THE IMPLICIT MARKET FOR CHARACTERISTICS OF MERINO WOOL:

AN HEDONIC APPROACH

By

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Disclaimer

I, Madeleine Ryan, certify that unless otherwise identified, all material contained within this thesis is my own original work, and has not been submitted for any degree, is not being submitted for any degree, nor has it been published elsewhere. All assistance used in the preparation of this thesis, whether oral or written, and all source materials, has been duly acknowledged where appropriate in this thesis.

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Abstract

This study employs an hedonic approach to analyse the impact of raw wool characteristics on clean price in markets for superfine, fine, medium and broad wool. Data for 232 209 Merino fleece lots sold in 2005-06 auction season were obtained from AWEX. The results obtained indicate that fibre diameter has the greatest influence on price in superfine, fine and broad markets, which implies that breeding programs should focus on this property. Lot contamination, including brands, unscourable colour and vegetable matter were found to impact negatively impact on price, suggesting that the dissemination of information along the supply chain needs to increase.

1 Introduction

The motivation for this thesis stemmed from a strong personal interest in the Australian wool industry and a concern for its future directions and prospects. While there are many areas that could have been analysed, this study investigates an area which can be applied practically at all levels of the supply chain.

The problem identified in this study is the lack of rigorous economic analysis concentrating on the issues facing the wool industry since deregulation. The other problem addressed is that of branding contamination. The presence of this attribute is believed to be discounted by processors as it results in increased costs and inconvenience.

This study aims to analyse the impact that various characteristics have on the price of Merino wool. This is in the context of lack of recent literature specific to this topic and industry concern about the severity of branding contamination on processor decision-making.

The main objectives of this thesis are:

- To identify the impact of several different attributes on the price of Merino fleece wool;
- To estimate the implicit prices of these different attributes to the price paid for a lot;
- To update the body of economic literature on the wool industry, as this has been an area that has been neglected since deregulation; and
- To examine the specific impact of branding contamination.

The hedonic method will be used to analyse the impact that various attributes have on wool prices. This approach has its origins in consumer demand theory, and derived demand in particular. Lancaster (1966) developed a new approach to consumer theory which focused on derivation of demand for a good being based on its characteristics rather than for the good itself. The approach of Rosen (1974) is used to determine the implicit prices of attributes that are revealed from the price observed for differentiated products, and the bundle of attributes associated with that product.

The data were obtained from the Australian Wool Exchange (AWEX) for all Merino fleece lots sold in the 2005-06 selling season. The population was segregated into four markets: superfine, fine, medium and broad.

The analysis examines both measured and non-measured attributes, and included fibre diameter, staple length, staple strength, weight, midpoint breakage, vegetable matter base, fleece type, method of clip preparation, lot contamination, location of sale, quarter of sale, storage centre and style. The model was then run using a double log functional form, which has the advantage of allowing coefficients to be interpreted as constant elasticities.

The information obtained from the study will be useful for all levels of the supply chain. The dissemination of this knowledge is likely to be most effective if carried out by an industry body such as AWEX.

Chapter 2 outlines the background relevant to the study. An insight is provided into the structure of the industry in Australia, the situation since deregulation, the auction system and the problem of branding contamination.

The literature review in Chapter 3 gives an overview of the theory of hedonic modelling within its context of demand theory. Theoretical studies are examined, along with empirical investigations, based on both the work of Lancaster (1966) and Rosen (1974). Other contributions, such as that of Ladd and Martin (1976) and Ladd and Suvannat (1976), are also discussed.

The conceptual framework for an hedonic analysis of the Australian wool industry forms the basis of Chapter 4.

Chapter 5 discusses the specifications of the model used to analyse the data. An analysis of the data is undertaken and the functional form justified.

The results of the four models are presented and analysed in Chapter 6, while Chapter 7 provides policy implications and conclusions that can be drawn from the results derived from the model and data.

2 Background

The Australian wool industry dominates the international market, accounting for approximately 25 per cent of global production in 2005 (Australian Bureau of Statistics (ABS) 2006). It is widely accepted that Australia produces a high quality woollen fibre. This can be attributed largely to the experience and expertise of Australian growers, who, through selective breeding and adaptation to the environmental conditions, have come to produce clean, superior wools which retain good strength (Australian Bureau of Statistics (ABS) 2003).

The long term trend of national sheep numbers reflects the impact of major domestic and international events, as well as new technologies and capital investment. Figure 2-1 shows that, at the end of World War Two, the national sheep flock was 95 million. The price spike in the late 1940s and early 1950s, reflected post-war price recovery, combined with high demand caused by the Korean War. This led to a surge in the profitability of wool which lasted for 20 years, with the flock size increasing to 180 million by 1965.

In 1970, the Reserve Price Scheme was implemented and guaranteed growers a minimum price at auction. Between 1980 and 1990, the price floor was progressively increased to a level which was well above the price that the market was willing to pay. The result of these artificially high prices was an increase in the size of the national flock, and by 1990 it had peaked at 184 million.

In 1991, the Reserve Price Scheme collapsed, leaving the industry with a stockpile of 4 million bales which were released gradually over the next ten years. This surplus led to a depression in wool prices over the 1990s, and sheep numbers fell to 111 million in 2001, and 94 million by 2003, before stabilising at 106 million in 2004-05 (Australian Wool Exchange (AWEX) 2005a; Peart *et al.* 2006).

Figure 2-2 shows that Australian shorn wool production peaked at 1100.3 megakilograms (greasy) in 1989-1990. Since then, production has progressively declined, before stabilising at 480 megakilograms in 2003-04. Production in 2004-05 was 480 megakilograms, and is forecast to decline to 470 megakilograms in 2005-06 (Australian Wool Exchange (AWEX) 2005b).

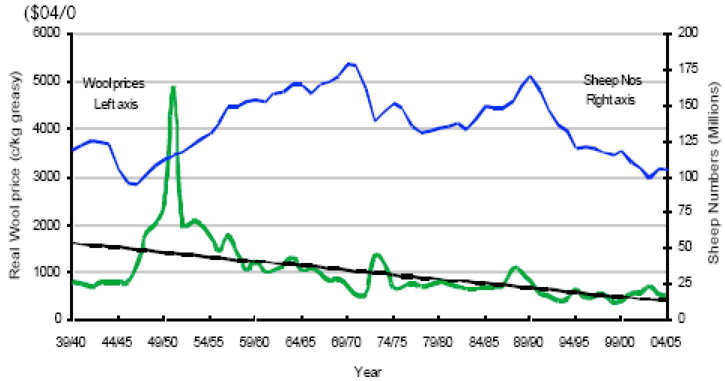


Figure 2-1: Real wool prices and sheep numbers, 1939-40 to 2004-05 (source: Peart *et al.* 2006).

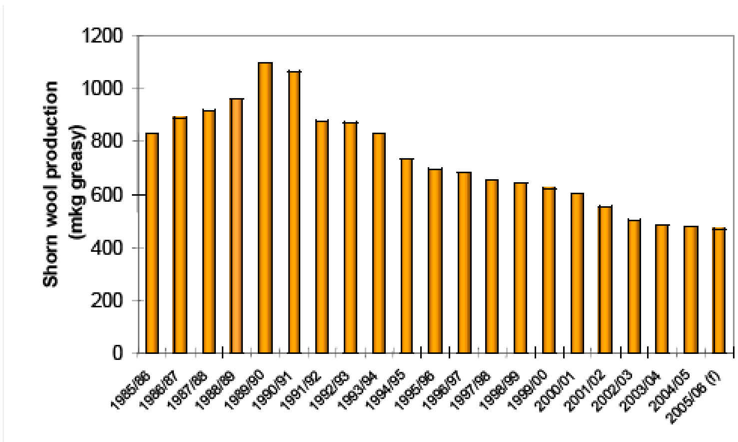


Figure 2-2: Australian shorn wool production, 1985-86 to 2005-06 (source: Australian Wool Exchange (AWEX) 2005b).

2.1 Industry structure

The various components of the wool industry make up a supply chain which represents a value delivery system. A supply chain describes the channel that stretches from the raw product to wool in various stages of transformation to the final buyers at the retail level (Kotler and Keller 2006 p.26).

Figure 2-3 represents the main components of the wool supply chain in Australia. Raw greasy wool produced by growers may be sold through a grower-owned marketing cooperative or directly to a private buyer. It is more common, however, for a broker to act as the agent or intermediary between the grower and the end-user.

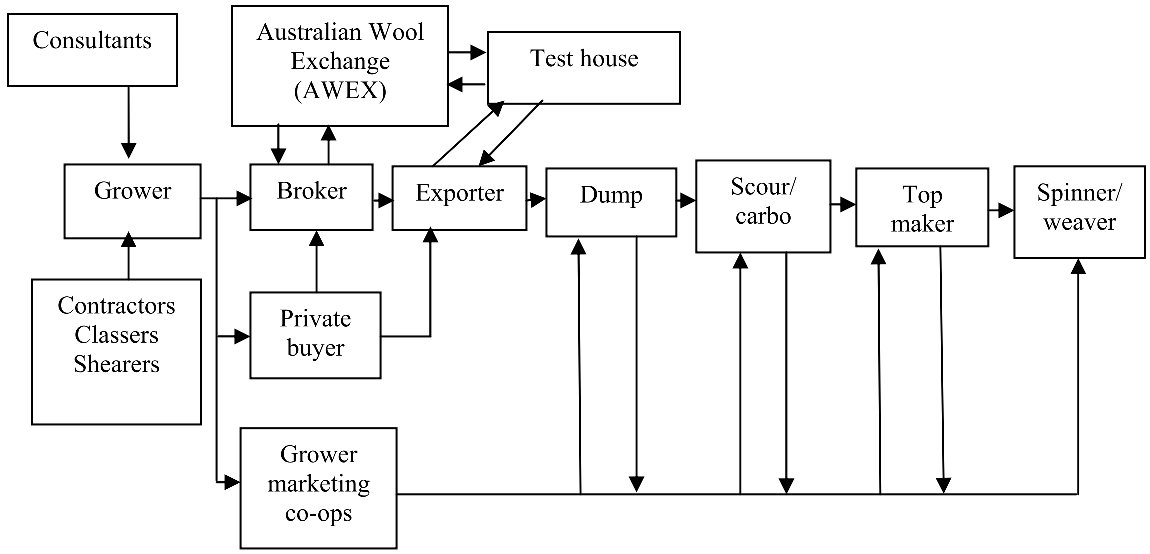


Figure 2-3: The wool pipeline (source: Australian Wool Exchange (AWEX) 2004).

Exchange of ownership from grower to end user is facilitated by a wool exchange, such as the Australian Wool Exchange (AWEX) Ltd., which deals with 86 per cent of wool sold in Australia each year. AWEX was founded in 1993 to facilitate the development of the Australian industry following deregulation. Currently, it provides a range of business services which include wool trading, market information and quality standards.

In Australia, Australian Wool Testing Authority (AWTA) Ltd. undertakes the objective measurement of certain fleece and fibre characteristics, including fibre diameter, staple length and strength, vegetable matter base, and point of breakage. This increases the information available to prospective buyers, and reduces the problem of asymmetric information in the marketplace (Australian Bureau of Statistics (ABS) 2003).

The vast majority of wool is processed overseas, shipped in a compacted form known as “dumping” to minimise transport and storage costs.

Processing of greasy wool involves scouring and cleaning to remove impurities, grease, dust, dirt, vegetable matter and contamination. Processing from this stage onwards depends on its type. In general, Merino wool is used in the worsted process, destined for clothing, and is thus made into top before being transformed further. The final step in the production process is the spinners and weavers who convert the raw material into a product which can be sold to consumers (Australian Wool Exchange (AWEX) 2004).

2.1.1 The auction system

Ninety five per cent of wool sold in Australia is auctioned. There are five selling centres in three regions: Sydney and Newcastle in the Northern region, Melbourne and Launceston in the Southern region and Fremantle in the Western region. Ninety five per cent of sales are conducted in Sydney, Melbourne and Fremantle. Sales are typically held in 45 weeks of the year, with an average of 2 selling days per week in each region (Australian Wool Exchange (AWEX) 2004).

Most wool sold through the auction system is represented by a sample which is viewed by prospective buyers prior to sale, along with a standardised lot report (Teasdale 2005). Brokers describe wool characteristics in a shorthand code which may describe raw wool characteristics or expected processing attributes which depend on the end user (Australian Wool Exchange (AWEX) 2004).

The auction system is a sensitive and responsive instrument prone to considerable price variation. Comparatively small deviations in supply and demand can have immediate effects on both buyers and sellers. However, the emergence of China as the main export destination of raw wool (50.87 per cent in 2004-05 (Australian Wool Exchange (AWEX) 2005b)) raises the issue of dependence on one market. This leaves the industry vulnerable to adverse conditions in that market (Lempriere 2006).

2.1.2 Industry standards

Since 1993, AWEX has acted to control standards in the Australian wool industry. The industry uses a generic typing system known as AWEX-Industry Description (ID) (Australian Wool Exchange (AWEX) 2004).

Grade standards are important in the marketing of agricultural commodities, such as wool, to ensure that information is conveyed to buyers about those supply attributes and defects which are economically significant. The aim of such a system is to reduce the costs associated with the transaction of trading a commodity with uncertain quality characteristics.

A grading scheme can be difficult to design and implement when the commodity has a number of uses and different buyers place different values on attributes (Tomek and

Robinson 2003 p.128-129). The system implemented for the Australian wool industry uses the AWEX-ID for non-measured, appraised characteristics of the wool, and this is combined with objective measurements for attributes such as fibre diameter and yield (Australian Wool Exchange (AWEX) 2004). The buyer therefore has a complete product description, with the price paid for a lot reflecting the supply of and demand for the attributes displayed.

Table 2-1 gives an example of the appraised, non-measured wool characteristics given by an AWEX-ID viewed by potential buyers prior to sale.

Table 2-1: Examples of AWEX-ID (ID: industry description) and interpretation (source: Australian Wool Exchange (AWEX) 2002).

AWEX-ID	Meaning
MF5E.H1R1	(Mandatory) Merino Fleece, Style Good, Vegetable Matter Type Seed. (Conditional) Light Unscourable Colour, Light Brands
MOF6M.140W3H2C2	(Mandatory) Merino Overgrown Fleece, Style Average, Vegetable Matter Type Moit*. (Conditional) Greasy Length 140, Strength Very Tender, Medium Unscourable Colour, Medium Cotting
MF1E.	(Mandatory) Merino Fleece, Style Choice, Vegetable Matter Type Seed.

**Moit: twigs, leaves and sticks.*

2.1.3 Buyers and sellers

The Australian industry is composed of many atomistic sellers (35 902 sheep farms in February 2006) (Peart *et al.* 2006), and relatively few buyers (72 in 2005/06) (Australian Wool Exchange (AWEX) 2006).

While this implies that sellers have no influence on price, there has been some evidence that there may be a degree of market power accruing to buyers. Simmons and Hansen (1997) developed a model of the Australian wool market, distinguishing between large and small buyers. The results suggested that larger buyers able to realise economies of scale will increase auction prices if there are a number of smaller, higher cost fringe firms also present in the market.

In 2005-06, the largest buyer accounted for 7.29 per cent of market share, with the next four largest buyers accounting for 6.44, 6.24, 6.14, and 6.10 per cent respectively. There were seventy three buyers in the market, but twenty-four firms accounted for 88.7 per cent of wool purchased, and the fifteen smallest buyers had an insignificant market share (Australian Wool Exchange (AWEX) 2006).

2.2 The industry since deregulation

The industry was deregulated in 1991 and the former Australian Wool Corporation being divided into several separate and private entities to manage the disposal of the stockpile. Additionally, these bodies were to maintain the industry, both financially, and in terms of marketing and research and development. After several changes over the course of the 1990s, the most recent incarnation emerged as Australian Wool Services (AWS) in January 2001.

AWS remains a holding company for Australian Wool Innovation (AWI) Pty Ltd and The Woolmark Company Pty Ltd. AWI was established to manage the (currently 2 per cent) wool levy paid by growers, as well as to outsource research and development and intellectual property management. The Woolmark Company, on the other hand, operates to promote Australian wool and to develop the Woolmark brand (Australian Wool Testing Authority (AWTA) 2005; The Woolmark Company 2006).

There have been several factors contributing to downward-trending prices since 1991. These include a contraction in demand for woollen textiles; increased competition from other fibres, both natural and synthetic; and changing consumer preferences. Combined with an insufficient growth in productivity levels, growers' declining terms of trade have not been offset, resulting in a movement of resources out of the industry (Perry 2005).

Premia accruing to finer micron wools over the 1990s led to a change in flock composition with an increased emphasis on finer wool. While superfine wool (18 micron) made up less than 10 per cent of the wool clip prior to 1991, this proportion has increased to approximately 30 per cent in 2005-06. Fine wools (19 micron) have increased their share of the clip in a similar fashion, while 21 micron wool has remained stable at about 20 per cent. However, 23 and 24 micron wool categories have declined from 25 to 10 per cent of the market. The application of a weighted average to the wool volumes sold in seasons 1999-2000 and 2004-05 indicate that the average fibre diameter of the Australian wool clip has fallen from 21.6 micron to 20.7 micron (Peart *et al.* 2006).

2.3 Recent industry trends

While wool has declined in relative importance within the Australian economy, it continues to rank highly among agricultural industries. In 2004-05, wool accounted for 6.7 per cent of gross value of farm production. Wool exports were valued at $2.8 billion, making it the fourth most important export industry behind beef, wheat and wine (Australian Wool Innovation (AWI) 2006a)

Between 1994-95 and 2004-05, strong international and domestic demand for beef, mutton and lamb has resulted in prices for these commodities rising significantly. Over the same period, while experiencing some year-to-year volatility, prices for grains and wool remained largely unchanged. In relative terms, wool has encountered a dramatic deterioration, leading to a tendency for farmers to alter their production mix, expanding cropping and beef activities at the expense of wool (Australian Wool Innovation (AWI) 2006).

Table 2-2: Sheep gross margins January 2006 (source: NSW Department of Primary Industries, 2006).

	Enterprise	GM/DSE	DSE Rating (per ewe or wether)
	Merino wethers		
1	19 micron	$19.01	0.9
2	21 micron	$11.72	1.0
3	23 micron	$10.10	1.1
	Merino ewes		
4	19 micron - Merino rams	$23.25	1.9
5	21 micron - Merino rams	$21.52	2.1
6	21 micron - Merino rams, wether lambs sold as trade lambs	$24.69	2.4
7	21 micron, high performance - Merino rams	$28.37	2.5
8	23 micron - Merino rams	$19.72	2.3
9	21 micron - maternal meat rams	$27.11	2.4
10	21 micron - 75% to Merino rams, 25% to terminal meat rams	$24.82	2.4
11	21 micron - terminal meat rams	$24.99	2.3
12	**1st cross ewes** - terminal meat rams	$25.56	2.7
13	**Dorper ewes** - Dorper rams	$20.80	3.0

The result of this relative price decrease has led to a change in the composition of the national flock. The current flock structure reflects an increased orientation towards lamb production through the development of a younger flock with a higher proportion of females (Australian Wool Innovation (AWI) 2006).

2.4 The market for wool

Australian Merino wool is used predominantly in the manufacture of apparel wear, accounting for 48.5 per cent of this market globally in 2002-03 (Australian Wool Innovation (AWI) 2004). However, wool makes up only a small proportion of the total fibre market. In 2003, the contribution of wool to total fibre use was 2.36 per cent and 3.5 per cent of the apparel fibre market.

Australian wool contributed 2.3 per cent of this second figure. While wool is generally considered to be used to produce more formal wear, the world apparel market is dominated by casual wear (70 per cent), made from cotton and synthetics. Further, young adults, who typically dominate discretionary spending on apparel, are influenced by price and performance rather than by fibre type (Australian Wool Innovation (AWI) 2004). This downward trend is forecast to continue in the medium term (O'Donnell, 2006 #203).

2.4.1 Sub-markets

The market for Merino wool is not a homogenous one. Typically, there are differing demands for different micron categories. The industry tends to break the market for Merino fleece into superfine, or those fleeces of 18.5 microns or less, fine, or fleeces between 18.6 and 20.5 microns, medium, or fleeces between 20.6 and 23.5 microns, and broad wools being greater than 23.5 microns (David Cother, pers. comm., 2006). The end use of each micron group will be quite different, with superfine wool destined for high-quality clothing manufacture, while broader wools will be used for more industrial purposes, such as in underblankets and low-quality knitwear (Alexander 1995).

2.4.2 Substitutes

The international textile market is extremely competitive, with manufacturers very responsive to changes in relative prices. Since the mid-1970s, the relative price of wool to polyester and wool to cotton has tended to keep be 2 to 3 times greater, with a slight upward movement experienced in the last decade due to increased investment in cotton and synthetic production facilities in China since 2000. The implication of this relationship is the weaker ability of wool to compete with cotton and synthetics on the global textile market (O'Donnell *et al.* 2006).

2.4.2.1 Cotton

The outlook for cotton forecasts that price will decline in response to increased supply in China, and a subsequent decline in demand for imports into the world's largest textile processing market. As productivity gains are realised by cotton producers around the world, with a subsequent increase in supply, prices are predicted to decline in real terms over the medium term (Drum *et al.* 2006). The result of the lower cotton prices is likely to have a negative effect on wool, in terms of its ability to compete.

2.4.2.2 Synthetic fibres

Polyester production has tripled in China since 2000 due to substantial investment in the textile and clothing industry. As a consequence, although oil prices have been high, synthetic prices have not reflected this. In the medium term, however, with oil prices predicted to remain relatively high, the increased cost of essential inputs will mean that the costs will be passed onto consumers. This implies that both cotton and wool will increase their competitiveness against synthetic fibres (Drum *et al.* 2006; O'Donnell *et al.* 2006)

2.4.3 Exports

China has been a dominant and increasingly important market for Australian wool exports in recent years. While in 2000-01 China accounted for 34.64 per cent of Australian wool exports, by 2004-05, this had increased by 50.87 per cent. The next most important market was Italy. However, its market share fell from 17.43 per cent to 12.98 per cent from 2001-01 to 2004-05. India represented the third largest export destination, and exports to India marginally increased from 5.93 per cent in 2000-01 to 6.32 per cent in 2004-05. Table 2 below demonstrates the top fifteen export destinations for Australian wool in seasons 2000-01 and 2004-05 (Australian Wool Exchange (AWEX) 2005; Australian Wool Exchange (AWEX) 2001).

The outsourcing of processing is reflected in the proportion of greasy wool exported. While in 2000-01 74 per cent of Australian wool was exported unprocessed, this proportion had increased to 84 per cent by 2004-05 (Australian Wool Exchange (AWEX) 2005; Australian Wool Exchange (AWEX) 2001).

Table 2-3: Export destinations 2001-02 and 2004-05 (source: Australian Wool Exchange (AWEX) 2001; Australian Wool Exchange (AWEX) 2005b)

Destination		Greasy equivalent					
2001-02	2004-05	Kg		% change		% total	
1 China	China	260 764 302	250 016 463	17.57	27.49	34.64	50.87
2 Italy	Italy	131 250 035	63 777 794	-2.34	1.71	17.43	12.98
3 India	India	44 615 051	31 083 540	4.87	13.69	5.93	6.32
4 Korea, Rep.	No country details	43 006 183	26 577 678	-11.66	1.85	5.71	5.41
5 Taiwan	Taiwan	39 604 647	20 747 281	-31.43	-0.34	5.26	4.22
6 Germany	Slovakia	35 502 153	12 628 015	26.78	-9.64	4.72	2.57
7 France	Thailand	34 523 420	11 266 831	-3.71	-15.43	4.59	2.29
8 Japan	France	23 980 855	11 127 667	-19.6	-41.4	3.19	2.26
9 Czech Rep.	Korea, Rep.	20 540 028	9 732 971	42.45	-8.67	2.73	1.98
10 Spain	Germany	15 215 812	9 498 016	7.82	-39.78	2.02	1.93
11 Thailand	Japan	14 166 785	6 726 513	0.97	-37.18	1.88	1.37
12 U.S.A.	Turkey	11 924 565	5 176 051	-16.14	-11.58	1.58	1.05
13 Turkey	Bulgaria	9 671 705	5 042 993	-8.71	10.22	1.28	1.03
14 Hong Kong	Malaysia	8 878 632	4 952 487	0.85	112.42	1.18	1.01
15 U.K.	U.S.A.	7 815 056	3 689 119	-19.48	22.86	1.04	0.75
Other		51 384 201	19 451 981	32.53	6.24	6.83	3.96
Total		752 843 429	491 495 401	4.05	32.77		

2.5 Branding contamination and wool clip preparation

Since the mid-1970s, there has been a movement away from traditional subjective classing to objective clip preparation (OCP) for all but the finer micron Merino fleeces. Since 1985, a Code of Practice has been implemented and progressively refined to simplify and standardise clip preparation practices. This is to ensure that processor requirements are met, thereby increasing returns to wool growers (Australian Wool Exchange (AWEX) 2005).

One of the major problems facing the industry is the presence of sheep branding fluid which resists commercial scouring. The expense and inconvenience resulting from its removal is a source of irritation for processors and often result in a discount for wool containing branding fluid (Lipson 1951).

Current industry recommendations suggest that classers should remove contaminated portions of the fleece and separate it into a “BRANDS” line. This requirement to remove affected wool and to identify it as such come from wool processors who have a varying level of tolerance of the presence of brands. This issue of contamination arises when processors are deciding which process is needed to treat raw wool. If the line is unmarked, then processors are inconvenienced when raw wool is turned into top for further transformation (Australian Wool Exchange (AWEX) 2005).

The buyer is placed at a disadvantage due to branding contamination for reasons including discolouration of otherwise clean lines; discolouration of wool grease; and a reduction in the choices available to processors. Growers are deprived of profits, with considerable discounts accruing to affected wool. Further, some mills place a complete ban on such wool.

Knowledge of fleece and fibre characteristics is imperative in making informed production decisions with the aim of maximising returns in the short run, and in the longer run producing the types of fibre demanded in response to price signals.

2.6 Concluding comments

The Australian wool industry is faced by many challenges, such as downward-trending prices, a changing marketplace and unpredictability. While growers no longer enjoy the returns of the 1980s, market conditions now more accurately reflect supply of and demand for wool. As a consequence, production patterns have altered such that the production of finer wool has increased, and that of coarser wools has fallen.

The key for the future viability and profitability of the industry lies in meeting market demand, but also in promoting wool as a desirable consumer product. In order for this to occur, the industry needs to increase its cohesion and adaptability. To ensure that growers are able to maximise returns from wool production, it is imperative that the value of the characteristics inherent within the fleece are known.

3 Literature Review

The purpose of this review is to critically examine and analyse previous literature concerning the demand analysis aspect of consumer theory. From this foundation, empirical hedonic approaches are investigated.

The review concentrates on consumer theory that represents a divergence from the traditional theory, that is that consumers purchase a bundle of goods and services to maximise utility, subject to a budget constraint. Instead, it is suggested that a good is consumed for the characteristics it contains. This concept, developed by Lancaster (1966), formed the foundation for further development of theory, but also for empirical studies. The hedonic approach has also been used extensively and is appropriate for its ability to estimate a value for the characteristics within a good.

3.1 Consumer theory

3.1.1 Traditional theory

A key concept developed by Marshall (1946 p.92) was that consumer demand is the principal influence on the demand for goods by producers. In purchasing a good to be used in production or to be resold, a manufacturer's demand is based on the anticipation of profits that may be earned. In this sense, consumer demand is the ultimate regulator of all demand. Utility is taken to be a proxy for desire or want, as it is argued that desire can only be indirectly measured through the exogenous phenomena to which they give rise.

The principal objective of consumer theory is to describe the factors which influence the amount spent by the consumer on goods and services in the marketplace and to evaluate the impact on this influence. It is assumed that the consumer will choose the commodity basket for which the utility function takes on the largest value, subject to budgetary constraints (Theil 1975 p.1). The consumer will rarely be able to purchase all goods and services desired, so there will be a specific combination of goods and services that the consumer will choose to maximise satisfaction (Cochrane and Bell 1956 p.89-90).

Debreu (1959 p.50-52) and Samuelson (1983 p.91-98) explained consumer market behaviour in terms of preferences which are analysed using the concept of utility. The analysis of utility is dependent on the fundamental assumption that the given prices and income, the consumer will select the combination of goods which is ranked highest on a subjective scale of preference.

Any analysis of a demand function is restricted in that it must be single valued, with each set of prices and income corresponding to an individual set of goods. Additionally, functions are homogenous of degree zero, meaning that a change in all prices and income in the same proportion will leave the quantity demanded unchanged.

3.1.2 Household production theory

Houthakker (1951/52) and Theil (1951/52) independently developed two influential models of consumer choice. Both proposed models for characteristic demand derived from within the utility maximisation framework (Angel *et al.* 1990). Two assumptions are implicit within the model; there is a continuum of quality levels, and the consumer chooses only one level of quality. Additionally, the price functions derived in this model are compatible with the concept of a hedonic price function (Hanemann 1982).

Quality variation, and the theory of consumer behaviour is the focus of Houthakker (1951/52). Becker (1965), Muth (1966), and Lancaster (1966), whose work analysed the impact of consumers also being producers. Rather than possessing attributes for ultimate consumption, goods are purchased as inputs into self-production functions for final characteristics (Rosen 1974 p.36).

The issue of goods being made up of utility-bearing attributes is explored more explicitly in Becker (1965), Muth (1966) and Lancaster (1966) than in Houthakker (1951/52). Rosen (1974) extended this analysis by considering the market for product characteristics, thereby incorporating both consumers and producers.

3.1.3 Characteristics and consumer theory

Lancaster (1966) considered that traditional theory did not deal with several areas in sufficient detail. These were the reaction of consumers to new commodities, and to variations in quality. He proposed an alternative approach which suggested that the good itself was not the object of utility, but rather, that it is from the characteristics possessed by the good that the consumer gains utility. Goods were then ranked preferentially according to their attributes (Lancaster 1966 p.133).

The obvious point to be noted is the importance of characteristics in Lancaster's theories (Hjorth-Anderson 1983). Lancaster (1991) emphasised vertical separation which allows demand for a group of goods to be analysed in relative isolation, in terms of attributes possessed. Using the characteristics approach, utility is derived as a function of characteristic qualities, obtained by being purchased as bundles within a good. That is, attributes cannot be obtained separately.

Lancaster's method assumed that the characteristics possessed by a good are determined objectively, but also that the utility derived from these attributes was ascertained in a more subjective manner. A good is purchased by the consumer for the purpose of obtaining certain characteristics, which in turn provide some level of utility (Ladd 1982). The major contribution of the new approach of Lancaster was the ability to differentiate objective from subjective choice, and demand theory (Hendler 1975).

Lancaster's theories had widespread appeal because a number of conclusions are reached using comparatively simple analyses. Two assumptions are made explicit in their model: linear consumption technology and independent distribution of characteristics in terms of utility among products. A third assumption, that every characteristic has non-negative marginal utility, is implicit (Ladd 1982).

Some of the problems with Lancaster's approach have been discussed by Hendler (1975), Lucas (1975) and Hjorth-Anderson (1983). Hendler (1975) examined the assumptions required to derive the objective efficiency frontier, which formed the basis of the Lancaster model. The main concern raised by Hendler rested with the contention that the Lancaster efficiency frontier is objective only when constricting assumptions are applied. It was maintained that it can only be applied to consumer choice, rather than being used as a general model of consumer demand as Lancaster (1966) deemed it to be.

The claim of Lancaster that he had developed "a model very many times richer in heuristic explanatory and predictive power than the conventional model of consumer behaviour" (Lancaster 1966 p.152-153) was questioned by Hendler (1975) on the grounds of the restrictive nature of the assumptions made, both explicitly and implicitly, within the model.

Lucas (1975) questioned the linear consumption technology assumption, which presumes that increasing consumption of a good by a given percentage will increase the amount of each characteristics obtained from that good by the same percentage. However, if the consumption technology is non-linear, then it is unlikely that the characteristics efficiency frontier will be able to be determined without detailed knowledge of the consumption technology.

The model of Lancaster (1966) provided a useful framework for the analysis of product quality, and consequently stimulated great interest in modelling demand for characteristics, due to its relative simplicity. However, it must also be noted that there are several restrictive assumptions that need to be considered.

3.1.4 Other models

Other studies of consumer goods characteristics (Ladd and Suvannat 1976; Ladd and Zober 1977) dispensed with assumptions used in Lancaster's models. Ladd and Suvannat (1976) did not assume either linear consumption technology or non-negative marginal utility, and in only one study did they assume independent distribution of characteristics. Total consumption of each characteristic was suggested to depend on the amount of goods consumed, and the characteristic input-output coefficient, x_{ij}. The magnitudes of the x_{ij}, similar to Lancaster (1966), are consumer boundaries, determined by producers.

Several hedonic price functions were derived by Ladd and Suvannat (1976). These stated that the price paid for a good will equal the sum of the marginal product of the various characteristics supplied by the good multiplied by the marginal implicit price of the characteristics. While the ideas discussed and developed in the paper assume the independent distribution of characteristics, it was pointed out that the analysis can easily be modified to dispense with this assumption.

The independent distribution of characteristics assumption was avoided by Ladd and Zober (1977). This study stated that utility is a function of services provided by goods, as opposed to services delivered by product characteristics and that the relaxation of

Lancaster’s assumptions will not destroy the usefulness of the model, as implications for further research into consumption behaviour can be drawn. Physical characteristics of a good were not considered to be consistent with the utility-bearing attributes of a good, which are subjective according to the consumer’s preference function (Angel *et al.* 1990).

A neo-classical and linear programming model is presented by Ladd and Martin (1976). Two observations are presented:

a) “Price of a purchased input equals the sum of the money values of the input’s characteristics to the purchaser; and

b) The demand for an input is affected by the input’s characteristics” (p.21).

The first theme implied that the money value of each characteristic of an input is equal to the marginal yield of the input characteristic multiplied by the marginal money value of one unit of the characteristics.

Further, Ladd and Martin suggested that the marginal value of a characteristic, as well as the marginal rate of transformation, may rely on the level of complementary or substitution relationships.

3.2 Hedonic price analysis

3.2.1 Background

Waugh (1928) pioneered research involving hedonic price functions by evaluating the factors influencing prices for asparagus, tomatoes and cucumbers. Waugh’s work deals with those factors (mainly physical attributes) that were perceived to have an impact on the price received for these vegetables, and studied the causes of price variations in individual commodity lots.

The term “hedonic” was first proposed in an article by Andrew Court (see Goodman 1998). Court’s work dealt with non-linearity issues, as well as changes in underlying bundles of consumption goods in his examination of the Detroit automobile industry, focused on price indices.

Goodman (1998 p.292) noted that “The term hedonic (in capitals) was used to describe the weighting of the relative importance of various components, such as horsepower, braking capacity, and window area, among others in constructing an index of ‘usefulness and desirability'". However, there were few studies in terms of hedonic price analysis prior to Griliches (1961).

3.2.2 Hedonic prices and implicit markets

The seminal analysis was that of Rosen (1974). Until this time, hedonic analysis was essentially limited to divulging the price of characteristics of a good (Mendelsohn 1987). Rosen defined hedonic prices as:

> "…the implicit prices of attributes and are revealed from observed prices of differentiated products and the specific amounts of characteristics associated with them" (Rosen 1974 p.34).

His approach was to consider product differentiation so that goods were defined by their characteristics, rather than as a large group of almost homogenous products. Goods were described as having *n* characteristics, which are objectively measured, and which, at any point along a plane, can be represented by a characteristics vector, $z = (z_1, z_2, \ldots, z_n)$. Product differentiation suggests that there will be a large selection of alternative bundles available.

Rosen emphasised that a hedonic price function will be a function solely of product attributes under conditions of perfect competition (Unwin 1999). Rosen's theory was based around competitive price determination in a market where the existence of many attributes lead to product differentiation (Oczkowski 2000).

In equilibrium, the seller offer function will be tangential to the buyer value function, with the common gradient at that point being the market-clearing implicit price function, $p(z)$, observations $p(z)$ representing an envelope of aggregate value and offer functions respectively.

Essentially, hedonic price functions relate product prices to the implicit price of the characteristics it possesses. These characteristics can be a measure of quality or utility to a consumer, or costs to a producer and can be both quantitative and qualitative (Unwin 1999). An issue of interest in the empirical investigation of hedonic models is analysing how the price of a unit of a good varies with the level of characteristics possessed. Further, given a hedonic equation, a set of demand and supply functions for these attributes can then be derived (Epple 1987).

3.3 Previous empirical work

3.3.1 Price index approach

Early work included that of Fettig (1963), Rayner (1968) and Rayner and Cowling (1968) on tractors. An attempt was made to generate price indexes that took into account the role of available information on quality changes in tractors in the postwar period.

However, it was not until Griliches (1971a), that the hedonic approach to the construction of price indexes was genuinely revived (Griliches 1971b). In conjunction with Triplett (1971), Griliches (1971c) found that quality was related to measurable characteristics of a good. Muellbauer (1974), on the other hand, attempted to relate the hedonic technique to a constant utility price index when quality changes are taken into consideration. This theoretical claim dealt solely with the demand side, making it noticeably different to the method used by Rosen (1974).

Although utilisation of the hedonic technique and associated hedonic price indices was widespread, the underlying theory remained under-developed (Feenstra 1995). Griliches (1990) and Triplett (1990) argued that such indices are merely an approximation for consumer welfare.

For a hedonic analysis, it is necessary that the market be in long run equilibrium so that the bid and offer curves of the buyers and sellers, respectively, will be equal. In several empirical applications to housing markets (Goodwin 1977; Goodman 1978; Bender and Hwang 1985), the assumptions on which long run is based appeared because of the high conversion costs of residential capital, the immobility of consumers, and the heterogeneity of the housing commodity (Goodman 1978). Solutions for this predicament included the separation of markets, both temporally and spatially (Kravis and Lipsey 1971) or into smaller submarkets (Straszheim 1975).

3.3.2 Input approach

Houthakker (1951/52) presented the idea, later extended by Becker (1965), Lancaster (1966) and Muth (1966), that attributes are purchased not for final consumption, but as inputs into further production processes. This form of analysis can be applied to agricultural commodities, such as wheat and wool, where differentiated products are separated by buyers on the basis of end-use. For example, the demand for raw wool is influenced by the degree to which fibres can be substituted in textile production and consumption (Beare and Meshios 1990).

Utility maximisation in the framework of consumer choice can be expanded to include choice with regard to both quality attributes and quantity. A consumer will make subjective decisions with respect to preferences for various combinations of characteristics (or qualities) contained within a good. The price of the good, however, will depend on the characteristics (Houthakker 1951/52). The utilisation of this technique in the hedonic model allows for the evaluation of the market price for an attribute dealing with quantity and quality simultaneously (Berck and Rausser 1982).

Accuracy and availability of information were considered important by Perrin (1980), in the soybeans and milk markets. In a case where information is only weakly conveyed, producers face a diluted derived demand for commodities, altering the optimal outcome in terms of price, quantity and welfare.

Asymmetry of information in wheat markets has attracted substantial coverage (Hill 1988; Espinosa and Goodwin 1991; Larue 1991; Ahmadi-Esfahani and Stanmore 1994). The demand for wheat characteristics, derived from demand from its end use, makes wheat a heterogeneous commodity and give rises to different grading systems. These systems allow more ready dissemination of information.

In practice, however, the economic efficiency of such grading practices were questioned on the grounds that little accurate information is conveyed, providing little incentive to improve grain quality. Larue (1991) was also criticised, by Ahmadi-Esfahani and Stanmore (1992), on the grounds that his study provided little in the way of useful conclusions, and that there were problems within the data and estimation technique.

Extensions to the simple input approach to hedonic analysis have also found support in the wool industry. Simmons and Hansen (1997) augmented the base model by including a variable measuring buyer concentration. Previous studies (Simmons 1980; Jackson and Spinks 1982; Gleeson *et al.* 1993) experimented with non-linearity, with the most significant variable found to violate the linearity assumption being micron. As a result, Simmons and Hansen (1997) incorporated micron count based on splines to ensure that continuity is assured between different micron segments despite the non-linear price-micron relationship.

In contrast, Angel *et al.* (1990) and Beare and Meshios (1990) analysed the importance of physical wool characteristics from the perspective of their relevance to different end uses. The implicit prices paid for these properties based on processing requirements, are reflected in the price paid for wool, which in turn is determined by the supply and demand curves for wools of different types (Maddever and Cottle 1999).

3.3.3 Lancastrian approach

The approach of Lancaster has been a popular framework for theoretical studies. Hjorth-Anderson (1983) questioned the practicality of Lancaster's model, however, on the grounds that only Lancaster (1971) appeared to have applied the structure to real-life problems. Dreze and Hagen (1978) implied that the hedonic technique can be used as a proxy interpretation as an empirical demonstration of Lancaster's (1971) theory, though this was regarded as flawed by Lucas (1975).

The characteristics theory formalised by Lancaster (1966) in particular, but extended by Ironmonger (1972) and Gorman (1980) gave rise to a substantial body of theoretical work, such as that by Lipsey and Rosenbluth (1971) and Archibald and Eaton (1989). However, there has been little in the way of empirical investigation undertaken to support the claim that objective functions are based not on the goods themselves, but on the characteristics contained within the product.

Some empirical support for the validity of the characteristics approach was provided by Burton (1994) for the insecticides market, and King (1976) conducted an empirical analysis of a housing market in which consumers make purchases of goods based relative efficiency of a bundle of characteristics. However, while the approach seemed appropriate enough, there were considerable obstacles to be overcome with respect to the measurement of such subjective components such as 'quality'.

Simmons (1980) applied the theory of demand of Lancaster (1966) to cross-sectional data in a measurement of buyers' valuations of wool properties. A possibility when analysing wool is that attributes may be interactively assessed. If this is the case, biases may be expected when carrying out a techniques similar to that of Griliches (1971c).

3.3.4 Two-step approach

Rosen (1974) and Freeman (1974; 1979) developed a framework in which to analyse demand for and supply of characteristics in heterogenous products. This approach involves two distinct steps. The hedonic price equation is used to estimate the marginal implicit prices of the product characteristics. These implicit prices are then used to estimate inverse demand functions, or the marginal willingness to pay functions for, in the case of Freeman (1979), a group of households.

Despite the usefulness of Rosen's approach in analysing commodity characteristics the second stage of the process had some significant pitfalls. When data from a single market are used, the second-stage inverse equation requires strong assumptions regarding the functional form in order for it to hold (Atkinson and Halvorsen 1984).

Similarly, Brown and Rosen (1982) criticised Rosen (1974) on the grounds that the second-stage may only reproduce the estimates provided in the first-stage unless additional restrictions are placed on the functional form of the price function, *p(z)*. In contrast to Atkinson and Halvorsen (1984), though, Brown and Rosen (1982) noted that while there are undoubtedly pitfalls corresponding to the hedonic technique, it remains a strong form of analysis for applied research.

3.3.5 Consumer goods approach

3.3.5.1 Food and capital goods

Hedonic price analysis has been carried out on a number of food products. An example of this was Morgan *et al.* (1979) in a study of breakfast cereals. Another study by Wahl *et al.* (1995) examined the valuation by consumers of characteristics for products such as beef. Japanese Wagyu beef demand was analysed to estimate market equilibrium for the implicit values for product characteristics, based on Rosen's (1974) market-based approach for the derivation of a hedonic price function.

Ladd and Suvannut (1976) also based their model of consumer good characteristics on the premise that products are desired for the utility that they provide, which in turn is dependent on the characteristics inherent within the product.

Previous studies on stone fruit (Harrington and Gislason 1956), automobiles (Cowling and Cubbin 1971), and capital goods (Dhrymes 1971) were found to be consistent with the theme that consumer demand is affected by the characteristics contained within a good. Work carried out by Waugh (1928), Dhrymes (1971), and Cowling and Cubbin (1971) produced results that were compatible with the proposition that "for each product consumed, the price paid for the product equals the sum of the marginal monetary values of the product's characteristics" (Ladd and Suvannat 1976 p.509).

Nerlove (1995) criticised the assumptions underlying the hedonic model for being too restrictive and that they do not hold in reality. Further, they make a large impact on the results obtained through empirical examination. In an application to wine and Swedish wine consumers, shadow prices for quality attributes are determined not through a regression of price on a vector of characteristics, but rather quantity sold is regressed on price and quality attributes.

3.3.5.2 Housing and urban amenities

Hedonic methodology with respect to urban amenities has an extensive history of examining theoretical and empirical issues from Anderson and Crocker (1971) to Straszheim (1975) in an investigation of market segmentation, to the identification of demand curves by Mendelsohn (1987), Epple (1987) and Bartik (1987). Other studies have dealt with the recognition that there are problems associated with hedonic benefit estimation (Graves et al. 1988), and simultaneity (Freeman 1979). This evolution and applicability to a wide range of circumstances means that the hedonic technique can be used as a standard by which other methodologies can be assessed (Brookshire *et al.* 1982; Brucato Jr *et al.* 1990).

In their work on urban air quality, Graves *et al.* (1988) questioned the robustness of hedonic price estimation as an increasing number of studies find matters of concern (Butler 1982; Roback 1982; Atkinson and Crocker 1987). However, despite this recognition there has been little in the way of systematic comparative analysis to ascertain the potential inaccuracies caused by separate problems.

Harrison and Rubinfeld (1978) investigated the methodological problems associated with the use of market data to analyse the willingness to pay for unpolluted air. The willingness to pay for clean air, associated with housing demand has been covered by several previous studies (Ridker and Henning 1967; Anderson Jr. and Crocker 1971; Wieand 1973; Nelson 1978), but little attention has been paid to the assumptions implicit within modelling techniques. The possibility of further transformation of inputs into the household is ignored, as this adds an extra complexity to the model, and is unnecessary with respect to demand for clean air in this particular circumstance.

3.4 Concluding comments

The literature covering the new approach to demand theory of Lancaster (1966) is extensive both in volume (King 1976; Simmons 1980; Burton 1994), and in criticism (Hendler 1975; Lucas 1975; Hjorth-Anderson 1983).

Apart from Lancaster's contribution, Theil (1951/52) and Houthakker (1951/52) provide a useful framework for the analysis of utility maximisation. Ladd and colleagues (Ladd and Martin 1976; Ladd and Suvannat 1976; Ladd and Zober 1977) use Lancaster's work as a basis but relax assumptions that are considered to be unnecessarily restrictive.

Rosen (1974) provided the seminal paper relating to the empirical applications of hedonic price analysis, while Griliches (1961; 1971c) provided a significant contribution to the body of literature.

Previous economic studies of wool attributes, such as Angel *et al.* (1990), Beare and Meshios (1990), and Simmons and Hansen (1997), utilised the hedonic technique in discerning the impact of various influences on the price of wool. As a consequence, this study of wool characteristics is to be conducted using an hedonic approach, developed by Rosen (1974) and applied to inputs by Ladd and Martin (1976), and based on the underlying concepts of the consumer demand theory of Lancaster (1966).

4 Analytical framework of an hedonic model

The demand for wool is analysed as farm-gate demand derived from demand at the retail level for a final consumer product. As a consequence, the theory surrounding an analysis of an hedonic model investigates the theory of derived demand, within the context of demand theory. The concept of household production theory, from which the input characteristics model originates, is considered and the applications of the theory specific to hedonic models are also scrutinised.

In an application to the Australian Merino wool industry, the consumer of raw wool is assumed to be a representative processor, where a processor is understood to be a producer of woollen tops for consumption in the worsted spinning sector of the woollen textile industry. This process uses fleeces only, and thus ignores the woollen spinning process and its use of scoured and carbonised, as well as noils and waste (Delius 1981). Sellers, on the other hand, are taken to be wool growers, though they are typically represented at auction by brokers acting on their behalf.

4.1 Theory of demand

4.1.1 Underlying logic of demand theory

Demand theory traditionally uses a household or individual consumer as the base unit where each agent is confronted by the problem of choice. However, wants arising due to basic need for food and shelter, personal characteristics, and physical and social environments, are subject to income levels. Thus the representative consumer will choose the outcome which best satisfies these wants given the constraints imposed on the situation (Tomek and Robinson 2003 p.9).

4.1.2 Consumer demand

Consumer demand refers to the quantity of a given product that a consumer is willing and able to purchase at different prices, *ceteris paribus*. Figure 4-1 is a graphical representation of the preferences of the processor, as the consumer of raw wool, is constructed in what is termed an “indifference map”. These preferences are fixed at any point in time. Each indifference curve identifies the combinations of two lots of raw wool that give the processor the same level of utility, the higher the indifference curve, the greater the processor's level of satisfaction.

Implicit within the depiction of the indifference map are the assumptions that raw wool is continuously divisible, and that the processor finds both wool lots equally desirable. The indifference curves will therefore be both continuous and downward-sloping (Tomek and Robinson 2003 p.10-11).

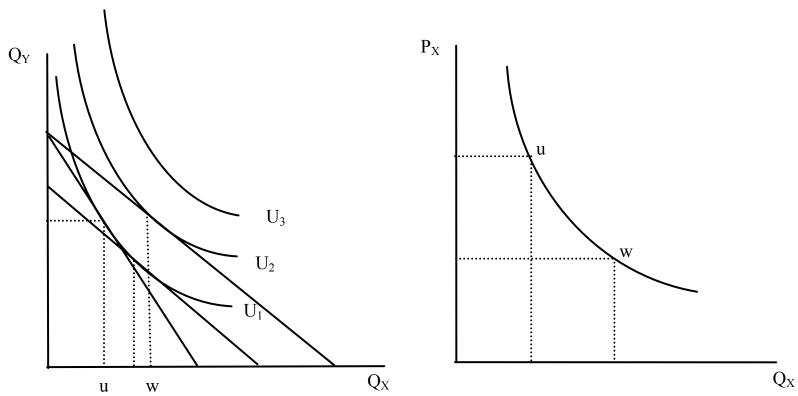


Figure 4-1: Relationship of consumer preferences to demand (source: Tomek and Robinson 2003).

The nature of the demand function describes how a consumer's utility-maximising choices will respond to a price change. It is important to distinguish between a movement along an indifference curve (substitution effect), utility held fixed, and a movement to a new indifference curve (income effect), which involves a change in purchasing power, relative price held fixed (Pindyck and Rubinfeld 2001 p.145).

4.1.3 Utility and the specification of demand

Conceptually, the processor wishes to maximise utility subject to income, utility being a function of goods and services consumed. It is assumed that the processor will prefer more wool to less, and that more will be purchased only if price falls (Tomek and Robinson 2003 p.9-10). The processor will act to maximise a monotone, continuous and quasi-concave utility function (Deaton 1986 p.1770).

4.1.4 Derived demand

The final consumer is central to the nature of primary demand for a woollen fabric and garments. Demand for raw wool at the farm level is then derived from demand for this primary demand (Tomek and Robinson 1998 p.28-29).

Lancaster (1971) viewed demand for a final product or a commodity at the farm-gate in terms of demand for its characteristics. For raw wool, the early processor does not make the ultimate fibre choice. Instead, the processor makes a consumption decision based the requirements of the spinner who converts the top into woollen fabric desired by the consumer (Drummond 1993).

4.2 Non-traditional consumer theory

4.2.1 The assumptions of new consumption theory

The processor chooses to maximise utility subject to a budget constraint, where raw wool is desired for the characteristics it contains. At the same time, the budget constraint is defined in terms where utility is defined in terms of raw wool itself, as a lot must be purchased in its entirety in order to receive the characteristics desired (Lancaster 1966).

The consumption problem subject to a budget constraint consists of two parts:

1. "An efficiency choice, determining the characteristics frontier and the associated efficient goods collections.
2. A private choice, determining which point on the characteristics frontier is preferred…" (p.139).

The first point is the matter pertaining to objectivity. That is, assuming the consumption technology to be objective, it follows that the characteristics frontier is also objective, and is the same for those processors under the same budget constraint.

Since marginal utilities are assumed to be positive, indifference curves have a positive slope. An efficient processor will consume on the line BCD. Any processor to the left of this line will be inefficient. Thus, this line BCD is known as the efficiency frontier. The efficiency frontier is an objective concept as it is constructed without the knowledge of preferences or utility functions.

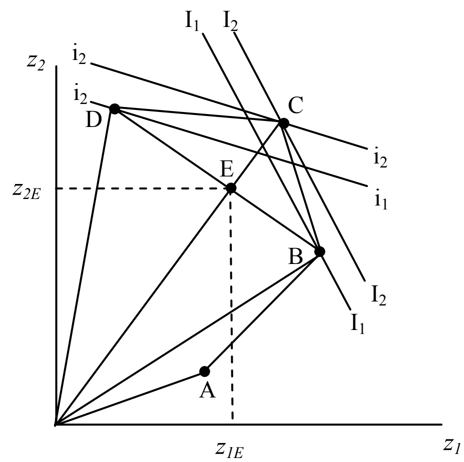


Figure 4-2: Exhibition of assumptions of independent distribution of characteristics, linear consumption technology, and non-negative marginal utility (source: Ladd 1982)

If the price of lot C increases until the maximum quantity able to be purchased given the budget constraint is represented by point F, the efficiency frontier will become BFD. Although neither processor can obtain amounts z_1 and z_2 defined by point E by purchasing C due to the binding nature of the budget constraint, the desired amounts may be obtained by the purchase of some of lot B and some of lot D.

Both processors will move from C to E, representing the efficiency substitution effect that is part of both processors' response to an increase in the price of lot C, regardless of preferences or utility. The first processor's movement from point C to E is a private substitution effect, however, as unlike the efficiency substitution effect, this second movement depends on processor preferences (Ladd 1982).

4.2.2 Consequences of assumption violation

Figure 4-2 demonstrates the three assumptions made by Lancaster (1966). Non-negative marginal utility is reflected by the downward-sloping indifference curves. However, if the processor is dissatisfied with the characteristics of raw wool purchased, then marginal utility may in fact be negative. If this were the case, then the indifference curves become upward-sloping, demonstrated below in Figure 4-3. The objective efficiency frontier breaks down, and knowledge with respect to processor preferences is necessary if efficiency is to be ascertained.

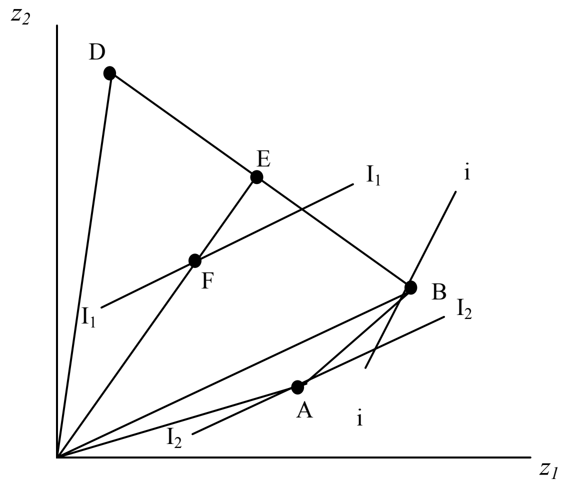


Figure 4-3: Violation of the assumption of non-negative marginal utility (source: Ladd 1982)

The analysis used by Lancaster (1966) is valid only if each point in characteristics space represents a specific combination of characteristics and a unique level of utility. If the assumption of independent distribution of characteristics is violated, the implication is that the objective frontier will break down. In order to evaluate the efficiency of a consumer, the relation of utility to the distribution of characteristics consumed among lots purchased must then be known.

Linear consumption technology implies that is consumption of wool is increased by *p* per cent, the amount of characteristics obtained from raw wool will also increase by *p* per cent. If consumption technology is not linear, it is not possible to determine the characteristics frontier without detailed knowledge of the consumption technology (Ladd 1982).

4.3 Product characteristics approach

4.3.1 Variation on neo-classical firm theory

Ladd and Martin (1976) develop a neo-classical input characteristics model that focuses on the role of input characteristics in a production process. Two themes are introduced: the price of a purchased input is equal to the sum of the money values of the attributes of the input to the buyer, and input characteristics affect the demand for an input.

Wool is considered to be useful because of the utility-bearing characteristics it contains. The contribution of raw wool to the production process will depend on the amount of characteristics provided, while total production will depend on the aggregate amount of all attributes provided by all wool types.

1.1.1 The input characteristics model

The production function for wool-based products, *w*, can be written as:

$$q_w = F_w(x_{1.w}, x_{2.w}, \ldots, x_{m.w}) \qquad (4.1)$$

Where q_w is the quantity of the w^{th} unit of woollen output produced, and $x_{z.w}$ is the total quantity of characteristic *z* that is entered into the production of wool. Equation 4.1 above states that the output of the w^{th} unit of woollen clothing and textiles is a function of the amounts of fleece and fibre characteristics used in its production.

The total quantity of each characteristic can be expressed as a function of the quantity of raw wool used and of characteristic input-output coefficients. As a consequence, $x_{z.w}$ can be denoted as:

$$x_{zw} = X_{zw}(v_{1w}, v_{2w}, \ldots, v_{nw}, x_{11w}, x_{12w}, \ldots, x_{znw}) \qquad (4.2)$$

Where v_{iw} is the amount of the i^{th} unit of raw wool used in the production of the w^{th} unit of woollen clothing and textiles. From here, the production function can be written as:

$$q_w = G_w(v_{1w}, v_{2w}, \ldots, v_{nw}, x_{11w}, x_{12w}, \ldots, x_{mnw}) \qquad (4.3)$$

The profit function of the firm can be written as:

$$\pi = \sum^{W}{}_{w=1} p_w F_w(x_{1.w}, x_{2.w}, \ldots, x_{m.w}) - \sum^{W}{}_{w=1} \sum^{n}{}_{i=1} r_i v_{iw} \qquad (4.4)$$

Where p_w is the price received for the sale of woollen products *w*, and r_i is the price paid for the purchase of lot *i*. The firm is assumed to maximise profit.

As F_w is a function of $x_{z.w}$, and $x_{z.w}$ are functions of v_{iw}, to differentiate the profit function Equation 4.4 with respect to v_{iw}, a rule for differentiating a compound function, or a function of functions, is utilised. This rule states:

$$\partial F_w / \partial v_{iw} = \Sigma(\partial F_w / \partial x_{z.w})(\partial x_{z.w} // \partial v_{iw}) \qquad (4.5)$$

Using this expression to differentiate the profit function, Equation 4.4:

$$\partial\pi/\partial v_{iw} = p_w\sum^{m}_{z=1}(\partial F_w/\partial x_{z.w})(\partial x_{z.w}/\partial v_{iw}) - r_i = 0 \qquad (4.6)$$

Solving for r_z:

$$r_i = p_w \Sigma_z(\partial F_w/\partial x_{z.w})(\partial x_{z.w}/\partial v_{iw}) \qquad (4.7)$$

Where $\partial x_{z.w}/\partial v_{iw}$ is the marginal yield of characteristic z to the production of the w^{th} wool-derived garment from the i^{th} unit of raw wool, $\partial F_w/\partial x_{z.w}$ is the marginal physical product from one unit of characteristic z used in the production of the w^{th} unit of woollen clothing, and $p_w(\partial F_w/\partial x_{z.w})$ is the value of the marginal product of the z^{th} characteristic used in the production of w. This can be interpreted as the imputed price paid for the z^{th} characteristic used in woollen garment w.

Let $p_w(\partial F_w/\partial x_{z.w}) = T_{zw}$. Equation 4.7 can then be re-written as:

$$r_i = T_{zw}(\partial x_{z.w}/\partial v_{iw}) \qquad (4.8)$$

Where $T_{zw}(\partial x_{z.w}/\partial v_{iw})$ is the value of the marginal yield of the z^{th} characteristic by the i^{th} lot in the production of woollen garment w. Equation 4.8 asserts that for each lot used to produce woollen product w, the price paid is equal to the sum of the values of the marginal product of the attributes of raw wool to the finished woollen garment. This is a demonstration of the first theme proposed by Ladd and Martin (1976).

The second theme is derived algebraically by firstly noting that the first-order conditions obtained in Equation 4.6 are a system of nW equations in the nW unknowns v_{iw}. Each part can be expressed as:

$$v_{iw*} = V_{iw}(p_1, p_2,\ldots, p_H, r_1, r_2,\ldots, r_n, x_{111}, x_{211},\ldots, x_{mnW}) \qquad (4.9)$$

If the second-order conditions for a maximum are satisfied, then the system has a solution stated above in Equation 4.9. In general, it is not possible to show that $\partial v_{iw*}/\partial x_{uvw} = 0$, thus demonstrating the second theme of Ladd and Martin (1976).

Ladd and Martin (1976) find that negative implicit prices are consistent with the input characteristics model, as well as with empirical evidence. This represents a violation of the non-negative marginal utility assumption maintained by Lancaster (1966). However, it is justified on the grounds that some characteristics of raw wool will be classified as "inferior" in that their presence will reduce the value of the lot. Alternately, some characteristics may have positive marginal values up to a point before becoming negative (Ladd and Martin 1976).

4.4 The implicit market for characteristics

Rosen (1974) related a model of product differentiation based on a presumption that products are desired for the utility-bearing characteristics that are implicit within them. Hedonic prices are the prices of these characteristics, revealed to the market in the price of the greasy wool, as well as the specific amounts of characteristics within the lot.

The problem of product differentiation is conceptualised in terms of underlying characteristics rather than from a large number of closely related homogenous lots.

4.4.1 Key assumptions

The model relies on several key assumptions. One of the most fundamental is that of perfect competition, where the input, raw wool is described by n number of objectively-measured attributes. At any point of the product differentiation plane, a good can be described by a vector of coordinates, $z = (z_1, z_2, \ldots, z_n)$ where z_i is the amount of the i^{th} characteristic contained within the lot. Product differentiation implies that there is a large range of alternative lots available to the buyer.

While studies by Houthakker (1951/52), Becker (1965), Lancaster (1966), and Muth (1966) emphasised the importance of the consumer also acting as a producer (that is, goods are purchased as inputs into a production process and are valued for final characteristics), Rosen (1974) moves away from this focus. Instead a model is presented which describes a market between buyers and sellers.

Price $p(z) = p(z_1, z_2, \ldots, z_n)$ is defined at each point on the plane, and acts as a guide for the locational choices of buyers and sellers with respect to the combinations of characteristics available. The situation is competitive as no single agent will influence price, with price treated as exogenous to decisions made. $P(z)$ clears the market, and is equivalent to the set of hedonic prices which equate the quantity of raw wool offered by a grower to the amount demanded by processors located at any point.

Growers operate to maximise profit, and the objective of processors is to maximise utility. Pareto optimality prevails, with no single agent being able to improve their position. Further, all optimum choices are feasible. Wool production is then altered by growers such that they contain the characteristics desired by the processor. Additional returns are realised by the grower for acting as a value-adding agent in this sense.

4.4.2 Market equilibrium

It is assumed that the market for a class of raw wool is large enough for the choice between different combinations of characteristics, z_i, to be continuous for the purposes of analysis. Further, the possibility of resale is ignored for simplification purposes.

Each lot has a quoted price determined by the market, which is also associated with a fixed value of the vector z. The wool market reveals an implicit price function, $p(z) = p(z_1, \ldots, z_n)$ which relates price to the characteristics contained within the model. This price function gives the minimum price of any combination of characteristics. This assumes that differentiated products are sold in highly interrelated, though separate markets.

The model developed by Rosen (1974) differs from that of Lancaster (1966) in that it assumes indivisibility. That is, existing packages of characteristics cannot be unbundled. Additionally, growers are assumed to be unable to repackage existing lots in this way, or find it infeasible to do so.

4.4.3 The consumption decision

Processors are assumed to purchase only one unit of a brand with a given value of z. The utility function, $U(x, z_1, z_2, \ldots, z_n)$ where x is all other goods consumed, is assumed too be strictly concave. The price of x is set equal to unity and income, y, is measured in terms of x. That is, $y = x + p(z)$. Utility is maximised subject to a non-linear budget constraint, and requires that x and $(z_1, z_2, \ldots, z_n)$ are chosen to satisfy the budget constraint, as well as the first order conditions, $\delta p/\delta z_1 = p_i = U_{zi}/U_x,\ i = 1, \ldots, n$.

The processor optimises utility by purchasing the lot that possesses the desired bundle of attributes. A value or bid function, $\theta(z_1, \ldots, z_n; u, y)$ according to:

$$U(y - \theta, z_1, \ldots, z_n) = u \quad (4.10)$$

Where income is represented by $\theta(z; u, y)$ and the expenditure a processor is willing to pay for alternative values of $(z_1, \ldots, z_n)$ at a given utility index.

Differentiate Equation 4.10 to obtain:

$$\theta_{zi} = U_{zi}/U_x > 0, \ \theta_u = -1/U_x < 0, \qquad and\ \theta_y = 1 \qquad (4.11)$$

$$\theta_{xizi} = (U_x^2 U_{zizi} - 2U_x U_{zi} U_{xzi} + U_{zi}^2 U_{xx})/U_x^3 < 0 \qquad (4.12)$$

The strict concavity of U implies that θ is concave to z. Further, Equations 4.11 and 4.12 show that the value function is increasing in characteristics, z_i, at a decreasing rate. Put another way, θ_{zi}, is the marginal rate of substitution between z_i and money (that is, x foregone), or the implicit marginal value placed on z_i by the processor at a specific utility index and income. This indicates the reservation demand price for an additional unit of z_i.

Optimum location, observed in Figure 4-4 below, occurs where the two curves, $p(z)$ and $\theta(z; u^*, y)$ are tangential. That is, the amount that a processor is willing to pay for z at a fixed utility index and income is $\theta(z; u, y)$. $P(z)$ is the minimum price that the market will accept. So, utility is maximised when $\theta(z^*; u^*, y) = p(z^*)$ and $\theta_{zi}(z^*; u^*, y) = p(z^*), i = 1, \ldots, n$, where z^* and u^* are optimum quantities.

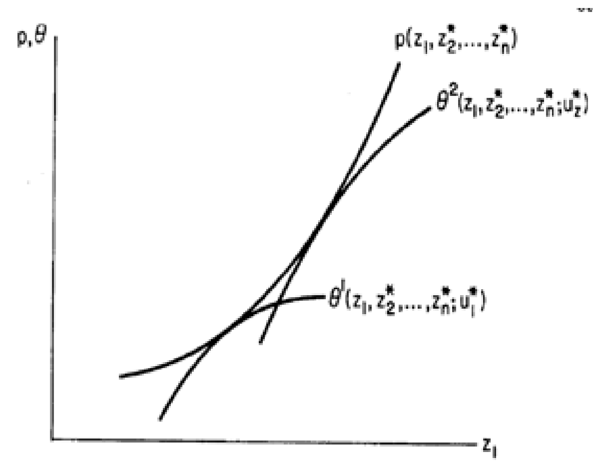


Figure 4-4: The consumption decision (source: Rosen 1974).

Figure 4-4 shows two different processors, one with an offer function, θ^1, and the other θ^2. The second buyer will purchase more of a brand offering a higher quantity of z_1.

A clear consequence of the model of Rosen (1974) is the natural tendency towards market segmentation. This implies that processors with similar offer functions will purchase lots with similar combinations of characteristics.

4.4.4 The production decision

Under the assumption of the model with respect to perfect competition, each "firm", or selling agent, will be an arbitrary group of atomistic producers, each acting independently of one another.

Total costs are denoted as $C(M, z; \beta)$, and are derived from the minimisation of input costs subject to a production function constraint which relates M, z and other factors of production. $M(z)$ is the number of units produced by a firm of a model that offers the characteristic, z. Marginal costs are increasing and positive given production of an additional unit of output. Additionally, growers are assumed to be competitors, though marginal costs of attributes, $p_i(z)$ are not necessarily constant as $p(z)$ is independent of M.

The optimal choice of M and z requires that:

$$p_i(z) = C_{zi}(M, z_1, \ldots, z_n)/M, \qquad i = 1, \ldots, n \qquad (4.13)$$

$$p(z) = C_M(M, z_i, \ldots, z_n) \qquad (4.14)$$

At the optimum, marginal cost of production per unit sold is equal to the marginal revenue attained from further characteristics. Additionally, output is produced up to the point where the revenue per unit, $p(z)$ is equal to the marginal production cost, and is appraised at the optimum bundle of characteristics.

Symmetrical with demand, an offer function is defined, $\varphi(z_1, \ldots, z_n; \pi, \beta)$, which indicates the minimum unit price per brand that the firm is will to accept. A family of production indifference curves are defined by φ, and $\varphi(z_1, \ldots, z_n; \pi, \beta)$ is found by removing M from:

$$\pi = M \varphi - C(M, z_1, \ldots, z_n) \qquad (4.15)$$

And:

$$C_M(M, z_1, \ldots, z_n) \qquad (4.16)$$

Then solve for φ in terms of z, π, and β. The next step is to differentiate Equations 4.14 and 4.15 to obtain $\varphi_{zi} = C_{zi}/M > 0$ and $\varphi_\pi = 1/M > 0$.

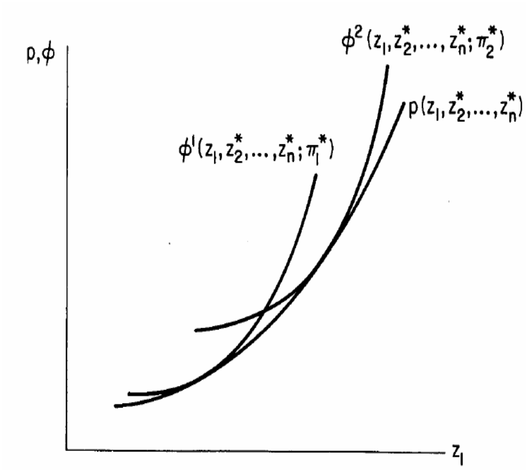


Figure 4-5: The production decision (source: Rosen 1974).

Assuming that the marginal reservation supply price, or φ_{zi} is increasing in z_i, and is constant in profit for attribute i, and since φ is the offer price, or the minimum price that the grower is willing to accept on a lot i at profit level π, profit will be maximised at an optimum point where the offer price is at a maximum given the constraint $p = \varphi$, where $p(z)$ is the maximum price that the market is willing to pay for this model.

Maximum profit and the optimum combination of characteristics thus satisfies $p_i(z^*) = \varphi_{zi}(z_1^*,\ldots, z_n^*;\ \pi^*,\ \beta)$, for $i = 1,\ldots, n$ and $p(z^*) = \varphi(z_1^*,\ldots, z_n^*;\ \pi^*,\ \beta)$. Producer equilibrium is found where the profit-characteristics indifference curve is tangential to the market characteristics-implicit price curve. Figure 4-5 shows the curve labelled as φ^1 as relating to a production unit processing production and cost conditions which are more suited to producing smaller amounts of z_1, while the curve labelled φ^2 refers to a firm that can produce comparatively higher values of z.

The two sellers are distinct due to differing values of β, or the various factors of production. There will be a distribution of β across all potential growers, represented by $G(\beta)$. The producer equilibrium is then embodied in a group of related offer functions that encompass the market hedonic price functions.

Empirically, the parameter *β* is anything that acts to shift cost functions between firms. This means that differences in on-farm input prices are feasible and there is no validation for the assumption of factor price equalisation. Secondly, differences in technology may also act as supply-shifters, particularly as they are often unmeasured, farm-specific factors of production.

4.4.5 An explanation of hedonic prices

At the optimum point, the buyer's value curve and the offer curve of the seller are tangential. The common gradient is given by the gradient of the market-clearing hedonic price function, *p(z)*. Observations *p(z)* represent a combined envelope of a related group of value functions, and another of offer functions.

If there is no variance in the factors of production, *β*, and all growers are identical, differences in price between discrete lots will equalise among sellers as constant profits comprise the offer functions. Distinct bundles of characteristics appear in the wool market to satisfy diverse processor preferences, and the situation persists so that no grower will want to alter the quality of wool offered.

If processors are homogenous, the market price, *P(z)*, will identify the composition of demand and equalise price differences across buyers.

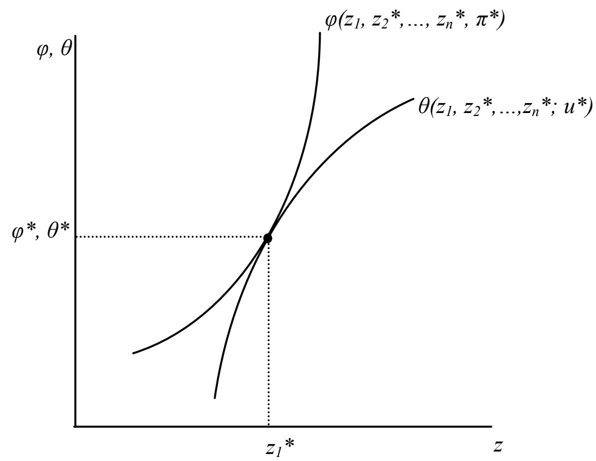
4.4.6 Summary of implicit markets and hedonic prices

The market for the characteristics possessed by a lot is not an explicit one. Rather, it is observed from the behaviour of the market for raw wool that is composed of these attributes. When the market for a wool type can be treated as indivisible bundles of characteristics, prices observed for the market will be comparable on these terms. The nature of the economic relationship between the prices and characteristics observed becomes apparent through the price differentials among goods. These price differentials can be therefore recognised to be equalising the disparities between the various bundles of characteristics embodied.

4.5 Application of theory to a functional model

An hedonic model has been chosen for its ability to used to analyse the characteristics within a lot. Demand for raw wool is derived from primary demand for woollen garments and fabric (Tomek and Robinson 2003). The input characteristics model of Ladd and Martin (1976) is relevant for its analysis of the role of raw wool characteristics within a production process. It is in this framework that the hedonic model will be estimated.

Figure 4-6: Market equilibrium. The producer's offer function is tangential to the consumer's value function.



The model developed will examine the impacts of characteristics on market price on the demand side only, though there will be a market equilibrium ascertained, as this is the price at which growers are willing and able to sell a wool lot and processors are willing and able to purchase that same lot. Figure 4-6 demonstrates the equilibrium described by Rosen (1974), where the grower's offer curve is tangential to the processor's value curve.

At the point of tangency, the grower is operating to maximise profits, while the consumer is maximising utility, subject to cost and income constraints respectively. Lots purchased by the processor are valued for their utility-bearing characteristics, with the contribution of raw wool into a production process dependent on the level of attributes inherent within it (Ladd and Martin 1976).

At this point, the optimum level of efficiency is achieved, from both an objective and a subjective point of view. This optimum represents a point on the efficiency frontier of Lancaster (1966), as any processor to the right or left of this line would be operating inefficiently. Likewise, the point is efficient from a subjective perspective also, as a private choice is made that maximises the optimum combination of characteristics (Ladd 1982).

4.6 Concluding comments

Derived demand forms the analytical framework within which this hedonic model lies. The approach taken is demand-side orientated, and as such concentrates on consumer theory. Lancaster's (1966) approach, in which processors maximise utility by purchasing raw wool for its characteristics, is utilised, with Ladd and Martin (1976) being influential with their input-characteristics model.

The implicit market for characteristics described by Rosen (1974) is the basis for equilibrium, in that the optimal point of efficiency is found where the buyer's value function is tangential to the seller's offer function. However, for the purpose of this specific hedonic model, the supply side is largely ignored aside from its role in determining the market price of a good.

Thus, the consumption decision faced by the processor is to combine the demand for certain characteristics of raw wool necessary for the production of wool tops, and the need to minimise the cost of purchasing that wool most suitable for the production process (Delius 1981). This dual problem is the force behind the determination of the price of a lot at auction.

5 Data and estimation procedures

An hedonic model was used in this analysis. It was derived from the input characteristics model of Ladd and Martin (1976), which was described in Chapter 3. The functional form chosen was double log, as explanatory power for the model exceeded that of the semi log model. Additionally, the advantage of a double log functional form is its ability to be interpreted as constant elasticities.

Auction price and lot characteristics data on Merino fleece lots sold in the 2005-06 selling season were obtained from AWEX. The data included 232 209 lots sold. This population was divided into four markets, superfine, fine, medium and broad, based on end use. After adjusted for incomplete observations, the sample size varied from 5536 observations for the broad market, 61 554 for superfine, and 65 535 for both fine and medium categories.

Ordinary least squares multiple regression is the econometric technique used to exude the implicit prices for the characteristics examined in each market.

5.1 Merino wool auction data

The data used in this model was obtained from AWEX auction data. AWEX, which deals with 86 per cent of wool sold in Australia each year and acts as the industry body that ensures standardisation of the wool-selling process, maintains an extensive database of all lots offered at Australian auctions. These data include full testing details, AWEX-ID appraisals, results of sales, wool description, buyer identification, price paid for lots sold or passed in, and information regarding location (storage, sale and origin) (Australian Wool Exchange (AWEX) 2005).

The data analysed was for all Merino fleece lots, both adult and weaner, sold at auction in Australia in the season 1 July 2005 to 30 June 2006. 232 209 lots were exhibited and sold through the auction system. From this population, four sub-populations were obtained, superfine (less than 18.5 micron), fine (18.5 to 20.5 micron), medium (20.5 to 23.5 micron), and broad (23.5 and above). This was done according to prevailing industry-reporting practices (David Cother, pers. comm., 2006) and was done to ascertain demand for different factors based on end use.

Superfine wools are used mainly in high-quality knitwear, while fine wool is used predominantly in the production of mens' and womens' woven outerwear. Medium wools, on the other hand, are destined for lower-quality knitwear, socks, underwear, and hand-knitting yarn, as well as non-apparel products such as pressed felts. Similarly, broad wools are used primarily in the manufacture of non-apparel products, for example, quilt fillings, furnishings, and blankets (Cottle 2000 p.319; Teasdale 2005).

The production process required for each of these end products is distinct, and thus the demand for attributes inherent within a lot will vary according to processing, and ultimately consumer, needs. Whitely (1987) notes that wool differs from many other agricultural commodities, including competing fibres, in that the raw product passes through a long and complex supply chain before it reaches the end user. Additionally, depending on the characteristics of the wool, there are a number of different production processes that can be used to transform the raw wool.

The measured characteristics, that is, micron, staple length and strength, and weight, were logged, along with the Australian clean on-floor (ACOF) price due to the non-linear relation of the variables with clean price. While vegetable matter base (VMB) and midpoint breakage are also measured, because it is possible for there to be a zero measurement, they were not logged. The objective specification of these characteristics is important in assessing the probable processing performance of greasy wool (Whitely 1987) and gives a more reliable indication of these aspects than visual appraisal (Cottle 2000 p.324).

The non-measured characteristics included in the model were fleece type (whether the fleece was from a weaner or adult sheep); lot contamination (whether branding or colour was present, and at what level of severity); method of preparation (whether the lot was bulkclassed or interlotted); location of sale, relative to Melbourne; quarter of sale, relative to Quarter 1; storage centre, relative to Fremantle; and style, relative to inferior, which is likely to have some significance in determining the processing potential, and therefore price (Ford and Cottle 1993).

Each sub-set was adjusted for administrative mis-entry. That is, observations with an entry of zero for micron, strength, length, yield (necessary for the calculation of clean price), weight, and price, were excluded. Price was also examined for extreme outliers by graphing price against micron. As a consequence, those observations with a price of over $7000 were also excluded. After adjusting for these potential sources of bias, the size for superfine was 61 554 observations, fine was 65 535, medium was 65 535, and broad was 5536. The fine and medium categories originally contained more than 65 535, but these observations were randomised, with some observations omitted to make these data more manageable.

The choice of variables was influenced by examination of any correlation between regressors, as well as through observation of the descriptive statistics for each model. Based on the relationships observed between the variables, wool base can be excluded from the model, because of its perfect correlation with Schlumberger dry yield, the measurement process used for market reporting. This was not unexpected given that wool base is simply a more refined process of measuring yield. Thus, inclusion of the two variables is likely to give rise to multicollinearity which occurs when two variables are closely related to one another. Should this be the case, while least-squares estimates may be found for each of the regression coefficients, there will be difficulty in interpreting these results as a given change in one of the correlated variables is likely to lead to a predictable change in its highly correlated partner (Gujarati 2006 p.84).

Hauteur was excluded on the grounds that it is a weighted average of staple length and strength, fibre diameter, midpoint breakage, and vegetable matter base measurements, all of which are included in the model.

To determine whether exclusion of hauteur could be justified, two versions of the model were run. The results indicated that explanatory power of the overall model was not greatly affected by the exclusion of hauteur, but the magnitude of the coefficient on midpoint breakage in particular was improved by its exclusion. Yield, similarly was not incorporated into the model as a separate variable, given that it is used to calculate ACOF price, and therefore has already been taken into account.

Descriptive statistics are provided in Tables 5-1 to 5-4 for each of the four models. The statistics described for measured characteristics need to be interpreted differently to those for non-measured variables. While the mean measurements for measured characteristics are absolute values, those observed for dummy variables are proportional figures which reflect the relative abundance of a particular attribute within the model. For example, according to the statistics for the superfine model, 3 per cent of lots were found to be bulkclassed, while only 1 per cent was interlotted.

Table 5-1: Descriptive statistics, superfine model.

Descriptive Statistics: Superfine Model

	Mean	Median	Maximum	Minimum	Std. Dev.	Skewness	Kurtosis	Sum	Sum Sq. Dev.
ACOF	1033.89	967.26	6982.87	200.00	290.00	4.59	48.81	61599224.00	0.00
Bulkclassed	0.03	0.00	1.00	0.00	0.17	5.56	31.88	1760.00	1708.01
Fremantle	0.06	0.00	1.00	0.00	0.23	3.83	15.66	3385.00	3192.68
Interlot	0.01	0.00	1.00	0.00	0.12	8.28	69.54	833.00	821.35
Launceston	0.03	0.00	1.00	0.00	0.17	5.55	31.77	1766.00	1713.65
Length	77.23	77.00	128.00	48.00	9.67	0.15	3.12	4601213.00	5575108.00
Micron	17.37	17.50	18.50	12.90	0.86	-0.88	3.40	1034760.00	44675.62
Newcastle	0.22	0.00	1.00	0.00	0.42	1.33	2.76	13324.00	10344.33
POBM	46.72	45.00	100.00	0.00	22.91	0.15	2.16	2783827.00	31258553.00
Q2	0.32	0.00	1.00	0.00	0.47	0.77	1.59	19072.00	12966.91
Q3	0.24	0.00	1.00	0.00	0.43	1.19	2.42	14525.00	10983.95
Q4	0.20	0.00	1.00	0.00	0.40	1.53	3.33	11727.00	9418.80
R1	0.00	0.00	1.00	0.00	0.05	20.48	420.56	141.00	140.67
R2	0.00	0.00	1.00	0.00	0.02	45.29	2052.48	29.00	29.99
R3	0.00	0.00	1.00	0.00	0.02	57.51	3308.00	18.00	17.99
S1	0.00	0.00	1.00	0.00	0.02	41.22	1700.29	35.00	34.98
S2	0.00	0.00	1.00	0.00	0.04	24.72	612.23	97.00	96.84
S3	0.02	0.00	1.00	0.00	0.13	7.25	53.60	1072.00	1052.71
S4	0.41	0.00	1.00	0.00	0.49	0.37	1.14	24314.00	14392.44
S5	0.54	1.00	1.00	0.00	0.50	-0.18	1.03	32449.00	14776.33
S6	0.03	0.00	1.00	0.00	0.16	5.98	36.82	1536.00	1496.40
Strength	36.58	37.00	68.00	8.00	8.46	-0.14	2.63	2179481.00	4263593.00
Sydney	0.33	0.00	1.00	0.00	0.47	0.72	1.52	19728.00	13195.71
VMB	1.26	1.00	18.50	0.00	1.07	2.82	18.49	75301.70	68245.08
Weaners	0.28	0.00	1.00	0.00	0.45	0.95	1.91	16966.00	12134.76
Weight	721.03	540.00	5289.00	65.00	599.26	1.62	6.23	42959006.00	21400000000.00

Table 5-2: Descriptive statistics, fine model.

Descriptive Statistics: Fine Model

	Mean	Median	Maximum	Minimum	Std. Dev.	Skewness	Kurtosis	Sum	Sum Sq. Dev.
ACOF	773.02	768.18	1888.22	124.42	89.67	0.28	3.96	50658355.00	527000000.00
Adelaide	0.05	0.00	1.00	0.00	0.21	4.30	19.48	3058.00	2915.30
Brisbane	0.05	0.00	1.00	0.00	0.22	4.00	17.00	3459.00	3276.43
Bulkclassed	0.05	0.00	1.00	0.00	0.23	3.94	16.51	3552.00	3359.48
Fremantle	0.22	0.00	1.00	0.00	0.42	1.32	2.75	14685.00	11394.00
Geelong	0.18	0.00	1.00	0.00	0.38	1.68	3.81	11703.00	9613.06
Goulburn	0.06	0.00	1.00	0.00	0.24	3.57	13.73	4183.00	3916.00
H1	0.14	0.00	1.00	0.00	0.35	2.11	5.47	8960.00	7734.94
H2	0.10	0.00	1.00	0.00	0.10	9.95	100.09	642.00	635.71
H3	0.00	0.00	1.00	0.00	0.00	255.99	65531.00	1.00	1.00
Interlot	0.04	0.00	1.00	0.00	0.20	4.68	22.89	2637.00	2530.89
Launceston	0.01	0.00	1.00	0.00	0.09	11.53	133.97	482.00	478.45
Length	84.92	86.00	136.00	49.00	11.17	-0.40	3.19	5564951.00	8175545.00
Melbourne	0.05	0.00	1.00	0.00	0.22	4.16	18.35	3229.00	3069.90
Micron	19.59	19.60	20.50	18.60	0.57	-0.08	1.81	1283674.00	21619.76
Newcastle	0.04	0.00	1.00	0.00	0.21	4.40	20.39	2933.00	2801.73
Newcastle1	0.06	0.00	1.00	0.00	0.24	3.75	15.04	3859.00	3631.76
NZ	0.01	0.00	1.00	0.00	0.11	8.91	80.34	796.00	786.33
OtherNSW	0.17	0.00	1.00	0.00	0.37	1.79	4.21	10895.00	9083.68
OtherSA	0.01	0.00	1.00	0.00	0.10	9.44	90.05	712.00	704.26
OtherVic	0.04	0.00	1.00	0.00	0.18	5.06	26.60	2294.00	2213.70
OtherWA	0.01	0.00	1.00	0.00	0.04	23.11	535.16	122.00	121.77
POBM	48.94	48.00	100.00	0.00	22.61	0.08	2.16	3207438.00	33493804.00
Q2	0.25	0.00	1.00	0.00	0.43	1.15	2.32	16453.00	12322.24
Q3	0.24	0.00	1.00	0.00	0.43	1.23	2.51	15595.00	11883.83
Q4	0.21	0.00	1.00	0.00	0.41	1.39	2.94	14034.00	11028.60
R1	0.01	0.00	1.00	0.00	0.09	11.06	123.31	523.00	518.83
R2	0.00	0.00	1.00	0.00	0.03	35.46	1258.25	52.00	51.96
R3	0.00	0.00	1.00	0.00	0.02	43.24	1870.37	35.00	34.98
Strength	33.93	34.00	70.00	9.00	8.77	0.12	2.75	2223452.00	5041607.00
Sydney	0.36	0.00	1.00	0.00	0.48	0.56	1.32	23881.00	15178.48
Sydney1	0.08	0.00	1.00	0.00	0.27	3.19	11.17	5007.00	4624.44
Tas	0.02	0.00	1.00	0.00	0.15	6.28	40.41	1546.00	1509.53
VMB	1.43	1.10	20.40	0.00	1.30	3.09	19.83	93564.90	110805.40
Weaners	0.08	0.00	1.00	0.00	0.28	2.98	9.86	5567.00	5094.09
Weight	1210.77	1003.00	7672.00	77.00	794.86	1.01	3.90	79345622.00	41400000000.00

Table 5-3: Descriptive statistics, medium model.

Descriptive Statistics: Medium Model

	Mean	Median	Maximum	Minimum	Std. Dev.	Skewness	Kurtosis	Sum	Sum Sq. Dev.
ACOF	680.47	681.62	961.54	346.15	51.38	-0.65	4.15	44592954.00	173000000.00
Adelaide	0.14	0.00	1.00	0.00	0.35	2.08	5.34	9124.00	7853.69
Brisbane	0.05	0.00	1.00	0.00	0.22	4.01	17.09	3443.00	3262.11
Bulkclassed	0.05	0.00	1.00	0.00	0.22	4.01	17.11	3439.00	3258.53
Fremantle	0.33	0.00	1.00	0.00	0.47	0.71	1.50	21858.00	14567.44
Geelong	0.17	0.00	1.00	0.00	0.38	1.73	4.00	11317.00	9362.65
Goulburn	0.01	0.00	1.00	0.00	0.12	8.15	67.44	944.00	930.40
H1	0.14	0.00	1.00	0.00	0.35	2.04	5.17	9357.00	8020.98
H2	0.09	0.00	1.00	0.00	0.09	10.66	114.62	562.00	557.18
H3	0.00	0.00	1.00	0.00	0.00	255.99	65531.00	1.00	1.00
Interlot	0.05	0.00	1.00	0.00	0.23	3.92	16.34	3584.00	3387.99
Launceston	0.00	0.00	1.00	0.00	0.04	24.13	583.12	112.00	111.81
Length	89.44	91.00	157.00	48.00	11.02	-0.74	3.94	5861411.00	7955516.00
Melbourne	0.04	0.00	1.00	0.00	0.20	4.58	22.00	2736.00	2621.77
Micron	21.69	21.60	23.50	20.60	0.78	0.48	2.24	1421758.00	39666.49
Newcastle	0.01	0.00	1.00	0.00	0.12	8.42	71.98	886.00	874.02
Newcastle1	0.02	0.00	1.00	0.00	0.16	6.11	38.38	1624.00	1583.76
NZ	0.00	0.00	1.00	0.00	0.04	24.46	599.22	109.00	108.82
OtherNSW	0.12	0.00	1.00	0.00	0.33	2.31	6.34	7988.00	7014.32
OtherSA	0.01	0.00	1.00	0.00	0.08	11.84	141.09	458.00	454.80
OtherVic	0.03	0.00	1.00	0.00	0.18	5.32	29.33	2094.00	2027.09
OtherWA	0.00	0.00	1.00	0.00	0.05	19.91	397.59	164.00	163.59
POBM	47.35	46.00	100.00	0.00	21.98	0.17	2.20	3102789.00	31668089.00
Q2	0.24	0.00	1.00	0.00	0.43	1.19	2.43	15969.00	12077.69
Q3	0.30	0.00	1.00	0.00	0.46	0.88	1.77	19576.00	13728.26
Q4	0.25	0.00	1.00	0.00	0.43	1.15	2.32	16447.00	12319.25
R1	0.01	0.00	1.00	0.00	0.12	8.30	69.87	912.00	899.31
R2	0.00	0.00	1.00	0.00	0.03	28.57	817.16	80.00	79.90
R3	0.00	0.00	1.00	0.00	0.03	37.70	1422.63	46.00	45.97
Strength	39.49	34.00	73.00	8.00	8.76	0.24	3.13	2260325.00	5031970.00
Sydney	0.23	0.00	1.00	0.00	0.42	1.28	2.63	15141.00	116421.76
Sydney1	0.05	0.00	1.00	0.00	0.22	4.01	17.09	3442.00	3261.22
Tas	0.01	0.00	1.00	0.00	0.08	12.32	152.93	423.00	420.27
VMB	1.38	1.00	24.60	0.00	1.28	3.37	24.74	90623.10	106940.70
Weaners	0.01	0.00	1.00	0.00	0.11	9.12	84.13	761.00	752.16
Weight	1462.07	1300.00	7312.00	91.00	867.70	0.72	2.96	95814010.00	49300000000.00

Table 5-4: Descriptive statistics, broad model.

Descriptive Statistics: Broad Model

	Mean	Median	Maximum	Minimum	Std. Dev.	Skewness	Kurtosis	Sum	Sum Sq. Dev.
ACOF	643.47	647.67	1036.08	325.38	46.04	-1.01	7.02	3561595.00	11728283.00
Bulkclassed	0.04	0.00	1.00	0.00	0.20	4.59	22.11	230.00	220.71
Fremantle	0.23	0.00	1.00	0.00	0.42	1.31	2.72	1250.00	967.71
Interlot	0.05	0.00	1.00	0.00	0.21	4.27	19.26	261.00	248.69
Launceston	0.00	0.00	1.00	0.00	0.01	74.38	5533.00	1.00	1.00
Length	92.29	94.00	129.00	52.00	11.26	-0.89	4.20	510832.00	701816.50
Micron	24.21	24.00	28.20	23.60	0.61	1.62	6.44	134010.70	2049.96
Newcastle	0.00	0.00	1.00	0.00	0.07	14.78	219.40	25.00	24.89
POBM	46.50	45.00	98.00	0.00	20.40	0.25	2.34	257353.00	2303496.00
Q2	0.23	0.00	1.00	0.00	0.42	1.29	2.67	1266.00	976.43
Q3	0.24	0.00	1.00	0.00	0.43	1.23	2.50	1322.00	1006.25
Q4	0.23	0.00	1.00	0.00	0.42	1.29	2.67	1267.00	976.97
Strength	38.88	38.00	78.00	8.00	8.75	0.33	..36	215216.00	423916.90
Sydney	0.10	0.00	1.00	0.00	0.30	2.70	8.27	468.00	421.92
VMB	1.33	1.00	13.10	0.10	1.08	2.13	11.40	7360.10	6413.75
Weaners	0.00	0.00	1.00	0.00	0.04	23.46	551.50	10.00	9.98
Weight	1328.44	1104.00	5835.00	112.00	841.60	1.03	3.59	7352893.00	3920000000.00

5.2 Specification of an hedonic model

Economic theory gives relatively little guidance with respect to the choice of functional form for an hedonic price function. This has led to the use of goodness-of-fit criterion as the preferred way to arrive at an appropriate form. Cropper *et al.* (1988) argue, however, that if the goal of research is to value the characteristics of a good, then the choice of the functional form should be one which most accurately estimates the marginal prices of the attributes. These marginal prices measure the consumer's willingness to pay for a commodity's attributes, and may be used to directly measure small changes in the levels of the characteristics as a consequence.

Additionally, prices at the margin represent the dependent variables in the estimation of marginal value functions. Subsequently, errors in measurement may bias the valuation of non-marginal characteristics also.

5.2.1 Compatibility of criteria for selection of a functional form

In general, it is difficult to find a functional form which satisfies all five criteria of theoretical consistency, range over which the form is applicable, flexibility, computational facility, and factual conformity. However, this will be very much dependent on the application, and it may be the case that such a form is found to be appropriate.

Some trade-offs will have to be made. There are, however, some compromises that should not be made. Any algebraic functional form should satisfy the requirements of theoretical consistency, at least in the local sense of the independent variables being analysed. Additionally, it is not generally recommended that computational facility be compromised as the probability of failure in the estimation of non-linear-in-parameters models is greater than for a linear-in-parameters model by at least one magnitude. Further, the statistical theory in these areas is typically less developed.

The sacrifice of flexibility is also not recommended. This is because lack of flexibility will limit the sensitivity of the model and limit the ability of *a priori* information in the data to influence the modeller's choice of functional form. Thus, unless there is strong prior information with respect to the actual functional form, flexibility should not be compromised either.

By a process of elimination, the domain of applicability is the only area in which some concessions may be made. In many cases, practical applications can be accommodated when the algebraic functional form is not theoretically consistent in a global sense, but is nevertheless consistent in a sufficiently large subset of the space of independent variables.

5.2.2 Functional forms

5.2.2.1 Choice of functional form

The functional form used will usually be an empirical, rather than theoretical matter. While theory is generally not robust enough to determine the functional form that should be used, there are some guiding principles that may aid in the decision, such as plotting the data, or choosing a model on the basis of R^2. Choosing a model based on the R^2 value, that is, the model which yields the highest value, has several problems also. Firstly, to compare two models based on R^2, the dependent variable needs to be in the same form.

The model selected for this analysis is double-log, which is used to measure elasticity or response of the dependent variable to a small change in an explanatory variable. The basis for choosing this model is the non-linear relationship observed between the dependent variable and several regressors. This relationship meant that the use of a linear model was ruled out. The choice between semi-log and double-log models was made based on the superior adjusted R^2 observed for the double-log. This comparison is legitimate for the fact that the dependent variable was logged in both models, and the same variables were estimated.

R^2 measures the proportion of variation in the dependent variable explained by the explanatory variables. In a linear model, R^2 measures the proportion of variation in Y explained by X. In the log-linear model, however, the proportion of variation of the log of Y is explained by the log of X. Conceptually, the first interpretation refers to absolute change, while the second is relative or proportional.

Even if the dependent variables are in the same form, a high R^2 does not necessarily indicate that a model is superior to another. For instance, the more variables included in a model, the higher the explanatory power. A more suitable method for choosing a functional form is based on the need to consider the relevance of explanatory variables included, and the underlying economic theory. From this, the expected signs on coefficients, their statistical significance and other derived measures, such as elasticity coefficients, can be assessed (Gujarati 2006).

A Box-Cox form was not considered, as while linear and quadratic forms are found to give the most accurate estimates of attribute characteristics, there is evidence to suggest that if there are characteristics that are hard to measure present, the Box-Cox form will tend to generate biased estimates (Cropper *et al.* 1988). Further, while Box-Cox transformations may be useful in allowing the data to determine the functional form that should be chosen, it can result in the derivation of complicated functional forms. The marginal implicit values of characteristics estimated using a Box-Cox form will be difficult to interpret (Wahl *et al.* 1995). Additionally, Box-Cox forms are found to be most effective given perfect information, which is rarely the case (Cropper *et al.* 1988).

5.2.2.2 Reasons for choosing double-log functional form

A feasible model was developed based on the data under two assumptions. The demand for wools of different fibre diameter is assumed to be separable from that of other inputs, and the demand for wools of disparate diameter are separable over a range of wool types (Beare and Meshios 1990). After analysing the data and examining the descriptive statistics, it was concluded that a double-log functional form was the most appropriate, and appeared to have the highest explanatory power.

The advantage of a double-log form is the ability to measure the elasticity of a demand system. This allows for analysis based on the response of price to small changes in the explanatory variables and its popularity in empirical studies is due to the fact that the slope coefficients can be interpreted as the elasticity of the dependent variable with respect to the regressors. Beare and Meshios (1990) utilise the model, also known as the constant elasticity model, as it provides "the simplest formulation of a theoretically consistent factor demand system" (p.59).

Hedonic analysis is based on the concept that a good is valued for its utility-bearing attributes, and that the consumer's utility is a function of both quantity and quality characteristics. The hedonic model to be estimated in double-log functional form is:

$$\boldsymbol{lnP_i = \alpha_0 + \sum^n_{i=1} ln\beta_i z_i + \sum^n_{i=1} \beta_i z_i + \sum^n_{j=1} \delta_j d_j + e_i} \qquad \textit{(5.1)}$$

Where lnP_i is the logged price of lot number i (c/kg clean); α_0 is the constant term, $\sum^n_{i=1} ln\beta_i z_i$ is the sum of logged measured characteristics; $\sum^n_{i=1}\beta_i z_i$ is the sum of measured characteristics where measurements may be zero; $\sum^n_{j=1} \delta_j d_j$ is the sum of non-measured characteristics; and e_i is the error term. An explanation of variables included and their interpretation is given in the next section.

The model, based on hedonic theory, is thus capable of recognising heterogeneity within a good. Clean price, the dependent variable, is simultaneously affected by the qualitative and quantitative properties of the commodity, where the quantitative component is comprised of the supply and demand forces affecting the price of the homogenous commodity. The qualitative element captures the role of changes in unmeasured aspects and their effect on price (Bowman and Ethridge 1992).

5.3 Variables

The majority of raw Merino wool is purchased with the objective of processing it into wool top so that is can be spun into woollen textiles in the worsted spinning process. The selection and purchase of a lot should not be based on the visual style of a lot as this does not guarantee the production of a top that will be any easier to sell or achieve a premium price at the spinning section of the production process. For instance, a top which is too long given its fibre diameter may be sold at a discount (Drummond 1993).

Early stage processors, the purchasers of greasy wool at auction, select a lot based on the assumption that they need to produce a quality product containing certain characteristics demanded by their customer, the spinner. To meet the requirements of the spinner, the top-maker needs to predict the type of top that will be produced from given greasy fleece and fibre characteristics (Turk 1993).

However, there is also evidence to suggest that substantial premia are paid for visual attributes, represented in style, which are argued to have little impact on processing efficiency (Scrivener *et al.* 1999; Vizard and Hansford 1999). As a consequence, this variable is included in the model where relevant. Other characteristics appraised subjectively by brokers and audited by AWEX, such as fleece contamination (colour and brands in particular) are included as they are believed to have an effect on the suitability of the top downstream of spinning, while not necessarily having an impact on spinning performance (Lamb and Yang 1997).

Additionally, external variables, such as sale centre, which reflects local market conditions, quarter of sale, which attempts to account for price trends, and storage location, which acts as an indicator of regional variation, are included where there are sufficient observations as they are considered to be influential on the pricing decision of the buyer. Table 5-5 displays a summary of the variables used, the associated unit of measurement, whether the variable is measured or appraised, and a brief explanation of the variables' importance.

5.3.1 Measured

Fibre diameter, measured in micrometres, or micron (μm, or 10^{-6}m) has an important effect on processing performance, as finer fleeces allow greater weights of material to pass though machinery in a given time. However, the major factor influencing demand is the fineness of the yarn that is spun from raw wool, with a minimum number of fibres necessary in the cross-section of a commercially acceptable yarn. Subsequently, there is a lower limit on the yarn count that can be spun from raw wool of a given fibre diameter. The evenness of yarn is also influenced by micron, especially in the worsted process since finer yarns can be spun from finer fibres and softer, lighter fabrics can be manufactured using these yarns (Cottle 2000 p.320).

The next most important factors are considered to be staple length and strength as they are used to predict key processing and product properties. They are measured by AWTA in a staple, which is a well-defined unit of fibres removed from a mass of greasy wool. Staple length is measured in millimetres (mm), and is highly correlated with average fibre length in the top, or hauteur and is more convenient to measure than greasy fibre length (Cottle 2000 p.324-325).

Table 5-5: Influences on the price of Merino wool, measured and non-measured variables.

Characteristic (Variable/s name)	Unit of measurement	Explanation
Measured		
Fibre Diameter (Micron)	Micrometres, or micron (μm)	Measured objectively by AWTA using technology which detects shadows of fibre snippets as they pass through a laser beam in solution, with each fibre tested individually.
Staple Length (Length)	Millimetres (*mm*)	Determined by the length of a sample staple projected along its axis, and obtained by measuring without stretching or disturbing the fibre crimp.
Staple Strength (Strength)	Newtons per kilotex (*Nkt*)	Calculation comprised of 2 parts. Staple thickness is determined by the weight and length of the staple, measured in ktex. Strength is then determined by the peak force required to break a staple, N.
Lot Weight (Weight)	Kilograms (*kg*)	Combined weight of total bales that compose a lot.
Midpoint Breakage (POBM)	Percentage of staple breakage (*%*)	Point of breakage is reported as the percentage of staples tested which break in the tip, middle or base third of the staple. Breakage in the middle is of most concern to processors.
Vegetable Matter Base (VMB)	Percentage of wool base (*%*)	The amount of clean dry vegetable matter present as a percentage of a greasy sample.
Non-Measured		
Fleece Type (Weaner)	Weaner=1 if present, 0 if not.	Fleeces analysed are either adult or weaner.
Method of Preparation (Interlot; Bulkclassed)	Interlot=1 if present, 0 if not; Bulkclassed=1 if present, 0 if not.	Where there is insufficient wool to make a complete line. Bulkclassed lots occur when bigger lines are made by mixing several smaller lines from several different growers (multiple components). Interlots occur when 1, 2 or 3 bales are put together to buil
Lot Contamination (Branding, *Ri;* Colour, *Hi*)	Ri=1 if present, 0 if not, i=1, 2, 3; Hi=1 if present, 0 if not, i=1, 2, 3.	Some lots may contain branding or colour contamination. Severity of presence may vary from light (R1, H1), to medium (R2, H2), to heavy or complete line (R3, H3).
Sale Location (Sydney; Newcastle; Launceston; Fremantle)	Sydney=1 if present, 0 if not; Newcastle=1 if present, 0 if not; Launceston=1 if present, 0 if not; Fremantle=1 if present, 0 if not.	A slight majority of sales are held in Melbourne, resulting in it being used as the basis of analysis. This variable represents price variation due to regional selling differences.
Quarter of Sale (*Qi*)	Qi=1 if present, 0 if not, i=2,3,4.	Relative to beginning of the selling season, this variable attempts to account for price variation across time.
Storage Location (Adelaide; Brisbane; Geelong; Goulburn; Melbourne1; Newcastle1; NZ; OtherNSW; OtherVic; OtherSA; OtherWA; Sydney1; Tas)	Adelaide=1 if present, 0 if not; Brisbane=1 if present, 0 if not; Geelong=1 if present, 0 if not; Goulburn=1 if present, 0 if not; Melbourne1=1 if present, 0 if not; Newcastle1=1 if present, 0 if not; NZ=1 if present, 0 if not; OtherNSW=1 if present, 0 if	Relative to Fremantle, Storage Location attempts to account for spatial price variation due to production differences, as well as biological and climatic factors.
Style (*Si*)	Si=1 if present, 0 if not, i=1, 2, 3, 4, 5, 6.	Relative to Style 7, this variable is included to evaluate the effect of the visual appraisal of a lot. Other styles are: 1 choice, 2 superior, 3 spinners, 4 best, 5 good, 6 average, and 7 inferior.

Staple strength is determined by the maximum force required to break a staple per unit of average linear density, denoted as Newtons per kilotex (Nkt) and is negatively associated with fibre diameter through yarn evenness. Yarn evenness, in turn, influences yarn strength through its impact on the likelihood of thin or weak positions (Lamb and Yang 1997). Staple strength appears to be largely a function of the change in fibre diameter along a staple (Cottle and Bowman 1990).

Point of breakage is reported as the percentage of staples which break in the tip, middle or base thirds of the staple and is generally associated with staple strength. If the staple tip is light and base is heavy, comparatively, the break will be close to the tip. Breakage in the middle of the staple is of most concern to processors, but only if staple strength is low. This is because middle breakage reduces the length of the fibre from the processed top, or hauteur. Low strength wool, or wool with a definite position of breakage, will not necessarily produce lower-quality fabric than a higher strength wool if tops of the same hauteur are produced (Cottle 2000 p.325).

Vegetable matter content is calculated as an oven-dried mass of ash- and ethanol-extractives-free burrs (including hard heads), seeds, leaves, and grasses present, and represented as a percentage of the sample. It is included in the model because its presence in greasy wool represents a large cost to processors in its removal, which depending on the type and extent of vegetable matter present, may damage the wool appreciably.

The reporting yield is the amount of clean fibre that is expected when a delivery of raw wool is processed. It is reported as a percentage mass of raw wool prior to processing, or as clean mass in kilograms. While it is not defined as an individual variable within the model, it is included through the calculation of Australian on-floor clean (ACOF) price, which is clean price divided by yield multiplied by one hundred (David Cother, pers. comm., 2006).

Of the measured characteristics, lot weight is the least important to the purchase decision, though of appreciable concern to the growing decision (Vizard and Hansford 1999). Weight of a lot is expressed in kilograms, and includes all bales present in the lot. As a consequence, bigger lots will have a higher net weight than smaller lots. A lot is any number of bales of wool of a similar mass and dimension, prepared for sale as a single package in accordance with accepted industry practices.

5.3.2 Non-measured

A number of non-measured characteristics are believed to have an impact on the pricing decision for a given lot. These factors were incorporated into the model as dummy variables, registering one if present and zero if not (Gujarati 2006 p.109).

Weaner fleeces are typically shorter, finer and weaker than adult wool, and there is likely to be a price differential between the two fleece types. A dummy variable was used to indicate weaner from adult fleeces.

Mixed lots are perceived to contain a greater degree of inherent variation which may lead to a down-grading of a lot by the buyer (David Cother, pers. comm., 2006). Methods of preparation other than normal classing procedures can be divided into bulkclassed lots or interlots.

A bulkclassed lot is composed of bales that contain wool that is blended from various sources, from the one country of origin. The most common practice is for brokers to combine bales from several growers to make one larger line which reduces the transaction and administrative costs associated with selling wool. An interlot is a lot of raw wool that is made up of bales that are matched by growers prior to testing and sale. These will typically be from different clips, but are not sufficiently large to build a line individually.

The two fleece contaminants were included in the model for different reasons. While colour is known to have an impact on processing costs, particularly at the dyeing stage (Turk 1993), branding contamination is not as well-quantified, although it has long been recognised as a problem (Lipson 1951b, 1951a; Rottenbury *et al.* 1983). The presence of branding contamination, R_i, was examined due to current industry concerns about discount that processors' give to affected lots.

Presence of colour, H_i, represents considerable scouring costs to processors. It is difficult to visually assess greasy wool visually for this attribute as the amount of colour that is either permanent or scourable is unknown until the wool is scoured (Turk 1993).

Generally, though, it is expected that the presence of colour will result in increasing discounts with increasing severity.

Sales take place in Melbourne, Fremantle, Newcastle, Sydney, or Launceston. Dummy variables were used to indicate location, with Melbourne as the base. Each sale centre is denoted as one if present and zero if not, relative to Melbourne. The inclusion of a variable for sale location attempts to account for regional market variation. The construction and differentials observed in the Northern, Southern and Western Market Indicators for clean price demonstrate the variability in prices across regions.

A seasonal dummy was also included, with Quarter 1 as the base. The season was analysed on a quarterly basis, starting at the beginning of the selling season, denoted as Quarter 1 (July, August, September). A large fall in prices was observed in December 2005 resulting in the expectation that lots sold in Quarter 2 (October, November, December) should receive a discount relative to Quarter 1. The market recovered in Quarter 3 (January, February, March), before softening slightly in Quarter 4 (April, May, June).

It is also expected that storage centre will influence price, and so dummy variables for storage centre were included in the model. There are considerably more storage centres than selling centres, most located in regional areas. The largest stores, however, are found close to selling centres, with Fremantle, used as the base, storing the largest volume of bales.

The style of a fleece is a subjective appraisal of the overall look and feel of a lot. It is included because, although there are persuasive arguments against its use as a basis for purchase (Scrivener *et al.* 1999; Vizard and Hansford 1999), it is perceived as continuing to influence prices paid, especially for lower styles (Style 1, superior, and Style 2, choice) (Australian Wool Exchange (AWEX) 2002).

5.3.3 Model for estimation of influences on the price of Merino fleece wool

$$\boldsymbol{lnACOF_i = \alpha_0 + \beta_1 lnMICRON_i + \beta_2 lnLENGTH_i + \beta_3 lnSTRENGTH_i + \beta_4 lnWEIGHT_i + \beta_5 VMB_i + \beta_6 POBM_i + \delta_1 WEANER_i + \delta_2 CLASSED_i + \delta_3 R_i + \delta_4 H_i + \delta_5 LOCATION_i + \delta_6 Q_i + \delta_7 STORAGE_i + \delta_8 S_i + e_i} \quad (5.2)$$

where:

$lnACOF_i$:	is the log of price of lot number *i* (c/kg clean);
α_0:	is the constant term;
$lnMICRON_i$:	is the log of the fibre diameter of lot *i* (micron);
$lnLENGTH_i$:	is the log of the staple length of lot *i* (millimetres);
$lnSTRENGTH_i$:	is the log of the staple strength of lot *i* (ktex/N);
$lnWEIGHT_i$:	is the weight of lot *i* (kg/lot);
VMB_i:	is the vegetable matter base of lot *i* (percentage by weight of greasy wool);
$POBM_i$:	is the midpoint breakage of staples sampled in lot *i* (percentage of staples tested);
$WEANER_i$:	is a dummy variable for adult or weaner fleece;
$CLASSED_i$:	is a dummy variable for whether lot *i* is classed as an interlot, or bulkclassed;
R_i:	is a dummy variable for branding presence;
H_i:	is a dummy variable for the presence of unscourable colour;
$LOCATION_i$:	is the selling centre, where lot *i* was sold;
Q_i:	is a dummy variable for the season in which lot *i* was sold;
S_i:	is the overall style of lot *i*;
$STORAGE_i$:	is the storage centre, where lot *i* was stored; and
e_i:	is the error term.

5.4 Concluding comments

The hedonic model is to be estimated using a combination of quantitative and qualitative variables. The quantitative variables are measured objectively by AWTA and are those most commonly measured according to industry practice. They are fibre diameter, staple length and strength, midpoint breakage, vegetable matter content, and lot weight. Non-measured characteristics include those appraised subjectively by brokers and AWEX, namely, lot contamination (colour and branding) and style. Additionally, there are variables included for those attributes that, although not inherent within the fleece or fibre, are considered to influence the price paid by buyers. These include fleece type, methods of clip preparation, sale location, storage centre and quarter of sale.

Data was drawn from the extensive database of AWEX for the 2005-06 selling season. The original population of 232 209 lots was divided into four categories based on fibre diameter, and the associated end use. As a consequence, the four models were superfine, fine, medium and broad. The motivation for this separation was the distinctly different markets and production processes that each micron category is destined for.

Finally, while theory does not dictate a functional form specific to an hedonic mode, to a large extent the data is influential in its determination, which resulted in the use of a double log for, which is also useful for its ability to interpret results as constant elasticities of demand, which is relative, rather than absolute, concept.

6 Empirical results

Four distinct markets were analysed based on fibre diameter and end use. Given the discrete nature of each market, different attributes were evaluated for each model. The superfine market had the greatest overall explanatory power and fibre diameter was the most significant property affecting the clean price of a lot in all models. Lot contamination, including vegetable matter, brands and unscourable colour caused substantial price discounts.

6.1 Analysis of results

Overall, the signs and magnitudes of coefficients were consistent with previous studies (Angel *et al.* 1990; Beare and Meshios 1990; Gleeson *et al.* 1993; Hansen and Simmons 1995; Simmons and Hansen 1997). Four models were estimated: superfine, fine, medium, and broad, the results of which are displayed in Tables 6-1 to 6-4, , and, the premia and discounts resulting from various characteristics are displayed in the Appendix in Tables 9-1 to 9-4. All four models are highly significant, with very high F-statistics. The adjusted R^2 for the superfine, fine and broad models are high for a model using cross-sectional data, while that estimated for the medium model is considered reasonable.

As expected, fibre diameter was the most important influence on the buying decision, attracting the greatest discount for micron above the average. Substantial vegetable matter presence also resulted in a large change in the magnitude of the coefficient, as did medium to heavy branding and colour contamination. Lots sold in October, November and December 2005 also attracted discounts compared to Quarter 1. Increasing staple length and strength represented a premium paid to growers, and in the superfine model, choice and superior style fleeces attracted a very large premium relative to inferior styles.

6.1.1 Comparison of the overall models

The overall explanatory power was greatest for the superfine model, with an R^2 of 0.73, and F-statistic of 6521.36. For the fine model, 56 per cent of variation in clean price was explained by the included characteristics, while for medium wools the R^2 was 0.39. The F-statistics for these models were 2416.00 and 1113.59 respectively. The R^2 rose slightly to 0.47 for the broad model, although the F-statistic fell to 302.92. While these R^2 results are not as high as that obtained by Hansen and Simmons (1995; 1997), this may be because of the way in which the samples were deconstructed for estimation purposes. Similarly, the R^2 obtained by Gleeson *et al.* (1993) was high, but this was because their specification was based on specific, rather than all, styles. Lots with high vegetable matter content and poor colour were also excluded.

6.1.2 Measured characteristics

6.1.2.1 Fibre diameter

Consistent with expectations, the findings of the superfine and fine models support the presumption that clean price is very responsive to small changes in fibre diameter, and demand for a lot, reflected by its value, will react in a strongly negative manner to increases in micron across the micron category.

The magnitude of the coefficient for fibre diameter in the superfine model shows that clean price will fall 2.61 per cent for a one per cent increase in micron, on average, indicating that wool within the superfine category is very price elastic. The magnitude of this result translates into a discount of 151.70c/kg clean received for an 18.44 μm lot, relative to the mean 17.39 μm, 1033.89c.kg lot.

Fine wools also exhibited price elasticity with respect to fibre diameter, the magnitude of the coefficient indicating that clean price will fall 2.01 per cent for a one per cent increase in micron. Relative to the mean price of the fine wool category, 773.02c/kg, and mean fibre diameter, 19.59 μm, the discount received for a 20.39 μm lot is 60.30c/kg.

Medium wools, in contrast were price inelastic and generally unresponsive to changes in fibre diameter. Other factors held constant, a one per cent increase in micron results in a 0.45 per cent decline in clean price. This means that, using the mean fibre diameter 20.70 μm as a basis, the price discount for a mean price of 680.47c/kg, is 12.17 cents, considerably less than that for fine wools, and that for superfine fleeces in particular.

Broad wools, on the other hand, were price elastic (elasticity of demand for fibre diameter in broad wools was -1.32), with a discount of 116.28c/kg across the micron range to 28.11 μm based on mean fibre diameter, 24.21 μm and price 643.47c/kg clean.

The divergence in the responsiveness of clean price to a small change in fibre diameter, other factors held constant, is due to the sensitivity of demand for the different wool types in terms of their respective end uses, and the number and type of substitutes available.

While finer wools are preferred for their processing efficiency and superior end product, the trade-off for processors is the cost of this input. If finer wools display a large enough premium compared with average prices, processors are likely to shift their purchasing decisions to a lot of a slightly higher fibre diameter within the micron category to minimise costs.

For medium fleeces, however, the type of processing which this wool category undergoes means that demand is relatively unresponsive across the micron range. Further, there is comparatively little difference in terms of processing efficiency and the quality of the final product. Broader wools, on the other hand, incorporate a much larger micron range. The implications of this are that price will be more responsive to change as fibre diameter approaches the upper end of the category.

6.1.2.2 Staple length and strength

The combined importance of staple length and strength is important in the initial stages of processing, as the mean length of fibres in the top will be dependent on the these two factors (Turk 1993).

Staple length was a significant positive variable in each micron category. The low magnitude of the coefficients shows that demand for staple length is inelastic. Further, elasticity decreases across the micron categories, from 0.48 for superfine wool to 0.15 for medium wool.

Based on mean prices for each micron category, as well as respective average length for each group, premia were attracted in each micron category. These ranged from 11.31c/kg clean for medium wools, to 61.15c/kg clean for superfine fleeces relative to mean clean prices of 680.47c/kg and 1033.89c/kg respectively, for lots 10mm above the mean.

The magnitude of the strength coefficient in all models indicated that demand within each category was inelastic with respect to this characteristic. This implies that staple strength is relatively homogenous throughout each micron category with a low degree of substitutability.

Inspection of the premia accruing to staple strength in excess of 10Nkt from the mean of each micron category (ranging from 33.90Nkt for fine fleeces to 38.88Nkt in the broad category), premia were observed for all categories, the largest being for superfine wools (46.45Nkt wools selling for 71.93c/kg above the average 36.58Nkt lots). For the two categories which were more price inelastic, that is fine and medium lots, the premia for staple strength 10Nkt above the mean were considerably less, 16.31c/kg and 13.74c/kg respectively.

Given the lower propensity for price to respond to small changes in staple strength in these categories, this is consistent with expectations. The results for the broad model indicated that relative to medium wools, broad fleeces were relatively less inelastic, in absolute terms, and the premium accruing to lots 10Nkt in excess of the mean strength, 38.88Nkt was only 10.44c/kg.

6.1.2.3 Weight

Weight was also analysed for all four models, but was found to have no impact in terms of the magnitude of the coefficient. The coefficient was zero in all models, but while it was not significant in the superfine class at any reasonable level, it was in both the fine and medium groups, as well as in broad wools at a one per cent level of significance.

The findings in the broader models suggest that weight is not a factor important in the decision-making of processors.

6.1.2.4 Midpoint breakage and vegetable matter base

Midpoint breakage is related to the strength of the staple, and also affected by the environmental conditions experienced by the sheep. A high proportion of midpoint breaks was expected to result in a substantial discount. This was supported by the results. The variable displayed a significant negative relationship for all models, increasing slightly with increasing micron.

While the magnitude of the coefficient was relatively small, the discounts received in all models were consistent with expectations (David Cother, pers. comm., 2006).

Midpoint breakage had the greatest effect on superfine fleeces as presumed. Although the percentage change resulting from an increase of one percentage point in midpoint breakage was small in relative terms (0.05 per cent), this translated into a discount of 25.53c/kg (compared to mean price 1033.89c/kg) for high levels of midpoint breakage (96.72 per cent relative to medium, 46.72 per cent).

Vegetable matter content, expressed as a percentage of wool base, affects the yield of a fleece, as too high a proportion of vegetable matter in the wool will increase the cost of processing to a point where it cannot be used in the worsted system. This will mean that it will have to be used in woollen processing instead, and this lead to a lower quality product, and hence lower-priced end product.

As a consequence, *a priori* expectations suggested that a sizeable discount would accrue to fleeces containing an above average proportion of vegetable matter. All four models displayed around the same mean vegetable matter content of 1.35 per cent (slightly lower in superfine fleeces at 1.26 per cent). The superfine model estimated a 3.28 per cent fall in clean price given a one per cent increase in vegetable matter, resulting in a discount of 158.79c/kg for lots 5 percentage points above the mean.

The relative effect declined to 1.75 and 1.62 per cent for the fine and medium groups respectively, resulting in respective discounts of 65.31c/kg and 53.36c/kg for lots containing vegetable matter content 5 percentage points above the mean. Coarse wools, on the other hand, received larger discounts relative to medium lots (61.23c/kg discount on the mean price for lots with a vegetable matter base of 6.33 per cent).

Since coarse wools are mainly processed into under-blankets, while medium wools tend to made into bedding and blankets, it is surprising that vegetable matter should have a greater impact on broad than medium wools.

6.1.3 Non-measured characteristics

6.1.3.1 Fleece type

A weaner fleece attracted a 3.65 per cent fall in clean price in the superfine group, resulting in a discount of 37.74c/kg, but this discount was considerably less in the fine and medium classes, where percentage decreases in clean price were 1.65 and 2.50

respectively (with a resultant 12.75c/kg and 17.01c/kg decline in clean price). The discount of 64.41c/kg (a 10.06 per cent fall in clean price for weaner lots relative to adult) for broad fleeces was substantially larger than any of the three finer categories.

Given that weaner fleeces are typically finer, weaker and shorter than adult fleeces, a discount is expected. The magnitude of the discount for broad wools may be due to the lower perceived quality of coarser weaner fleeces, particularly in terms of staple strength and length, as well as the fact that there are relatively few weaners in this category. Since broad wools will be purchased for strength and length over fibre diameter given their end uses, a decline in these factors is likely to result in a substantial discount.

6.1.3.2 Method of preparation

Interlot and bulkclassed lots compared to grower clips typically attract a discount given the greater degree of variability that a processor may expect to find on purchase. The results support this expectation, with the superfine class displaying the largest fall in clean price if a lot is sold as an interlot or bulkclassed rather than being grower-classed (4.83 per cent and 5.08 per cent respectively).

Bulkclassed lots attracted a larger reduction in price, in general than interlots. This is consistent with expectations and may be explained by the fact that while interlots originate from the same property, but different clips, bulkclassed lots tend to be sourced from several properties, resulting in a higher risk of variability in characteristics within a lot.

This leads to a slightly greater discount being paid to the bulkclassed lots, for superfine models this being 50.04c/kg and 52.63c/kg relative to the mean superfine price of 1033.89c/kg. The responsive of clean price to interlots fell as fibre diameter increased. The discount attracted for bulkclassed lots in the broad category were greater than those for medium wools (24.26c/kg relative to 643.47c/kg for broad wools, and 23.68c/kg relative to 680.47c/kg for medium wools).

6.1.3.3 Lot contamination

The presence of branding and its impact on clean price has not been examined comprehensively to date. However, this warrants analysis given that processors are observed to react adversely to branding contamination, particularly downstream of top-making. Turk (1993) notes that incorrectly used brands are a problem because the colours are difficult or impossible to scour out, especially when used with solvents.

In general, medium level branding attracted the largest negative response in clean price. The largest response occurred for superfine wools containing medium level branding. For these lots, the medium level contamination resulted in a 10.63 per cent decline in clean price. Relative to the mean price of 1033.89c/kg, this meant a discount of 110.12c/kg clean. In contrast, light contamination in medium wools led to a 0.63 per cent fall in price and 4.29c/kg discount relative to mean price of 680.47c/kg.

Unscourable colour presented a problem in fine and medium wools, but was not present in sufficient numbers to analyse in either the superfine or broad categories. Colour is an issue because whiter wools are preferred by spinners for their superior ability to hold dye, with whiter wools being associated with brighter colours after dying (Turk 1993).

For the two models examined, the findings suggest that colour has a significant negative impact on clean price. Fine wool lots with colour contamination are discounted between 8.97c/kg for light colour to 53.34c/kg for heavy colour relative to the mean class clean price, 773.02c/kg, while medium lots are more severely discounted for heavy colour contamination than for branding contamination (49.88c/kg and 74.92c/kg) respectively).

6.1.3.4 Sale location

Location of sale has an effect on clean price for superfine lots sold in Sydney, Newcastle, and Launceston. Sales held in Fremantle, however, were not significant. Relative to Melbourne, wool auctioned at the three centres were higher compared to Melbourne. Wool sold in Newcastle received the largest positive price differential, 8.31 per cent above those in Melbourne on average.

The higher price received for wool sold in Newcastle may be attributed to the role of expectations and the proximity of the centre to the superfine and fine wool-growing areas of the Northern Tablelands. In comparison, buyers in Western Australia expect to see overall lower quality fleeces. Relative to the mean price, 1033.89c/kg, Newcastle-auctioned lots receive a premium of 86.09c/kg on average. Lots sold in Sydney and Launceston also receive clean prices in excess of Melbourne prices (2.50 per cent and 2.71 per cent respectively).

Launceston, stages only one auction a year, which may involve the sale of better Tasmanian fleeces, resulting in a slight upward bias in buyer expectations. Sydney, on the other hand, would be more likely to sell a greater proportion of superfine fleeces given its proximity to the other traditional fine-wool regions of the Central and Southern Tablelands of New South Wales, also resulting in greater expectations of overall fleece quality relative to those in Melbourne.

6.1.3.5 Quarter of sale

The quarter in which a lot was sold is important, and could be seen as a proxy for external price movements, including exchange rate fluctuations and seasonal factors, over the 2005-06 selling season.

These findings are consistent with observation of the Australian Eastern Market Indicator (EMI) (see Figure A-1 in Appendix) over 2005-06. While Australian wool prices were downward inclined in the first two quarters, they recovered in the latter two quarters to end the season at a similar level to which they started.

6.1.3.6 Storage location

Storage location was also examined for fine and medium wools, relative to Fremantle which warehouses the largest quantity of bales. Results for this variable were not very conclusive, with a number of locations being insignificant in both the fine and medium models. Storage centre did appear to have a slightly greater effect on fine wools, however, excluding New South Wales centres other than Newcastle, and Katanning in Western Australia.

The insignificance of a number of storage centres in this group, as well as the relatively small impact on price of many of the centres, indicates that this is probably not as important an influence on clean price as some of the other variables. This can be seen through observation of the higher coefficient of determination for the superfine model which does not include centre of storage as a regressor, yet displays greater overall explanatory power than either of the models which do incorporate it.

6.1.3.7 Style

While all lots sold through the auction system by AWEX receive an appraised style, either choice (1), superior (2), spinners (3), best (4), good (5), average (6) or inferior (7), the visual assessment of fleeces has been called into question given that it has been observed that buyers tend to purchase based on direct measurements, and their own, rather than someone else's, subjective opinion (Gleeson *et al.* 1993).

The visual appraisal of fleeces, or the overall style, was assessed for the superfine model relative to inferior style. It was expected that all other styles would attract a premium above the price received for an inferior style lot, and this was supported by the findings of the model.

While styles other than inferior style certainly attract a premium, this is more likely to be due to the measured attributes that comprise the higher quality lots rather than the subjective appraisal. Evidence has been found to suggest that superfine fleeces were identified to receive premia and discounts in the raw wool market based on visual appearance.

6.2 Concluding comments

Overall, the model with the greatest explanatory power was superfine, which also attracted the greatest premia and discounts for the attributes included. This implies that the characteristics examined explain the majority of variation in the clean price of a lot and that the impact of unassessed external factors is relatively trivial.

Fibre diameter is the attribute most important to the purchase decision, particularly for finer wools. This is due to the highly elastic nature of demand for fibre diameter across a micron category. Lot contamination, from vegetable matter, brands and unscourable colour resulted in considerable discounts where present.

Table 6-1: OLS results, superfine model.
Table 6-2: OLS results, fine model.

OLS Results: Superfine Model

Variable	Coefficient	Std. Error	t-Statistic	Prob	% Change
Intercept	11.15	0.04	251.31	0.00	
MEASURED ATTRIBUTES					
LnMicron	-2.61	0.02	-172.07	0.00	
LnLength	0.48	0.00	114.07	0.00	
LnStrength	0.30	0.00	142.79	0.00	
LnWeight	0.00	0.00	-1.23	0.22	
POBM	0.00	0.00	-25.89	0.00	-0.05
VMB	-0.03	0.00	-75.06	0.00	-3.28
NON-MEASURED ATTRIBUTES					
Fleece Type (Relative to Adult)					
Weaners	-0.04	0.00	-33.71	0.00	-3.65
Method of Preparation (Relative to Grower-Classed)					
Interlot	-0.05	0.00	-17.59	0.00	-4.83
Bulkclassed	-0.05	0.00	-29.53	0.00	-5.08
Branding (Relative to No Contamination)					
R1	-0.02	0.01	-2.72	0.01	-1.81
R2	-0.11	0.01	-7.69	0.00	-10.63
R3	-0.09	0.02	-4.47	0.00	-8.22
Sale Location (Relative to Melbourne)					
Sydney	0.02	0.00	25.23	0.00	2.50
Newcastle	0.08	0.00	48.37	0.00	8.31
Launceston	0.03	0.00	8.25	0.00	2.71
Fremantle	0.00	0.00	-0.59	0.56	-0.10
Quarter of Sale (Relative to Quarter 1)					
Q2	-0.06	0.00	-42.40	0.00	-5.35
Q3	0.08	0.00	57.32	0.00	7.94
Q4	0.08	0.00	63.58	0.00	8.07
Style (Relative to Style 7 (Inferior))					
S1	0.88	0.05	16.57	0.00	139.74
S2	0.61	0.03	21.12	0.00	83.28
S3	0.36	0.01	24.78	0.00	43.78
S4	0.12	0.01	9.86	0.00	12.69
S5	0.09	0.01	7.62	0.00	9.65
S6	0.07	0.01	5.99	0.00	7.63

R-squared	0.73	**F-statistic**	6521.36
Adjusted R-squared	0.73	**Prob(F-statistic)**	0.00

OLS Results: Fine Model

Variable	Coefficient	Std. Error	t-Statistic	Prob	% Change
Intercept	11.38	0.03	336.27	0.00	
MEASURED ATTRIBUTES					
LnMicron	-2.01	0.01	-178.01	0.00	
LnLength	0.19	0.00	66.46	0.00	
LnStrength	0.11	0.00	86.88	0.00	
LnWeight	0.00	0.00	3.40	0.00	
POBM	0.00	0.00	-21.86	0.00	-0.03
VMB	-0.02	0.00	-43.18	0.00	-1.75
NON-MEASURED ATTRIBUTES					
Fleece Type (Relative to Adult)					
Weaners	-0.02	0.00	-12.01	0.00	-1.65
Method of Preparation (Relative to Grower-Classed)					
Interlot	-0.04	0.00	-21.39	0.00	-3.64
Bulkclassed	-0.04	0.00	-25.59	0.00	-3.95
Branding (Relative to No Contamination)					
R1	-0.01	0.00	-3.13	0.00	-0.97
R2	-0.06	0.01	-4.93	0.00	-5.99
R3	-0.09	0.01	-6.91	0.00	-8.88
Unscourable Colour (Relative to No Contamination)					
H1	-0.01	0.00	-11.89	0.00	-1.16
H2	-0.03	0.00	-6.44	0.00	-2.49
H3	-0.07	0.00	-48.44	0.00	-6.90
Sale Location (Relative to Melbourne)					
Sydney	0.03	0.00	13.24	0.00	2.60
Newcastle	0.03	0.00	10.46	0.00	2.94
Launceston	0.09	0.00	30.27	0.00	9.36
Fremantle	0.02	0.00	7.24	0.00	2.09
Quarter of Sale (Relative to Quarter 1)					
Q2	-0.08	0.00	-142.22	0.00	-7.77
Q3	0.04	0.00	48.25	0.00	3.83
Q4	0.04	0.00	40.99	0.00	4.48
Storage Location (Relative to Fremantle)					
Adelaide	0.02	0.00	5.32	0.00	1.70
Brisbane	0.01	0.00	3.33	0.00	1.05
Geelong	0.04	0.00	14.20	0.00	4.23
Goulburn	0.03	0.00	10.24	0.00	3.17
Melbourne1	0.04	0.00	12.40	0.00	3.97
Newcastle1	0.02	0.00	6.45	0.00	2.19
NZ	0.06	0.00	17.09	0.00	6.20
OtherNSW	0.00	0.00	1.49	0.14	0.44
OtherVic	0.06	0.00	14.19	0.00	5.77
OtherSA	0.03	0.00	10.63	0.00	3.48
OtherWA	0.00	0.01	0.04	0.97	0.03
Sydney1	0.00	0.00	0.67	0.50	0.21
Tas	0.03	0.00	8.42	0.00	2.93

R-squared	0.56	**F-statistic**	2416.00
Adjusted R-squared	0.56	**Prob(F-statistic)**	0.00

Table 6-3: OLS results, medium model.
Table 6-4: OLS results, broad model.

OLS Results: Medium Model

Variable	Coefficient	Std. Error	t-Statistic	Prob	% Change
Intercept	6.98	0.02	301.22	0.00	
MEASURED ATTRIBUTES					
LnMicron	-0.45	0.01	-64.76	0.00	
LnLength	0.15	0.00	57.63	0.00	
LnStrength	0.08	0.00	72.48	0.00	
LnWeight	0.00	0.00	8.59	0.00	
POBM	0.00	0.00	-25.21	0.00	-0.03
VMB	-0.02	0.00	-43.67	0.00	-1.62
NON-MEASURED ATTRIBUTES					
Fleece Type (Relative to Adult)					
Weaners	-0.03	0.00	-7.51	0.00	-2.50
Preparation Type (Relative to Grower-Classed)					
Interlot	-0.04	0.00	-29.75	0.00	-3.48
Bulkclassed	-0.04	0.00	-27.83	0.00	-3.54
Branding (Relative to No Contamination)					
R1	-0.01	0.00	-2.92	0.00	-0.63
R2	-0.09	0.01	-9.16	0.00	-8.58
R3	-0.08	0.02	-5.03	0.00	-7.33
Unscourable Colour (Relative to No Contamination)					
H1	-0.01	0.00	-8.61	0.00	-0.65
H2	-0.04	0.00	-9.96	0.00	-3.65
H3	-0.12	0.00	-108.44	0.00	-11.01
Sale Location (Relative to Melbourne)					
Sydney	0.00	0.00	2.60	0.01	0.40
Newcastle	0.00	0.00	0.08	0.93	0.02
Launceston	0.02	0.00	3.60	0.00	1.81
Fremantle	-0.01	0.00	-7.84	0.00	-1.34
Quarter of Sale (Relative to Quarter 1)					
Q2	-0.08	0.00	-147.43	0.00	-7.53
Q3	0.00	0.00	3.76	0.00	0.22
Q4	-0.02	0.00	-23.51	0.00	-1.58
Storage Location (Relative to Fremantle)					
Adelaide	-0.01	0.00	-4.94	0.00	-0.88
Brisbane	0.00	0.00	-0.16	0.87	-0.03
Geelong	0.00	0.00	-1.36	0.17	-0.24
Goulburn	0.00	0.00	-0.06	0.95	-0.02
Melbourne1	0.00	0.00	-2.09	0.04	-0.43
Newcastle1	0.00	0.00	0.13	0.90	0.03
NZ	0.01	0.01	2.29	0.02	1.23
OtherNSW	-0.01	0.00	-5.54	0.00	-1.04
OtherVic	0.01	0.00	1.86	0.06	0.60
OtherSA	-0.01	0.00	-2.62	0.01	-0.55
OtherWA	0.01	0.00	4.23	0.00	1.51
Sydney1	-0.02	0.00	-7.38	0.00	-1.60
Tas	-0.01	0.00	-2.34	0.02	-0.80

R-squared	0.39	**F-statistic**	1113.59
Adjusted R-squared	0.39	**Prob(F-statistic)**	0.00

OLS Results: Broad Model

Variable	Coefficient	Std. Error	t-Statistic	Prob	% Change
Intercept	9.51	0.14	68.03	0.00	
MEASURED ATTRIBUTES					
LnMicron	-1.32	0.04	-29.75	0.00	
LnLength	0.21	0.01	21.08	0.00	
LnStrength	0.07	0.00	15.25	0.00	
LnWeight	0.00	0.00	2.48	0.01	
POBM	0.00	0.00	-9.68	0.00	-0.04
VMB	-0.02	0.00	-16.18	0.00	-1.98
NON-MEASURED ATTRIBUTES					
Fleece Type (Relative to Adult)					
Weaners	-0.10	0.04	-2.66	0.01	-10.01
Preparation Type (Relative to Grower-Classed)					
Interlot	-0.04	0.00	-9.49	0.00	-3.77
Bulkclassed	-0.04	0.00	-9.25	0.00	-3.62
Sale Location (Relative to Melbourne)					
Sydney	0.02	0.00	5.65	0.00	1.56
Newcastle	0.00	0.01	-0.27	0.79	-0.25
Launceston	-0.03	0.00	-10.30	0.00	-3.33
Fremantle	-0.01	0.00	-4.87	0.00	-1.08
Quarter of Sale (Relative to Quarter 1)					
Q2	-0.06	0.00	-36.63	0.00	-6.10
Q3	0.01	0.00	5.55	0.00	1.28
Q4	-0.02	0.00	-7.70	0.00	-1.58

R-squared	0.47	**F-statistic**	302.92
Adjusted R-squared	0.47	**Prob(F-statistic)**	0.00

7 Policy implications and conclusions

The assumptions of an hedonic model are based on the market for raw wool being perfectly competitive. While this assumption is valid on the supply side, there is some suggestion of buyer concentration (Hansen and Simmons 1995; Simmons and Hansen 1997). As a consequence, implications extracted from the results need to take this into consideration. Additionally, inferences can be drawn from the variables analysed in the study only, and these focus on demand-side factors.

Within the constraints of the underlying theoretical framework, the implicit values of attributes estimated are important to wool growers, as well as industry organisations such as AWEX and broking firms, so that resources can be allocated efficiently. Knowledge of these values indicates which characteristics should be considered in determining action to be taken along the supply chain (Ahmadi-Esfahani and Stanmore 1994). This is useful because one of the main difficulties associated with wool production is the problem of multi-quality requirements.

Investment along the wool marketing chain should be directed to the quality attributes which have the greatest market value. According to the analysis, these are low fibre diameter, staple length, staple strength, and style. However, the relationships of these characteristics with other factors, such as weight and non-wool characteristics also need to be considered.

Currently, price signals provided by the wool marketing system indicate that finer micron wools are preferred within the superfine, fine and broad markets. However, there has been industry concern about over-supply of superfine and fine wools (Woolmark Business Intelligence 2006). The results of this study show, however, that these markets are demanding wool of lower fibre diameter. As a consequence, wool growers should continue to produce finer wools and to focus breeding programs on minimising fibre diameter to maximise profits.

Production of wool with fibre diameter may not be profitable for all growers. The main objective of the grower is to maximise net profits from producing wool and thus offset any effect that focusing on fibre diameter has on staple strength and meat attributes such as body weight (Vizard and Hansford 1999).

Finer wools can be processed more efficiently into fabric and garments demanded at the retail level (Whitely 1987). The large premia paid for lots of lower fibre diameter within the finer markets support this presumption and indicate that there is an incentive for processors to invest in research and development to encourage production of finer micron wools without compromising staple strength.

This would benefit the industry as a whole, because it would enable grower funds currently directed to AWI for similar purposes, to be redirected into other projects, such as product marketing (Australian Wool Innovation (AWI) 2006b). The other advantage is that investment by wool processors may increase dialogue along the wool supply chain. This enhances the probability that retail demand will be met and the efficiency along the wool marketing chain improved.

Strategic investment by wool processors also provides a role for AWEX and wool broking firms to act as intermediaries between growers and processors. With their access to key personal information and their ability to communicate with both growers and processors with relative ease, the costs of investment are diminished.

The results of the study also indicate that lot contamination, including brands, unscourable colour and vegetable matter, represents a sizeable cost to processors. Knowledge of market valuations of wool attributes appears essential for developing effective marketing strategies. The large discounts accruing to contaminated lots signal that an increased emphasis needs to be placed on the importance of effective clip preparation and classing techniques to alleviate this problem.

The presence of branding fluid has long been known to be a problem (Lipson 1951a, 1951b). The findings of this study imply that the magnitude of this problem needs to be reinforced along the wool supply chain. Available options need to be assessed to evaluate which is likely to be the most efficient outcome. Two possible solutions include directing scarce grower funds into research and development in this area, or focusing on educating growers to avoid branding on the main fleece and to class according to the industry code of practice. The political friction associated with determining where funding is directed implies that in the short term, the dissemination of information is likely to be the more viable option.

Medium to high levels of vegetable matter represent a negative price influence for wool in all markets, and this is demonstrated by the sizeable discounts received for this attribute. This is also a form of contamination which is recognised to reduce processing efficiency (Ford and Cottle 1993).

Although the type and concentration of vegetable matter tends to vary seasonally, it may be reduced with relative ease if it is possible to adjust the timing of shearing and crutching to minimise its presence in fleece wool. Sound farm management practices, including integrated weed management, are also likely to reduce the incidence of some types, and create benefits that may be realised by non-wool enterprises at the grower level.

Reducing lot contamination involves increasing awareness along the supply chain so that information is fed back to growers. It is an important consideration because the discounts received by contaminated lots indicate that it adversely affects processing, which has an impact on the quality of the product that can be sold to the final consumer.

The dissemination of this information and potential solutions to the problem creates a series of tasks along the marketing chain, from brokers to AWEX to processors. The cost of the contamination to processors suggests that there is an incentive for them to invest in problem reduction.

These funds can then be used by AWEX to reinforce the importance of following objective clip preparation practices and the industry code of practice to produce a commodity that is demanded by buyers. In conjunction with individual broking firms, which have the advantage of personal relationships with clients, greater awareness needs to be created at the grower level.

Growers will only adopt suitable practices aimed at meeting raw wool specifications of processors if the costs, implicit and explicit, are perceived to be exceeded by the returns. If changing breeding plans to favour lower fibre diameter and altering farm management practices to reduce fleece contamination are perceived to compromise potentially greater returns from other sources, then these practices are less efficient and will not be undertaken.

This issue is of topical concern because of the profitability of other farm enterprises relative to wool. Concentrating investment of scarce farm funds into wool implies that these capital resources are then unavailable to be used in other areas which may yield greater financial returns. As a result, for the necessary improvements to be made, the solution needs to be inexpensive relative alternative investments, as well as being profitable.

Ultimately, however, investment in reducing fibre diameter and lot contamination along the marketing chain is dependent on primary demand for woollen products. If there is lack of demand at this level, then the cost of increasing efficiency or productivity of current wool-growing practices may not be justified.

By signalling to the market that lower fibre diameter is preferred, processors are indicating that there is a demand for woollen garments manufactured using finer micron wools. This implies that funds should be directed to consumers to increase their awareness of the advantages of superfine and fine wools. Marketing strategies should be directed at reducing the perception that wool is prickly and uncomfortable, and promoting the fact that wool is a high quality, natural fibre. The funding for such a campaign needs to be provided by both industry bodies, such as AWI and the Woolmark Company, on behalf of wool growers who want to sell their raw product, but also from wool processors who want to sell their manufactured product.

By sharing the cost among processors and grower bodies, the burden on the Australian wool industry is reduced. While Australia dominates the global raw wool market, the majority of processors are of European and Chinese origin. Thus the risk of such an investment in advertising and promotion is reduced, and the benefits are shared between the two sectors of the marketing chain.

This study analysed the role that certain raw wool properties play in determining the price paid for lots sold in Australia. The implicit values reported have important implications for wool growers, breeders, processors, marketers and policy makers along the wool supply chain. However, more specific analyses of the costs and benefits of related factors are required to broaden the scope of the conclusions regarding objective clip preparation, breeding programs and advertising and promotion.

Finally, a more comprehensive study that utilises data over a number of selling seasons, perhaps since deregulation, would increase the plausibility of the findings. This would be particularly beneficial for developing marketing strategies aimed at specific end user groups.

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A Appendix

Table A-1: Premia and discounts relative to mean measurements, superfine model.
Table A-2: Premia and discounts relative to mean measurements, fine model.

Superfine Model
Premia and Discounts Relative to Mean Price (1033.89c/kg clean)

	Premium	Discount
Measured Attributes		
Micron (18.44µm relative to 17.37µm)		-151.70
Length (87.02mm relative to 77.23mm)	61.15	
Strength (46.45Nkt relative to 36.58Nkt)	71.93	
Weight		
POBM (96.72% relative to 46.72%)		-25.53
VMB (6.26% relative to 1.26%)		-158.79
Non-Measured Attributes		
Weaners		-37.74
Interlot		-50.04
Bulkclassed		-52.63
R1		-18.75
R2		-110.12
R3		-85.16
Sydney	25.90	
Newcastle	86.09	
Launceston	28.07	
Fremantle		-1.04
Q2		-55.42
Q3	82.26	
Q4	83.60	
S1	1447.66	
S2	862.76	
S3	453.55	
S4	131.46	
S5	99.97	
S6	79.04	

Fine Model
Premia and Discounts Relative to Mean Price (773.02c/kg clean)

	Premium	Discount
Measured Attributes		
Micron (20.39µm relative to 19.59µm)		-60.30
Length (95.86mm relative to 84.92mm)	16.31	
Strength (43.95Nkt relative to 33.93Nkt)	22.42	
Weight		
POBM (98.94% relative to 48.94%)		-11.51
VMB (6.43% relative to 1.43%)		-65.31
Non-Measured Attributes		
Weaners		-12.75
Interlot		-28.14
Bulkclassed		-30.53
R1		-7.50
R2		-46.30
R3		-68.65
H1		-8.97
H2		-19.25
H3		-53.34
Sydney	20.10	
Newcastle	22.73	
Launceston	72.36	
Fremantle	16.16	
Q2		-60.06
Q3	29.61	
Q4	34.63	
Adelaide	13.14	
Brisbane	8.12	
Geelong	32.70	
Goulburn	24.51	
Melbourne1	30.69	
Newcastle1	16.93	
NZ	47.93	
OtherNSW	3.40	
OtherVic	44.60	
OtherSA	26.90	
OtherWA	0.23	
Sydney1	1.62	
Tas	22.65	

Table A-3: Premia and discounts relative to mean measurements, medium model.
Table A-4: Premia and discounts relative to mean measurements, broad model.

Medium Model
Premia and Discounts Relative to Mean Price (680.47c/kg clean)

	Premium	Discount
Measured Attributes		
Micron (22.56μm relative to 21.70μm)		-12.17
Length (99.80mm relative to 89.44mm)	11.31	
Strength (44.23Nkt relative to 34.49Nkt)	13.74	
Weight		
POBM (97.35% relative to 47.35%)		-10.13
VMB (6.38% relative to 1.38%)		-53.36
Non-Measured Attributes		
Weaners		-17.01
Interlot		-23.68
Bulkclassed		-24.09
R1		-4.29
R2		-58.38
R3		-49.88
H1		-4.42
H2		-24.84
H3		-74.92
Sydney	2.72	
Newcastle	0.14	
Launceston	12.32	
Fremantle	9.12	
Q2		-51.24
Q3	1.50	
Q4		-10.75
Adelaide		-5.99
Brisbane		-0.20
Geelong		-1.63
Goulburn		-0.14
Melbourne1		-2.93
Newcastle1	0.20	
NZ	8.37	
OtherNSW		-7.08
OtherVic	4.08	
OtherSA		-3.74
OtherWA	10.28	
Sydney1		-10.89
Tas		-5.44

Broad Model
Premia and Discounts Relative to Mean Price (643.47c/kg clean)

	Premium	Discount
Measured Attributes		
Micron (28.11μm relative to 24.21μm)		-116.28
Length (101.95mm relative to 92.29mm)	13.64	
Strength (48.88Nkt relative to 38.88Nkt)	10.44	
Weight		
POBM (96.50% relative to 46.50%)		-12.74
VMB (6.33% relative to 1.33%)		-61.23
Non-Measured Attributes		
Weaners		-64.41
Interlot		-24.26
Bulkclassed		-23.29
Sydney	10.04	
Newcastle		-1.61
Launceston		-21.43
Fremantle		-10.55
Q2		-39.25
Q3	8.24	
Q4		-10.17

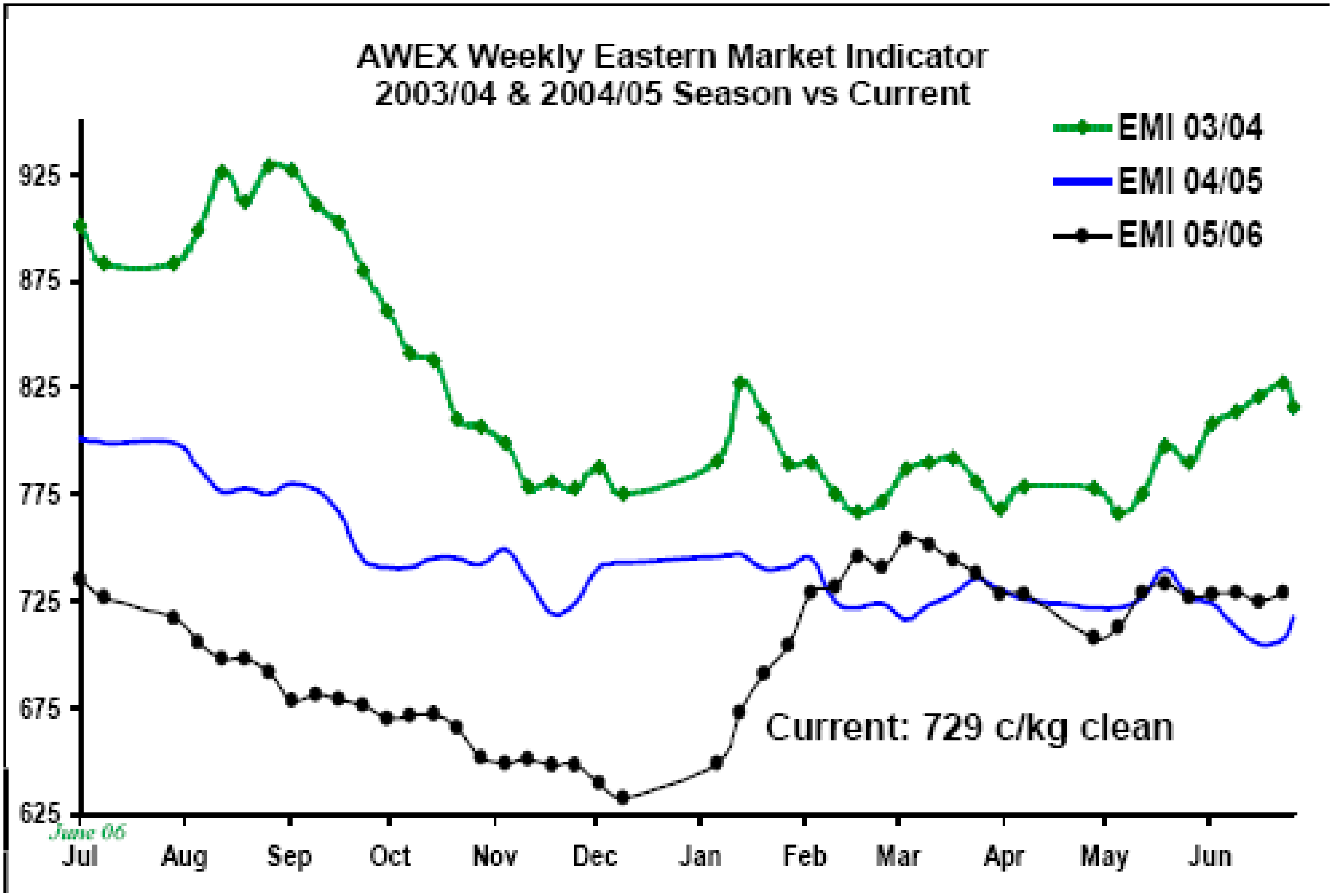

Figure A-1: Eastern Market Indicator, 30 June 2006 (source: Landmark 2006).