1   Auction versus Purelana: calculation of associated cost to NZWSI

Auction	Cost	Purelana	Cost
Clean Price (c/kg)	**350.0**	Clean Price (c/kg)	**350.0**
Hedging cost for 60 days sale confirmation to next *Auction* Use of money 9.5% =(350*9.5%*60)/365 = 5.5 Management of finance @ 5% = (350*5%*60)/365 = 2.9 Storage of physical hedge stock 9 c /bale/day 135 kgs clean/bale = (60*9/135)=4.0 **Total = 5.5 + 2.9 + 4.0** Broker delivery charge $10.70 /bale = (10.7/135)*100	**12.4**	Only currency hedging as price agreed well in advance	**0.0**
Transport to scour Storage cost for 30 days from payment until scouring Use of money 9.5% =(350*9.5%*30)/365 = 2.7	**7.9** **5.2**	NZWSI share ($10.70/bale) of service provider charge of $13.20 /bale = (10.7/135)*100 Transport to scour	**7.9** **5.2**
Management of finance @ 5%=(350*5%*30)/365 = 1.4 Storage @ 9 c /bale/day 135 kgs clean/bale = (30*9/135)=2.0 **Total =2.7 + 1.4 + 2.0**	**6.1**	Storage cost for 30 days from 50% part payment until scouring Use of money 9.5% =(350*50%*9.5%*30)/365 = 1.4 Management of finance @ %=(350*50%*5%*30)/365 = 0.7 Storage @ 9 c /bale/day 135 kgs clean/bale = (30*9/135)=2.0 **Total =1.4 + 0.7 + 2.0**	**4.1**
		Purelana premium (5% of base price) =350*5%=17.5 Rebate $2.50/bale = (2.50/135)*100 = 1.9 Pool payment (0 to 17.5 c/kg) (It varies) = 0.0 Purelana Incentive = 17.5 + 1.9 + 0.0 =19.4 **Free use of grower money 150 days @ 50%=** **(350*50%*9.5%*150)/365 = - 6.8**	
No equivalent	**0.0**	Purelana incentive less free use of grower money	**12.6**
Total cost to NZWSI	**381.6**	**Total cost to NZWSI**	**379.8**

5.3.2 Growers' Impact

From the growers' perspective as well the associated cost are further quantified. As shown in Table 5.2, the net returns to growers from the Auction pathway is 319.0 c/kg while it is 346.0 c/kg from the Purelana pathway.

Table 5.2   Auction versus Purelana: calculation of associated cost to Growers

Auction	Revenue	Purelana	Revenue
Auction based price clean c/kg	350.0	Auction based price clean c/kg	350.0
No Equivalent		*Purelana* premium (5% of base price) =350*5%=17.5 Rebate $2.50/bale = (2.50/135)*100 = 1.9 Pool payment (0 to 17.5 c/kg) (It varies) = 0.0 *Purelana* Incentive = 17.5 + 1.9 + 0.0 =19.4 **Free use of grower money 150 days @ 50%** **=(350*50%*9.5%*150)/365 = - 6.8** *PURELANA* incentive less free use of grower money =12.6	
	0.0		12.6
Total growers revenue	350.0	Total growers revenue	362.6
	Cost		**Cost**
Freight to brokers store	5.2	Freight to depot	5.2
Brokers fees (weighted average) 85% mainline @ 10 c/kg greasy 15% small/bin lines @ 30 c/kg greasy Average yield (75%) (85%*10+15%*30)/75%	17.3	Grower share ($2.5/bale) of service provider charge of $13.20 /bale = (2.5/135)*100	1.9
Meat and wool levy @ 2.5%	7.0	Meat and wool levy @ 2.5%	7.0
Core testing	1.5	Supervised core testing - $100 per lot @ 30 bales average 4050 clean	2.5
Net to growers after cost	319.0	**Net to growers after cost**	346.0

5.3.3 Costs of Risks in Both Systems

The initial risks associated with *Auction* and *Purelana* sourcing options which could be identified from the perspective of NZWSI are summarised in Table 5.3.

Among the risks, it is found that 'sales volume risk' and 'unable to get wool risk' are highly significant to NZWSI in the *Auction* pathway. On the other hand, the risk of 'prior commitment to take wool' is highly significant in the case of the *Purelana* pathway. Hence, the cost of risk is calculated for these two risks only.

Table 5.3 Summary of associated risk with *Auction* and *Purelana* sourcing options.

Auction	Purelana

•   currency and market risks
    ➢   sale today for delivery in 6 months
    ➢   Has currency (buy & sell options) and market risk (hedge by buying physical stock)
    Net risk = minimal
	Sill have currency risk (take buy & sell option)
	
	Net risk = minimal

•   NZWSI sales volume risk
    ➢   No exposure
    ➢   400,000 bales/year
	• Committed to take wool
	    ➢ Uncertainty over sales
	    ➢ Could also end – up with imbalanced stock
	    ➢ At 100,000 bales ok but at 200,000 bales would have periods of over stocking

•   Unable to get wool risk
    ➢   10 -15 c/kg
    ➢   5% time
	No risk

The cost of risk is calculated for the 'unable to get wool risk' in the Auction system and the 'committed to take wool' risk in the Purelana system (Table 5.4 and Figure 5.8). The cost of risk is calculated for the volume of wool from 0 bales to 400,000 bales and presented in Figure 5.8. NZWSI seeks to purchase 400,000 bales annually. A highlight is made in Figure 5.8 for the cost of risk in the Purelana system and associated volumes. More specifically, a comparison is made for the equivalent cost of risk $185,625.00 pa. for both systems because this cost of risk is the amount in buying 220,000 bales (the volume NZWSI currently purchasing from Auction system). The same cost of risk is there just for purchasing 97, 832 bales in the Purelana system. In other words, the cost of risk is high in Purelana system in comparison with Auction system. For example, at 400,000 bales the cost of risk in Purelana system is $ 758,958.90 pa. whereas it is $ 337,500.00 pa. for Auction system.

Table 5.4   Calculation of cost of associated risk with Auction and Purelana sourcing options.

AUCTION		PURELANA	
Risk	**Cost of Risk**	**Risk**	**Cost of Risk**
<u>**Unable to get wool**</u>		<u>**Committed to take wool**</u>	
@ 0 bales	$0.00	**@ 0 bales**	$ 0.00
@ 50,000 bales 5 % of 50,000 bales = 2500 bales @ 135 kg = 337500 kgs * average risk (12.5 c/kg)	$42,187.50 p.a.	**@ 50,000 bales** = 50,000@15% late delivery = 7,500 bales (Finance for 60 days @ 9.5%)= 60*9.5%*7500*135/365= $ 15,811.00 for 60 days	$94,866.00 p.a.
@ 100,000 bales 5 % of 100,000 bales = 5,000 bales @ 135 kg = 675,000 kgs * average risk (12.5 c/kg)	$ 84,375.00 p.a.	**@ 100,000 bales** = (100,000*15%)*(60*9.5%)* 135 / 365 = $ 31,623.00 for 60 days	$189,738.00 p.a.
@ 220,000 bales 5 % of 220,000 bales = 11,000 bales @ 135 kg = 1485000 kgs * average risk (12.5 c/kg)	*$ 185,625.00 p.a.*	*@ 97, 832 bales* = (97,832*15%)*(60*9.5%)* 135 / 365 = $ 30,957.69 for 60 days	*$ 185,626.16 p.a.*
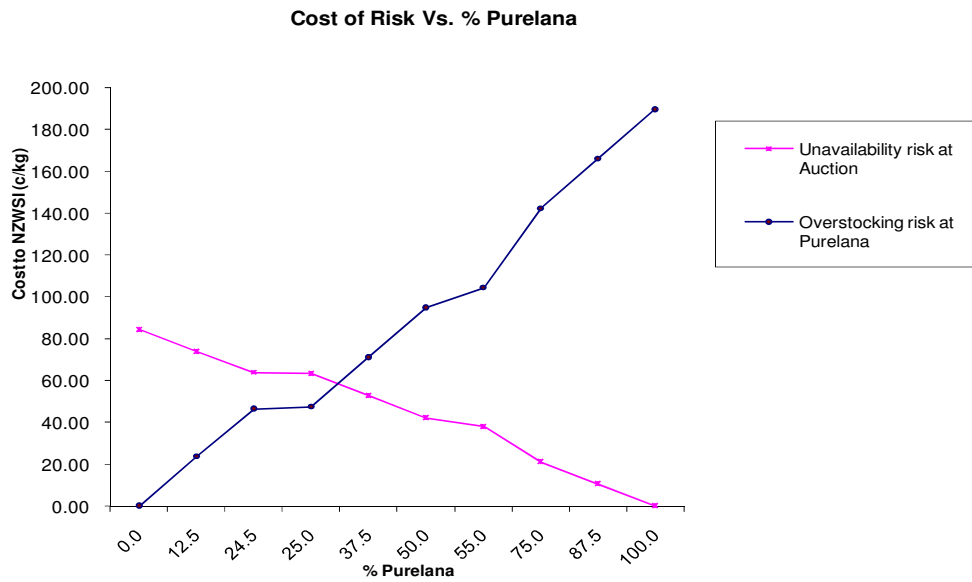
**Figure 5.8 A graph showing the cost of risk against the volume of wool (%
Purelana).**

However, all the cost of risk is basically depends on factor (% of late delivery or non-delivery of original contracted volume). The late delivery 15 % - in Purelana is not fixed and could be variable over the year due to suppliers changing shearing pattern, climate, changing their flock and other farming practices.

The result from the data is presented in Figure 5.9.

In preparation for the generalization of the optimization model let $A(y)$ be the cost of risk associated with auction and $B(y)$ the cost of risk associated with direct purchase.
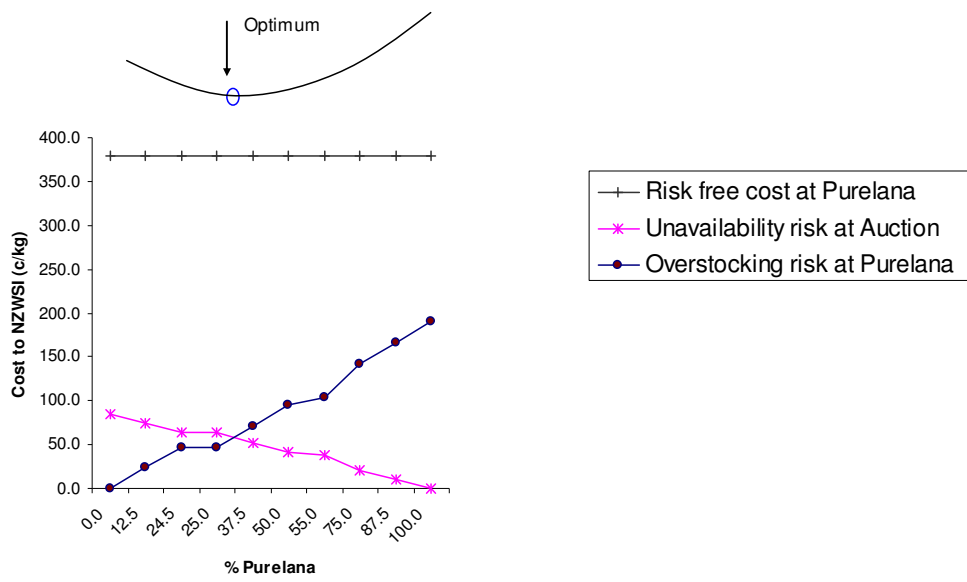
Figure 5.9 Buyer's optimization graph generated from actual NZWSI data.

In part II, further discussion is developed in light of the unexpectedly small difference to NZWSI of the Purelana versus Auction route (Table 5.1).

5.4 Discussion and Implication for the Future

The analysis presented above clearly shows that there is an optimum proportion of Purelana and that the company's positioning should be therefore to aim for that proportion sourced each of the two routes.
The company accepted this in principle, in the short term. However, we were intrigued by an unexpected result from the analysis. Namely, that in the cheaper Purelana option, the company had voluntarily elected to give nearly all of the savings to the growers by setting the Purelana incentive at such a generous level. This obviously provided incentive for growers to encourage Purelana participation. Further discussion and testing of this aspect revealed a new set of longer term strategic risks which provided the motivation for this behaviour.

The New Zealand sheep industry has been in decline and continues to decline. It has been forecast that sheep numbers will drop by a further 5 million sheep from today's 33 million sheep within 5 years (MWNZ, 2006).

There is consequently overcapacity in the post farm industry infrastructure and servicing. NZWSI is positioned as the largest and most efficient of the current exporting companies. It has the most modern plants[25] and currently enjoys about 30 % market share of all wool scoured and 40% of all wool exported in scoured form.
The company is therefore seeking to position itself as the lowest cost producer in a declining commodity market (NZWSI, 2007).

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[25] NZWSI owns and operates what are arguably the world's two most advanced and efficient strong wool scours: (1) Whakatu, Hawkes Bay, North Island and (2) Kaputone, Christchurch, South Island. Between them Whakatu and Kaputone can process 400,000 bales of wool per year.

If we think of the growers perspective as calculated in Table 5.2, the net return to growers after cost is 27 c/kg more in the Purelana than in the Auction pathway. This shows that the buyer is to superficial appearances being generous to growers by providing all the benefit to them. This amount (27 c/kg) is partly the result of the incentive to the growers provided voluntarily by NZWSI. This incentive is the sum of three components, namely, premium, rebate and the pool payment to the growers. Among these three components, rebate to the growers is paid based on the number of wool bales supplied in the Purelana direct supply initiative. The quantity of wool supplied by the growers to the Purelana pathway is intended to be directly influenced by the rebate to the growers. If the decision on providing the rebate amount to the growers varies then the quantity and hence the proportion of wool in the Purelana pathway also varies. This also affects the total cost to the buyer in the Purelana pathway. The total additional cost in Purelana as explained earlier is $b(y)$. We can now mathematically formulate that $b(y)$ is the function of the rebate amount. If we suppose the rebate amount by NZWSI is θ then,

$$b(y) = f(\theta). \hspace{4cm} \textbf{5.1}$$

Further, as θ varies, the minimum cost to NZWSI also varies and there is a different optimal position for the amount of wool NZWSI wishes to purchase via Purelana. Equally growers will provide more or less wool to Purelana depending on the value of θ. We include this extra degree of freedom in our optimization model to be developed in Chapter 6.

Although there is great pressure from growers for new initiatives to lift farm gate prices, there is nonetheless a perfectly winnable, dominant and profitable market position for NZWSI to take providing it remains the lowest cost operator and national wool production remains significantly above the capacity of the two NZWSI plants.

Taking this into account, it is clear that the NZWSI benefit sharing philosophy is aimed not so much being generous to growers as it is at securing long term wool supply.

The longer term risk optimization therefore includes additional strategic factors. Let us call the first "risk of access to adequate wool". This applies to the Auction route (Figure 5.10). A second which applies to Purelana is "lack of greasy wool infrastructure" risk (Figure 5.11).
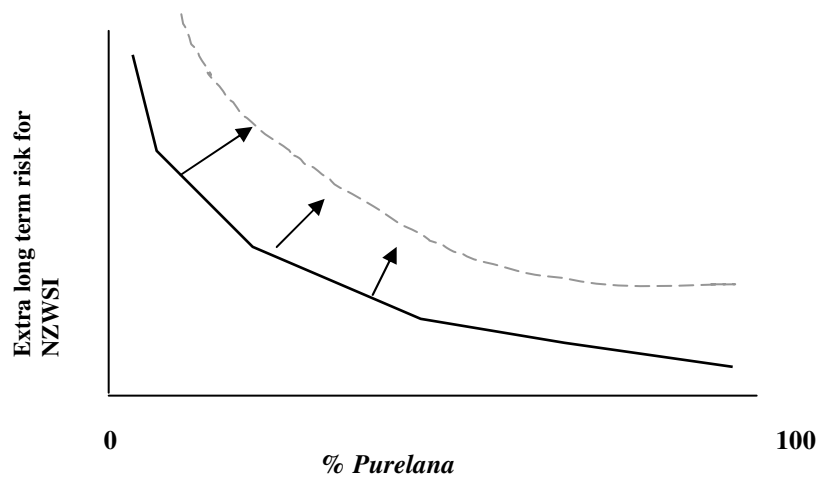
Figure 5.10 **Schematic diagram showing the risk of access to adequate wool in the Auction route. The 'unable to source wool risk' moves to the right over time as wool is removed from the auction by brokers. Currently low risk is moving to high risk.**
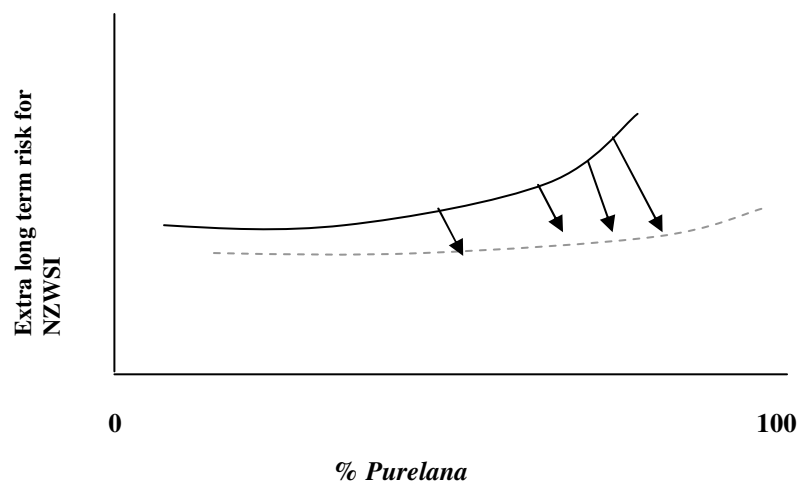
Figure 5.11   Schematic diagram showing the lack of greasy wool infrastructure in the Purelana route. The cost of overstocking moves down and to the right over time as infrastructure is put in place by NZWSI to store wool. Currently high risk is moving to lower risk.

If these risks are added to the risks identified earlier, the behaviour of the company can more easily be understood. By giving all the Purelana benefit to the growers it is positioning itself to ensure wool supply in the long term. The behaviour of the company can be seen to be very rational from their perspective.

On top of this, the Purelana initiative is certain to evoke a competitive response from the brokers. Brokers own most of the infrastructure to handle wool aggregation and storage from the farms. They have well established business relationships with farmers often underpinned by capital lending to farmers. Purelana will need to be powerful enough to displace these loyalties.

Equally although the brokers have represented the growers for many years to try and get the best price on their behalf, the brokers do not currently have good knowledge of or infrastructure to deal with clients in the export markets.

As demonstrated in Figure 5.10 and Figure 5.11, there will be a loss of access to high volume at auction which will increase the risk whereas the risk of 'lack of greasy wool infrastructure' in Purelana will decrease. Therefore NZWSI will want to build grower participation in Purelana sooner rather than later and may seek to achieve this by arbitrarily lifting the rebate to growers even though it increases short term total cost to NZWSI.

It is possible that Purelana could restructure the whole on-shore servicing industry. If NZWSI is successful in sourcing increasing volumes of wool via Purelana, it will need to build capacity to source and handle and store greasy wool. It is also quite likely that brokers will withdraw wool from the Auction and seek to develop their own exporting capability. If this happens the larger brokers will be in the best position and the fight for the traded grower wool will intensify as the uncommitted fraction shrinks.

It is possible that two or three larger fibre firms integrated from farm to overseas customer will emerge. If this does occur, then a major merger of these firms, similar to that which happened to Fonterra in the New Zealand dairy industry, could occur.

5.5 Summary

The initial premise was that the Purelana route would have a lower overall cost structure, but that if a high proportion of all NZWSI purchases were to be made that way then there would be a risk that NZWSI could be caught with locked in purchase obligations in a falling market. Equally it was recognised that if all wool is purchased at auction, then NZWSI would face different risks associated with the non-availability of specific wools when needed.

It was hypothesised therefore that there would be an optimal or target proportion of wool purchases that NZWSI should seek to make via the Purelana route.
By pricing the risks we have been able to set up a simple model to find the proportion of Purelana which gives the overall minimum cost to NZWSI.

In the course of doing so, we have had occasion to analyse the detailed costs involved in each route. This has shown that, as currently configured, the Purelana route does indeed reduce overall cost. Specifically, the grower receives an extra 27.0 c/kg clean from Purelana and NZWSI sources its wool for 1.8 c/kg less.

We found that under the initial short term risks identified then NZWSI would minimise total supply cost at around 37.5 % Purelana and 62.5 % auction.

However in the discussion section we speculate about new risks unfolding from wool industry consolidation and reform. We perceive the auction supply side risk increasing due to falling sheep numbers and control of the auction system being in the hands of competitors. Equally as NZWSI builds capacity and infrastructure to accommodate larger volumes of Purelana, the overstocking risks will reduce. These two developments will likely affect the cost of risk calculations and drive the minimum cost position in favour of rather higher proportions of Purelana sourced fibre. NZWSI also has the option, as efficiencies emerge, of increasing the share of benefits accruing to itself without reducing

the grower benefit as greater volumes are established. The current strategy is clearly aimed at building market share as fast as possible without actually costing NZWSI any more to source its wool.

The next chapter will focus on formulating a more formal optimization model and theoretical mathematical modelling aspects of identified risk and cost.

Part Three:

In this third part of the study, we are now in a position to predict the average cost in c/kg to the buyer for wool type i (say, Z_i) by formulating an optimization model. In part one, we have demonstrated that how the average cost ($\overline{x}_i$) for type i at auction is formed. Similarly, in part two we defined and presented that if the proportion of wool bought at auction is (y), then the additional cost at auction is $a(y)$, proportion of wool bought at direct supply is $(1-y)$ and the additional cost at direct supply is $b(y)$. Further, the cost of risk at auction is $A(y)$ and the cost of risk at direct supply is $B(y)$. All of these components can now be brought together to formulate the optimization model. This optimization model aims to minimize Z_i. Thus, this optimization model predicts the value of "Z_i" where to first order

$$Z_i = y.\big(a(y)+A(y)\big)+(1-y)\big(b(y)+B(y)\big)+\overline{x}_i$$

for any given $\overline{x}_i$ we minimize Z_i as a function of y. A more precise minimization could also be developed to take into account the minor dependency of $a(y)$ and $b(y)$ on $\overline{x}_i$.

Further, in this part, our understanding of the loyalty rebate amount provided to growers by NZWSI in direct supply is mathematically modelled along with the proportion of wool sought by the buyer, additional cost in auction and direct supply, the auction cost, cost of zero risk, cost of can't get wool risk and cost of overstocking risk.

Chapter 6

FORMULATION OF A GENERALIZED OPTIMIZATION
MODEL FOR MIXED SOURCING OF AGRI-RODUCTS

In previous chapters we showed how the buyer of a commodity such as wool, in our case NZWSI, can minimize the cost to themselves by buying a proportion of their requirements at auction and the remainder via direct supply. Although purchase via direct supply generally has a lower direct cost structure, over reliance on direct purchase carries risks of over stocking. If this over stocking risk is calculated and factored into the real cost of the decision, not all wool will be purchased this way. Equally if too much reliance is based on auction purchase the buyer risks being unable to secure adequate supplies of wool. This too has a risk which we have costed and factored into the optimization calculations in the previous chapter.

So, we showed that there is a unique proportion, which the buyer should seek to acquire via direct supply.

However, in reviewing the dynamics occurring in real time during the course of this study in the competitive landscape of the New Zealand wool industry it became apparent that the buyer had direct control over one further degree of freedom. In particular, we introduce, θ - the rebate amount - as a further degree of freedom to this optimization. So far in this analysis we have incorporated the rebate offered to growers as a given or constant. But in fact it is a variable under control of the buyer.

Initially we were confused as to why these rebates were so large. In fact the rebate offered by NZWSI was so large that nearly all the savings in direct cost from direct supply sourcing were being built into this rebate and given back to the growers willing to supply via the direct supply route.

After some consideration it became clear that the rebate was large in order to encourage grower participation. A small rebate clearly was unlikely to represent a sufficient encouragement to persuade growers to change long established practices and loyalities.

We have covered a number of key ideas in previous chapters that we can build upon to address the core issue of how buyers can optimize their wool buying strategy to gain the minimum average cost in c/kg. In this chapter, we are now in a position to formulate a generalized optimization model for agri-products taking into account the various costs from a buyer's perspective. We begin first though with a brief presentation on the rebate, the role of the rebate, and modelling of the rebate taking into account the growers' perspective. Different rebate scenarios are considered and we discuss how the buyer can further develop his strategy to optimize his total cost by varying the rebate.

We also show in the final section of the thesis how the output from our optimization model feeds into the linear programming theory of blend formation which can be carried out by exporters prior to scouring. The chapter is then discussed and summarised.

6.1 The Role of the Rebate in Negotiations

In this section, we aim to cover relevant background literature on the rebate's role in buyer-supplier negotiation from the modelling perspective.

There are various models developed and reported in the operations research literature considering the role of rebates. A model determining the optimal refund rate of rebates as a proportion of the retail price was developed (Ali, Jolson, & Darmon, 1994). This model considered four ways by which rebates contribute to incremental sales namely; brand switching, repeat purchases, purchase acceleration and category expansion. The other model (Jolson, Wiener, & Rosecky, 1987) showed that infrequent rebate users far outnumbered heavy or non-users in a randomly selected sample of appliance shoppers in a large eastern city. A model developed by Khouja (2006) found that optimal rebate value is jointly determined with price. The model was developed for manufacturing planning with a one-time offering of the rebate where linear and non-linear redemption rates were analysed.

In another model, an attempt was made by Soman (1998) to establish optimal rebate value by formulating profit maximization in which demand and redemptions are linear functions of rebate value.

Our model differs from this literature in that we consider the total cost for a buyer operating in parallel sourcing options instead of in a direct relationship like a manufacturer or retailer. Further, we will incorporate the rebate into the risk free cost.

Indeed as shown in Chapter 5 the rebate had initially been set by NZWSI (the buyer) at a level where the risk free cost (to NZWSI) would be almost constant irrespective of the amount being purchased via direct supply. All the savings were being rebated. Enquiry of the exporter revealed that even at this high level, inadequate quantities were being offered to NZWSI from throughout New Zealand for them to meet the level at which their total cost would be minimized.
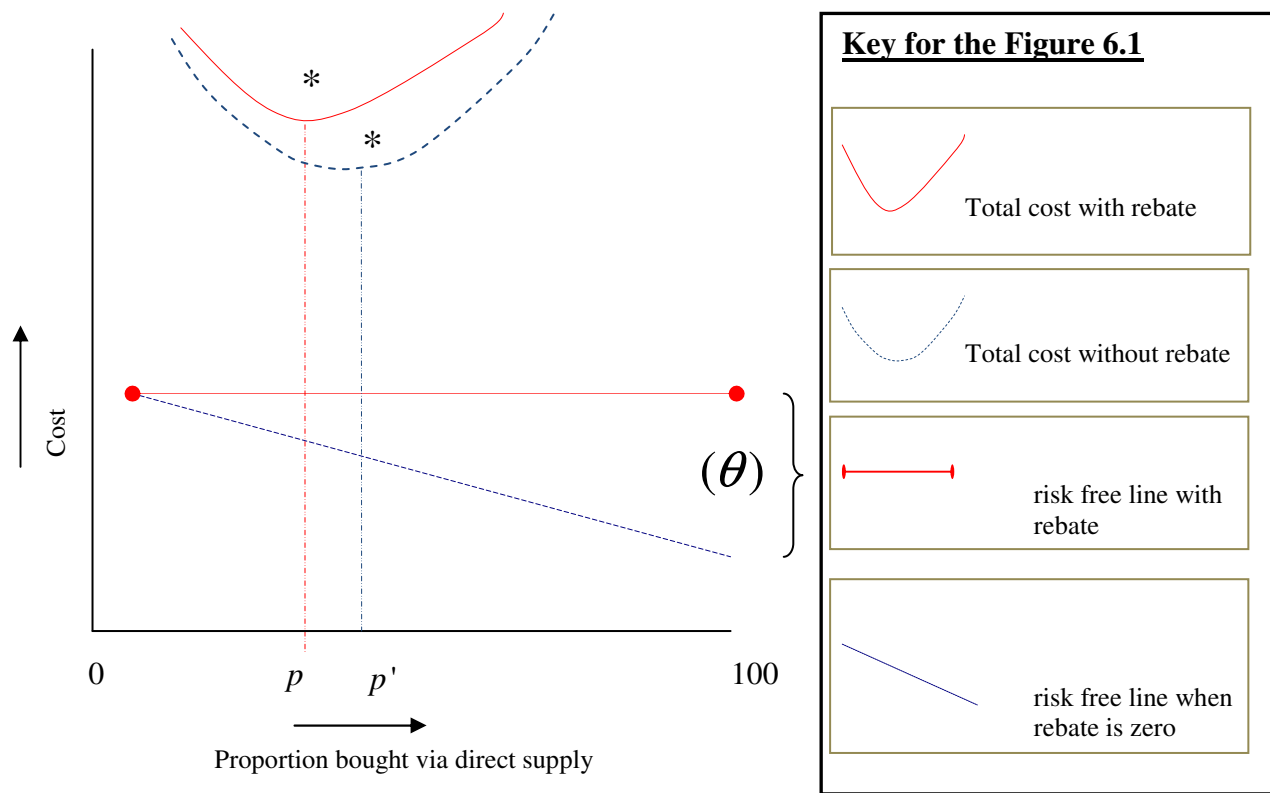
Figure 6.1 Schematic diagram showing the conceptual relationship between total cost and optimal proportion corresponding to risk free line with rebate (in red colour) and risk free line when rebate is zero (in blue colour). Keys for the Figure 6.1 show the legend.

In the Figure 6.1 above, p is the proportion desired to be bought with the current rebate and p' is the proportion desired to be bought with no rebate. The buyer obviously desires to buy more wool with no rebate than when the rebate applies.

But even with the rebate at such a high level, the company, NZWSI was still not able to source enough wool to achieve p.

It follows from the above that even if the rebate were to be increased further, the buyer could still minimize his overall cost, even though he was paying the grower more to deliver via direct supply.

As presented in Figure 6.2, the rebate is increased from its original position. The rebate is represented by angle α. This angle represents the decision of buyer on rebate. So, in effect the rebate is just another variable under the control of the buyer. It is used by the buyer to ensure that the growers provide enough wool so that the buyer can achieve the desired proportion bought at direct supply.

Now in the Figure 6.2,

$$\alpha = f(rebate) \qquad\qquad\qquad \textbf{6.1}$$

Let us introduce α as a variable.

If the buyer has a total annual wool requirement of X kg, and the rebate, θ is set at a level where the buyer desires to buy a proportion p via direct supply, then the actual kgs he will need to buy, P is given by,

$$P = p \cdot X \qquad\qquad\qquad \textbf{6.2}$$

This shows that there is an extra level of complexity. To further understand this complexity we need to consider the growers perspective. Considering the growers perspective we further can model the rebate.
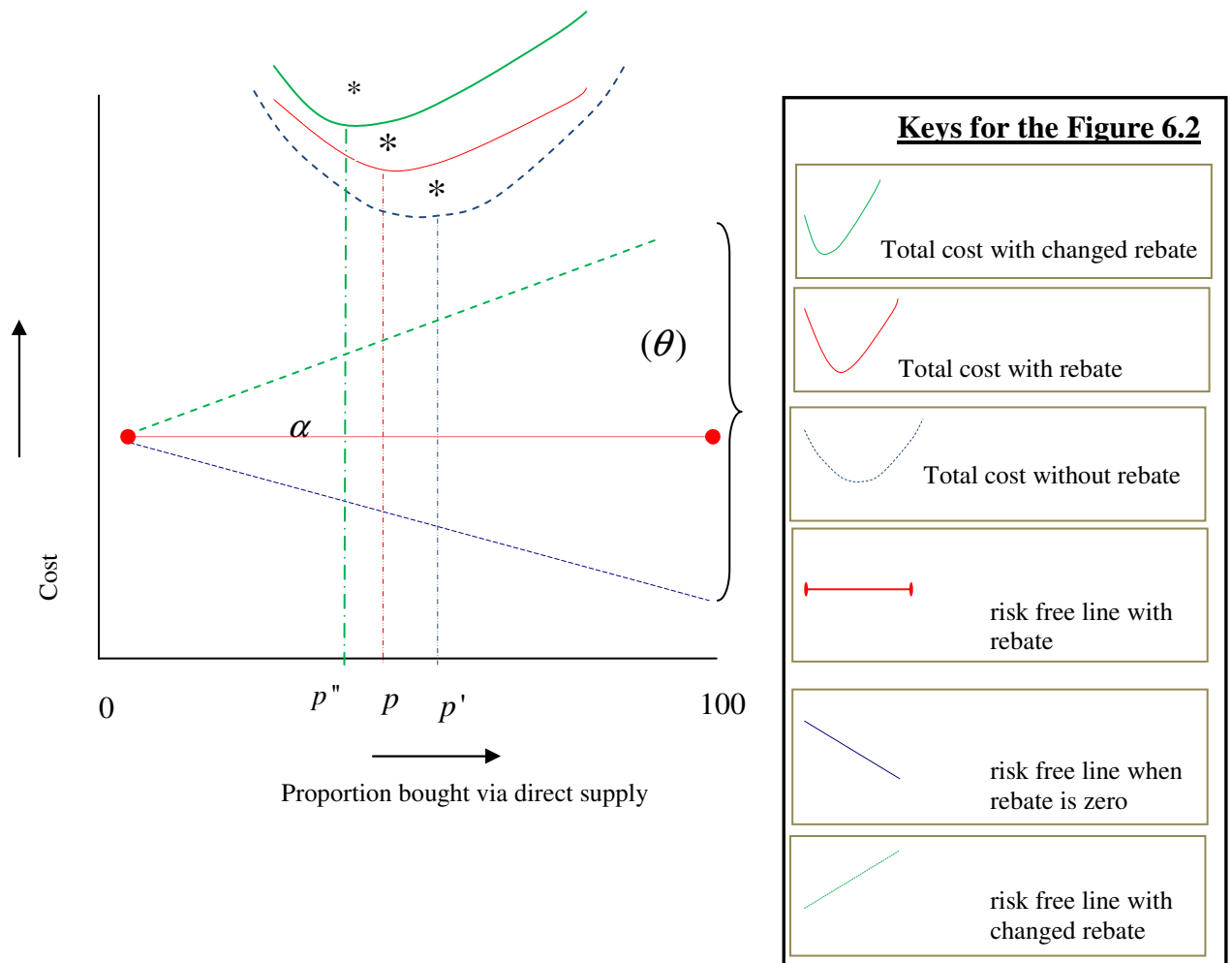
Figure 6.2 Schematic diagram showing the conceptual relationship between total cost and optimal proportion corresponding to risk free line with changed rebate (in green colour), with constant rebate (in red colour) and risk free line when rebate is zero (in blue colour). Keys for the Figure 6.2 show the legend.

6.2 Modelling the Rebate: Grower's Perspective

In order to model this extra level of complexity we need to characterize the growers response to the rebate. For a given level of rebate, characterized by α, the total quantity Q supplied by all New Zealand growers may be given by,

$$Q \ = \ ff\,(\alpha) \qquad\qquad\qquad \textbf{6.3}$$

The form of this equation is unknown but we could fit a function to the following data as follows:

rebate = 0	$Q = 0$
rebate	
(current level)	$Q = 2$ mkg
rebate = 2 x current level	$Q = 20$ mkg
rebate = 3 x current level	$Q = 70$ mkg
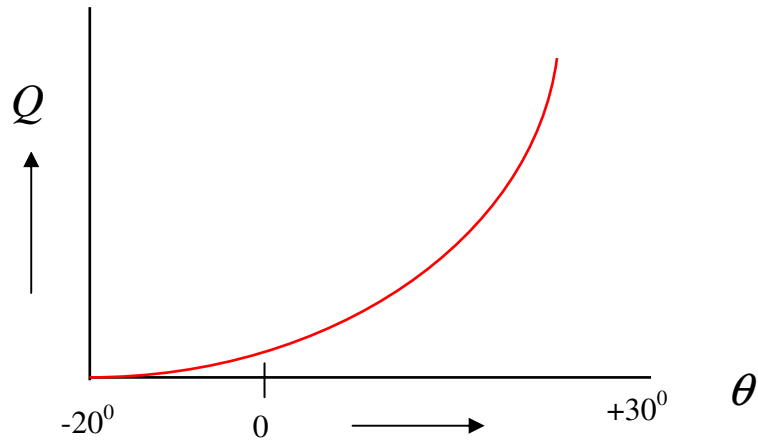
Figure 6.3 Schematic diagram showing the conceptual relationship between the total quantity Q supplied by all New Zealand growers and a given level of subsidy to growers by buyers characterized by θ. The relationship between these two variables might conveniently be represented by an exponential curve.

Step 1: rebate = zero

With the rebate set at zero, the model will calculate that the buyer desires to purchase p' based on the actual direct costs, plus the risk of unavailability of wool, plus the cost of the risk of over stocking. Given that he requires X kg per year, then this implies he would desire to purchase a quantity P' via direct supply,

$$P' = p'X \qquad\qquad 6.4$$

But at zero rebate, the amount the growers wish to supply is $Q' = 0$.

Step 2: increase rebate to flatten the risk free cost

In this situation as depicted in Figure 6.2, we calculate p with $\alpha \approx 0$. The quantity now desired from direct supply is less than p', it is now P where

$$P = p \,.\, X \qquad\qquad 6.5$$

The growers wish to supply $Q = 2$ mkg at this level of rebate.
If P is actually say 50 mkg, then the buyer is still well short of the amount he would prefer to buy via direct supply (to minimize his total cost).

Step 3: continue to increase θ

In this situation, it is necessary to give the growers a bigger rebate than the actual cost saving in direct costs. As α increases, the proportion desired from direct supply, which minimizes the buyers total cost falls i.e. $p'' < p$. The total quantity he desires is,

$$P'' = p'' .\, X \qquad\qquad 6.6$$

But as α increases so does Q, the quantity growers wish to supply. α should be increased progressively until,

$$P\ '' = Q*\qquad\qquad\qquad\textbf{6.7}$$

This will minimize the buyer's total overall cost. The equations can be solved numerically using bisection.

For given α, we can find a value of y which minimizes Z_i.

Given $\qquad\qquad Q = ff(\alpha)$

and $\qquad\qquad P = X.p_{\min(\theta)}$

we solve for θ or α by bisection.

The bisection theorem assumes that the given function $f(x) \in c[a,b]$ and that there exists a number $r \in [a,b]$ such that $f(r) = 0$

If $f(a)$ and $f(b)$ have opposite signs, and $\{c_n\}$ represents the sequence of midpoints generated by the bisection process, then

$$|r - c_n| \le \frac{b-a}{2^{n+1}}\ \text{for}\ n = 0,1....,$$

and the sequence $\{c_n\}$ converges to the zero $x = r$

That is, $\qquad\qquad \lim_{k\to\infty} c_n = r.$

(Weisstein, 2009)

In the next section, we present the optimization models.

6.3 The Optimization Models

6.3.1 The Optimization Model and Average Cost to the Buyer for Particular Type of Wool

In the previous chapters we explained the associated costs $(\overline{x}_i)$, $a(y)$, $b(y)$ and cost of risks $A(y)$ and $B(y)$ along with proportion of wool bought at auction (y) and via direct supply $(1-y)$ for a buyer who sources wool from two parallel options (auction and direct supply) simultaneously. We investigated that it is possible to predict the average cost in c/kg to the buyer for wool type (i) - say Z_i - by formulating an optimization model where

$$Z_i = y.\big(a(y) + A(y)\big) + (1-y)\big(b(y) + B(y)\big) + \overline{x}_i \qquad\qquad \textbf{6.8}$$

for any given $\overline{x}_i$ we minimize Z_i at a function of y.

Further, as explained in Chapter 5.4 and Table 5.2, the quantity of wool supplied by growers (Q) is a function of θ - the decision of NZWSI on rebate to the growers. Hence, $(b(y))$ is also a function of θ. This quantity θ can be included in the optimization model such that for a given θ we solve Z_i as a function of y. The optimization model that predicts the average cost in c/kg to the buyer taking θ into account is presented in the following equation

$$Z_i = y.\big(a(y) + A(y)\big) + (1-y)\big(b(\theta, y) + B(y)\big) + \overline{x}_i \qquad\qquad \textbf{6.9}$$

Following the above equation 6.9, if we consider the response of the growers in an offered (θ) condition by NZWSI, we could model the growers' response. To model such response following factors need to be taken into account. Let us assume

(1-y) = proportion desired to be bought from direct supply

P*   = Quantity from direct supply representing (1-y)

p*   = Proportion needed from direct supply

Q   = Total wool supplied to NZWSI by the growers

As we explained before, the motivation factor for growers to supply the wool clip to NZWSI is the rebate (θ) amount provided to the growers by NZWSI. So, the total wool supplied to NZWSI by the growers (Q) is a function of rebate (θ). Similarly, from the perspective of NZWSI, the quantity of wool from direct supply representing the desired proportion (Q) is also a function of (θ). If for any given (θ), Q is less than P, then NZWSI will need to change (θ) to get more supplied. It is because the growers are not responding enough to NZWSI that NZWSI has given so much away. In such a condition, for the proportion to be bought from direct supply (1-y) to be optimum it follows the following algorithm.

> *Postulate* (θ) *;*
> *Calculate P* and Q,*
> *If P* not equal to Q adjust* (θ).
> *Solution for (1-y) is when P*=Q.*

Where *P**= p* (1-y).

An approximate solution testing the values postulated for *Q* together with NZWSI's actual data yields an optimal rebate at 40% above the current fiscally neutral level at which point NZWSI would wish to purchase 19% via Purelana, and growers would willingly supply exactly the requisite annual tonnage, 7.5 mkg.

6.4 Relationship to Past Studies on Wool Blend Formulation

The total cost Z_{Total} for many lots of wool can be computed once we predict Z_i. The task of assembling such a processing parcel has been comprehensively studied previously (Carnaby 1983). In fact most processing lots are blends of different wool types. The formulation problem is essentially a linear programming optimization which is described below.

6.4.1 Linear Programming

As described in Carnaby (1983), a general definition of a linear programming problem is given as follows:

"Given a set of *m* linear inequalities or equations in *r* variables, we wish to find non-negative values of these variables which will satisfy the constraints and maximise or minimise some linear function of the variables.

Mathematically, this statement means we have *m* inequalities or equations in *r* variables of the form:

$$a_{i1}.x_1 + a_{i2}.x_2 + \dots\dots\dots\dots + a_{ir}.x_r \left| \ge, =, \le \right| b_i$$
$$i = 1, 2, \dots\dots\dots, m$$

6.10

Where for each constraint one and only one of the signs $\ge, =$, or $\le$ holds. We seek values of the variables *x* satisfying the above equation and

$$x_j \ge 0 \qquad j = 1, 2, \dots\dots\dots, r$$

6.11

and which maximise or minimise

$$Z = C_1.x_1 + C_2.x_2 + \dots\dots\dots + C_r.x_r.$$

6.12

The a_{ij}, b_i and C_j are constants."

Using the equation above and equation 6.9, we come up with the equation 6.13 which can be used in calculating the minimization of total cost for many lots of wool,

$$Z_{Total} = C_1 Z_1 + C_2 Z_2 + C_3 Z_3 + ...C_N Z_N. \qquad \textbf{6.13}$$

6.5 Discussions

In Chapters 4 and 5, we described and computed in detail various costs. We summarized these costs in this Chapter 6. We take into account all the associated costs to develop the optimization model that is capable of predicting the average cost in c/kg to the buyer for a particular wool type.

From the risk perspective, associated risks and the costs of such associated risks in two parallel supply systems are described in the previous Chapters (4 and 5). Two major risks are identified. The first one is 'can not get wool risk' if all the wool is sourced via auction pathway and the second risk is 'oversupply' or 'over stocking' risk if all the wool is sourced via direct supply pathway. Mathematically speaking, the behaviour of a buyer that was investigated in this study characterized these two major risks as two competing exponential functions. One risk which is 'can't get wool' is behaving like a decreasing exponential function whereas the second risk 'over supply' or 'overstocking' is behaving like an increasing exponential function. These risks have contributed to forming the total cost to the buyer. On top of these risks, the incentive provided to the growers by NZWSI has also contributed for the total cost to NZWSI (Detailed calculation of this incentive is made in Table 5.2). In particular, the decision on the rebate by NZWSI which we described by a notation θ is the reason in the variation of the minimum cost to NZWSI. As θ varies, the minimum cost to NZWSI varies and it is likely that growers provide more wool in direct supply. This situation creates an equilibrium position. In other words,

the more the rebate to the growers the more will be the quantity of wool supplied by them and more the variation will be in the minimum cost. This behaviour is shown by the buyer to secure the wool from direct supply.

Generally speaking, the behaviour will apply not only in the wool supply-chain. Such behaviour could be expected in securing any commodity with associated risks and is likely to apply to the supply-chain of other commodities as well. As the buyers in general want to secure a commodity to maintain their business process it is likely that they will pay higher rebates to the growers / suppliers even if that may at first sight appear illogical based solely on the actual direct costs.

6.6 Summary

We presented the associated risk free costs in two supply systems of the New Zealand wool clip. The constituents factors that contributed in forming these associated costs are described.

We investigated that it is possible to predict the average cost in c/kg to the buyer for wool type *(i)* - say Z_i - by formulating an optimization model. With such prediction, it is possible to calculate the total cost for whole parcel of wool.

Further, we investigated the associated risks in two supply systems and found that the mathematical model based on these risks is of general utility to other agricultural commodities. We linked the output of our model to earlier linear programming models of wool blend formation.

We present our final chapter next where we summaries the limitations, contributions and the future direction identified from this study.

Chapter 7

CONCLUSIONS AND RECOMMENDATIONS

This chapter reviews the key findings of this research as well as its limitations and potential future research.

7.1 Review of Key Findings

System modelling has been established as a science and an art in the research arena for a long time. With the help of system modelling techniques it is possible to characterize a schematic diagram of a system under study. System models provide an abstraction of reality that helps to provide an insight to the question under investigation. On the other hand, as today's world is challenging and competitive the need of optimization techniques to better run enterprises is an essential one. The CEO of any organisation may be seeking for an optimization model of their business process to gain the goal of their respective enterprise.

This study investigated three main areas. The **First** was the potential use of system modelling techniques for price formation of a niche agricultural commodity – wool in two different marketing approaches namely auction and direct supply that are running simultaneously and parallel in New Zealand. A first system model was developed to characterise the price formation of the New Zealand wool clip in the New Zealand wool auction. This system model considered the scenario after auction and before auction while determining the price formation in the open out cry auction environment of New Zealand wool. The second system model characterized the price formation process and the wool flow in a direct supply of strong wool of New Zealand. The **Second** detailed investigation was a determination of average cost for wool irrespective of the selling system as determined by the physical properties of the wool. The **Third** investigation was the formulation of an optimization model to calculate the average optimal cost for a buyer

who is operating in two parallel and simultaneous sourcing options. This model can be generalised to all agricultural commodities that are traded via auction and direct supply. This approach is believed to be particularly significant to New Zealand since its economy is heavily reliant on agricultural commodities and their trading. This research demonstrated that system modelling techniques, analytical approaches and optimization models in combination can provide an insight to the price dynamics for an agricultural commodity that is complex in nature. This approach provided an efficient way to better understand the price dynamics of New Zealand wool. The results can potentially be useful for buyers of agricultural commodities which are traded via auction and direct supply.

7.2 Contributions

We believe that the contribution of this study can be categorized into three main points. The **First** one is the development of a systems model for the price formation of the New Zealand wool clip for a buyer who is sourcing the wool from auction. This system model incorporates the constituent factors considered by a buyer during and after auction while making a decision to purchase wool. The **Second** contribution is the formulation of a system model for a buyer who sources wool from a direct supply pathway. In this system model the cost derived from the auction pathway is taken into account as a reference cost. In this setting, the importance of the auction cost is relevant to both pathways. The **Third** contribution is optimization models for a buyer operating in a two parallel but simultaneously occurring pathways. These optimization models take into account the average cost at auction for a particular type of wool, proportion of wool bought at auction, total cost at auction, proportion of wool bought at direct supply, associated risks, the factored cost of these associated risks and the total cost at direct supply. These three models are original and none appear to have been described previously. It is hoped that these three models will be of quite general utility and also be useful therefore for other agricultural commodities that are traded simultaneously via *auction* and direct supply.

7.3 Limitations of the Research

Though the findings and formulations from the present research revealed promising results, some limitations should be pointed out.

The **First** limitation was the need to develop a consensus for the class description and discrimination of the wool types among the various buyers, sellers and growers. On the other hand, a demarcation on the subjectivity among the class categories is also needed. Having said that, it needs to be taken into account that wool is a fibre came from different breed of the flocks, different parts of the body within a sheep and various geographical locations dictated by weather and farming practices. These variations are the reasons why wool is a complex fibre for which to determine the price. This fibre is heterogeneous in character but a fuzzy homogeneity among the fibres is a challenge for its discrimination. While keeping an eye on the data, the analytical approaches are promising to provide the insight of the price dynamics of the New Zealand wool clip.

The **Second** limitation was related to the roles of the participants in the New Zealand Wool Industry. Though the role of each stakeholder has been understood for a long time, these days the role is crossing over. In this context, it is worth defining the role of the participants and their changing roles.

The main purpose of the modelling carried out in this thesis was to illustrate the mathematical principles which constrain buyer strategy in a commodity market. The models are simple first order models, but they have shown some previously undiscussed phenomena. Although the thesis has carried out only limited prediction, the results seem sensible. Second order corrections to the assumptions could be added. There is interdependency in terms of both physical properties and in the optimization study. Including that may increase precision at the risk of a loss in clarity of the underlying principles.

7.4 Future Direction

We identified the potential areas of future research. These can be classified into three categories. The **First** one is an improvement in the definition of class categories and description of the wool clip. The **Second** one is the definition of the roles of the participants of the wool industry and development of their cross-over of the roles. The **Third** one is the practical application of the system models and the optimization model so that the stakeholders who are involved in the wool trading can be benefited. We believe that a user friendly Graphical User Interface (GUI) would contribute for the efficiency in the decision making. At start a GUI having less functionalities would help. With the development of this, more complexities can be incorporated to ease the decision making of the stakeholders. As outlined in the Chapter 6, such a GUI can be generalised to better understand the price dynamics of other agricultural commodities that are traded via auction and direct supply. The standardisation and embedding to GUI of the price dynamics would be a big challenge but not impossible.

A further intriguing prospect relates to the potential to simplify the overall optimization problem. In the blend optimization, blend price is minimized subject to various inequality constraints on the physical properties. However the price of an individual lot is also a function of these same properties. It may be possible to integrate the regression equations into the simplex solution of the linear programming formulation. But that would be a major task and beyond the scope of the present thesis plan.

The models produced in this study are rich sources of information for wool buyers and other stakeholders of the wool industry. They could be made more precise by incorporating second order dependencies between the variables. They need further mathematical development and more intensive testing. But their main value in the context of this thesis has been for conceptual purposes rather than precise prediction. Consequently, the availability of these models open new research opportunities for investigating the price dynamics of the agricultural commodities that are traded via auction and direct supply, and possibly the relationships of price dynamics between the

commodities, for instance, inter and intra fibre competition in relation to wool and competition among other commodities. The monitoring of price dynamics of agricultural commodities should be prioritised as it is the area where most of the revenue is generated for the economies of New Zealand. We believe that the economies of New Zealand and its position in the OECD countries demand system models and the generalised optimization models that are produced from this study.

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Appendices

Appendix A

Order Statistics: a Mathematical Foundation of Auction Bidding

The random variables arranged in orders are said to be order statistics. In the auction environment, bidders bidding follow such order statistics. A detail description on order statistics is covered in (Arnold, Balakrishnan, & Nagaraja, 1992). This book presents order statistics in a statistical basis. The other book (Krishna, 2002) presents order statistics to support auction theory. We follow Krishna (Krishna, 2002) in our body text and here in the Appendix A to describe order statistics.

Let $X_1, X_2, \ldots., X_n$ be n independent draws from a distribution F with associated density f. Let $Y_1^{(n)}, Y_2^{(n)}, \ldots., Y_n^{(n)}$ be a rearrangement of these so that $Y_1^{(n)} \geq Y_2^{(n)} \geq \ldots. \geq Y_n^{(n)}$. The random variables $Y_k^{(n)}, k = 1, 2, \ldots., n$ are referred to as order statistics.

Let $F_k^{(n)}$ denote the distribution of $Y_k^{(n)}$, with corresponding probability density function $f_k^{(n)}$.

When the sample size n is fixed and there is no ambiguity, we will economize on notation and write Y_k instead of $Y_k^{(n)}$, F_k instead of $F_k^{(n)}$ and f_k instead of $f_k^{(n)}$. We will typically be interested in properties of the highest and second-highest order statistics, Y_1 and Y_2.

Highest Order Statistic

We derive the highest order statistics as follows:

The event that $Y_1 \le y$ is the same as the event: for all k, $X_k \le y$. Since each X_k is an independent draw from the same distribution F, we have that

$$F_1(y) = F(y)^n \qquad\qquad \text{A-1}$$

The associated probability density function is,

$$f_1(y) = nF(y)^{n-1} f(y)$$

We observe that if F stochastically dominates G (for all x, $F(x) \le G(x)$) and F_1 and G_1 are the distributions of the highest order statistics of n draws from F and G, respectively, then F_1 stochastically dominates G_1.

Second-Highest Order Statistic

The second highest order statistic Y_2 can also be easily derived. The event that Y_2 is less than or equal to y is the union of the following disjoint events: (i) all X_k's are less than or equal to y and (ii) $n-1$ of the X_k's are less than or equal to y, and one is greater than y. There are n different ways in which (ii) can occur, so w have that

$$\begin{aligned} F_2(y) &= F(y)^n + nF(y)^{n-1}(1 - F(y)) \\ &= nF(y)^{n-1} - (n-1)F(y)^n \end{aligned} \qquad\qquad \text{A-2}$$

The associated probability density function is

$$f_2(y) = n(n-1)(1 - F(y))F(y)^{n-2} f(y) \qquad\qquad \text{A-3}$$

Again, it can be verified that if F stochastically dominates G and F_2 and G_2 are the distributions of the second-highest order statistics of n draws from F and G, respectively, then F_2 stochastically dominates G_2.

Relationships
Observe that

$$F_2^{(n)}(y) = nF(y)^{n-1} - (n-1)F(y)^n$$
$$= nF_1^{(n-1)}(y) - (n-1)F_1^{(n)}(y)$$

and so,

$$f_2^{(n)}(y) = nf_1^{(n-1)}(y) - (n-1)f_1^{(n)}(y) \qquad \text{A-4}$$

This immediately implies that the expected value of second highest order statistic is,

$$E[Y_2^{(n)}] = nE[Y_1^{(n-1)}] - (n-1)E[Y_1^{(n)}]$$

And also,

$$f_2^{(n)}(y) = n(n-1)(1-F(y))F(y)^{n-2}f(y)$$
$$= n(1-F(y))f_1^{(n-1)}(y) \qquad \text{A-5}$$

The above treatment of equations show that how order is defined and this lead to the expected value of the bidders in auction environment.

Appendix B

Wool Valuing Code Associated with the Database

Available from Local Auction Centre

NZWSI Valuing Code

CATEGORY		LENGTH	(Barbe)	DESCRIPTORS		
A	-	A 6/8"	130mm	A	Autumn (sound)	-
B	Bellies	B 5/7"	125mm	B	Burr	(1-6)
C	Clothing Oddments, B/P	C 4/7"	120mm	C	Cotts	(1-4)
D	Down Fleece	D 4/6"	115mm	D	Skirt / B- or Disc Type	(1-4)
E	Eye Clips	E 4/5"	110mm	E	Contains Bellies	(1-4)
F	Mainbody Wool	F 4/7" tender	105mm	F	Felted Wools	(1-4)
G	Soft Cotts	G 3/5"	100mm	G	Good Side of Type	(1-2)
H	Hard Cotts	H 4"	95mm	H	Shorn Hogget	-
I	-	I 3/4.5"	95mm	I	Urine Stain	(1-3)
J	Mud/Slipe	J 3/4"	90mm	J	Mud	(1-6)
K	Crutchings	K 3/6" v tender	85mm	K	Dusty	(1-6)
L	1st Lambs	L 2/4"	80mm	L	Treefoil	(1-6)
M	2nd Lambs	M 3"	75mm	M	Pen Stain	(1-4)
N	Necks	N 2/3" long	65mm	N	-	-
O	Black	O 2/3"	60mm	O	Dag	(1-4)
P	Pieces	P 1/3"	55mm	P	Water Stain	(1-4)
Q	Backs	Q 1/2.5"	50mm	Q	Very Mixed Micron	(1-4)
R	Double Fleece	R 1/2"	40mm	R	Very Mixed Length	(1-4)
S	Second Pieces & Lox	S 1/1.5"	35mm	S	Kempy	(1-4)
T	Brands			T	Tender	(1-4)
U	Drysdale	T 1/4"	65mm	U	Lustre	(1-6)
V	Dead	U -	-	V	Black Fibre	(1-4)
W	Open Cotts	V -	-	W	Woolly Hogget	-
X	Dag	W -	-	X	Bulk	(1-4)
Y	Stain	X 3/6" A-T3	105mm	Y	Thistle	(1-6)
Z	Down Odds	Y 1" >	20mm	Z	Moit / Seed / Pine	(1-6)
		Z -	-			

COLOUR CODE

Half Bred

		F	N	P,B,C	S	K	L	M
A/BB OR SUPG/D	0	1-					1-	
B/BB OR GD/AV	1	2-	2-	3-	3-	2.5-	1.1-1.5	2-
B OR AV	2	2.1-2.5	2.1-3.0	3.1-5.0	3.1-4.5	2.6-3.5	1.6-2.0	2.1-3.5
B-	3	2.6-3.0	3.1-3.5	5.1-6.0	4.6-6.5	3.6+	2.1-2.5	3.6-5.0
B/C OR AV/POOR	4	3.1-4.5	3.6-4.5	6.1-7.0	6.6-8.5		2.6-3.0	5.1-6.5
C OR POOR	5	4.6-6.0	4.6+	7.1-9.0	8.6+		3.1+	6.6+
C/R OR DISC	6	6.1-7.5+		9.1-10				

Merino

		F,N	P,B,C	S
A/BB OR SUPG/D	0	0.5-		
B/BB OR GD/AV	1	1-	1.5-	2-
B OR AV	2	1.1-1.5	1.6-2.5	2.1-3.0
B/C OR AV/POOR	3	1.6-2.5	2.6-4.0	3.1-4.0
C OR POOR	4	2.6-3.0	4.1-5.5	4.1+
C/R OR DISC	5	3.1+	5.6+	

X Bred

		F	N	P	B	C	S	K	L	M	Y
A/BB OR SUPG/D	0	2-					3.4-	1.9-	1.5-		
B/BB OR GD/AV	1	2.1-3.0	3.4-	5-	6-	4.5-	6.5-	2.0-3.5	1.6-2.0	3.0-	
B OR AV	2	3.1-4.5	3.5-4.5	5.1-7.0	6.1-7.0	4.6-6.0	6.6-7.5	3.6-4.4	2.1-2.5	3.1-3.6	
B-	3	4.6-5.0	4.6-5.0	7.1-7.5	7.1-8.0	6.1-7.0	7.6-8.5	4.5-5.4	2.6-3.0	3.7-4.5	
B/C OR AV/POOR	4	5.1-6.0	5.1-6.0	7.6-9.5	8.1-10.0	7.1-8.5	8.6-10.5	5.5-6.9	3.1-4.0	4.6-6.5	8-
C OR POOR	5	6.1-7.5	6.1+	9.9-11.5	10.1-12.0	8.6-10.5	10.6-12.5	7.0-8.4	4.1-5.0	6.6-8.0	
C/R OR DISC	6	7.6-8.5+		11.6-13.4	12.1-14.0	10.6-12.5	12.6+	8.5+	5.1-6	8.1-9.0	8.1+

Appendix C

A Sample Market Report

NATIONAL MARKET REPORT

Thursday, 30 April 2009 Week 44

Compared South Island sale 26/3/2009

Mid Micron Fleece	28 Micron and finer		10 to 20% dearer
	29 to 31.5 Micron		2 to 4% dearer

Compared North Island 23/04/2009

Fine Crossbred Fleece	32 to 35 micron		2 to 3 % Dearer
Fine Crossbred Early Shorn and Second Shear	32 to 35 micron		4 to 7 % Dearer
Coarse Crossbred Fleece	36 micron and Coarser	B style and better	Fully firm
		B minus	2 to 3 % Dearer
		BC	Sellers Favour
Coarse Crossbred Early Shorn and Second Shear		All styles	4 to 6% Dearer
First Lambs			7 to 12% Dearer
Second Lambs			2 to 4 % Dearer
Crossbred Oddments	Combing		1.5 to 2.5 % Dearer
	Clothing		2 to 3 % Dearer

Bales on offer   13,914   Bales Sold 11,813   85.0 % Sold

Competition

This week's South Island wool sale generally strengthened on the back of stronger Chinese interests, despite a potentially unhelpful exchange rate factor.

Compared to last sale, the weighted wool currency indicator strengthened by nearly one per cent which would normally have a negative impact on local wool prices.

Recent stronger world wool markets have helped boost local levels, particularly categories suitable for China, however the carpet sector also benefited.

A small selection of Mid Micron wools 28 micron and finer strengthened 10 to 20 per cent with 29 to 31.5 micron lifting 2 to 4 percent.

Fine crossbred fleece 32 to 35 micron was 2 to 3 percent stronger with the fine crossbred shears gaining 4 to 7 percent.

Lambs fleece were strongly contested gaining significantly as the sale progressed increasing between 7 and 12 percent.

Carpet type fleece were firm to 3 percent dearer with coarse shears strengthening between 4 and 6 percent. Oddments were 1.5 to 3 percent stronger.

MARKET SELECTION

30 April 2009

MAIN BUYERS

Masurel	2,500
JS Brooksbank	2,200
Dawsons	1,800
NZ Wool Services	1,500
Fuhrmann	1,100
W G Robinson	1,100
Bloch and Behrens	600
J Marshall	400
G Modiano	200

SELECTION– SOUTH ISLAND   **13,914 Bales**

Merino Fleece	0.3 %
Halfbred Fleece	2.5 %
Halfbred Oddments	0.8 %
Fine Crossbred Fleece	11.8 %
Fine Crossbred Early Shorn and Second Shear	11.3 %
Coarse Crossbred Fleece	21.4 %
Coarse Crossbred Early Shorn and Second Shear	16.0 %
First Lambs	15.8 %
Second Lambs	2.0 %
Crossbred Combing Oddments	3.8 %
Crossbred Clothing Oddments	8.4 %
Cotts	1.6 %
Miscellaneous	4.3 %

Appendix D
Uncontrollable and Controllable Variables in Auction
and Direct Supply From Buyer's Perspective.

AUCTION		PURELANA	
Uncontrollable	**Controllable**	**Uncontrollable**	**Controllable**
- Competitors sales	- NZWSI Stocks	- Changes in farming practices affecting indicated wool flow and types.	- Promotion
- Competitors stocks	- NZWSI sales		- Marketing
- Wool flows	- Currency Hedging	- Currency fluctuations	- Contracted supply
- Growers reserve prices	- Client relationship	- Competitors actions	- Price / Cost Structure
- Brokers actions (Cross over of role as an exporter)	- Selection of raw wool	- Weather effects	- Branded product
	- Quality of wool purchased	- Demand	- Minimise competition
- Demand		- International economic factors	- Pre knowledge of delivery times and types
- Currency fluctuations	- Relationship with competing bidders		
- Growers preparation of wool	- Relationship with selling brokers.		- Growers / buyer direct relationship
- Weather impact			- Storage space and costs
- Changing farm practices			
- Financial return impact			
- International economic factors			

Appendix E

Random Factors, Associated Risks and

Corresponding Variable Actions in New Zealand Wool

Auction from Buyer's Perspective

RANDOM FACTORS	RELATED RISK	VARIABLE ACTIONS
Currency	Stronger NZ Dollars= Normally a lower NZ price Weaker NZ Dollars = Normally higher NZ price	▪ Decision to cover or not to cover currency ▪ Market may ignore currency influence ▪ Customers may resist adverse currency affect and collectively absorb any advantageCurrency volatility during auction
Competition	Strong = Normally higher prices Weak = Normally easier market	Dependent on ▪ Wool volumes available ▪ Range of types offered ▪ Individual companies exposure ▪ Individual companies cash flows ▪ Personalities ▪ Future amount of wool available
Wool Flow	▪ High = Can contribute to a softer market ▪ Low = Can increase prices	Variables include World economic situation ▪ Fashion requirements ▪ Local economics of farming affecting farming practices ▪ Climate impact eg; droughts
Brokers Control	▪ Acting as a Broker – Wool flows regularly with all types available ▪ Acting as a purchaser – Wool flows unpredictable	• Broker acting on behalf of grower gets income from high throughput. Keen seller on behalf of grower • Broker acting as a purchaser uses position to extract a margin on their behalf – Disrupts normal Grower / Broker / Buyer relationship.

Appendix F

Random Factors, Associated Risks and

Corresponding Variable Actions in the Direct Supply

of New Zealand Wool from Buyer's Perspective

RANDOM FACTORS	RELATED RISK	VARIABLE ACTIONS
Currency	Stronger NZ Dollars = Normally a lower NZ price Weaker NZ Dollars = Normally higher NZ price	Minimal affect on 'fixed' contract prices Corresponding affect on 'Express' contract prices similar to auction Opportunity to minimize risk through future contract arrangements with end users
Competition	Limited risk – supply contracted	Alternative groups could offer similar concept to growers Competitors may undermine 'trust' with growers by attacking the system
Wool Flow	High flow	Will create relative pressure on facilities, borrowings and meeting payment schedules May mean WSI needs to pull back from other purchasing avenues. While auction is visible market setter.
	Restricted flow	Low risk as wool already contracted to WSI
Brokers Control	Eliminate the 'Purelana' system	Broker acting on behalf of grower gets income from high throughput. Keen seller on behalf of grower Broker acting as a purchaser uses position to extract a margin on their behalf – Disrupts normal Grower / Broker / Buyer relationship.