1. INTRODUCTION

Australia is the worlds' second largest exporter of beef, exporting 66% (DAFF 2012) of the 2.1 million tonnes (ABS 2012) of beef and veal produced in 2011-2012 to over 100 countries (DAFF 2012) around the world. Whilst Australia only accounts for 4% of the worlds beef supply (MLA 2012) compared to the United States of America with 20%, and Brazil with 16%, Australia provides 16% of the global export market for beef (Anonymous 2012).

The development of the Meat Standards Australia (MSA) grading model (Thompson 2002, Polkinghorne *et al.* 2008b) represents the best existing total quality management approach for improving beef quality and palatability (Smith *et al.* 2008). The unprecedented collaboration of scientists and industry was formally recognised by the broader scientific community, bestowing the "2010 Australian Research Council Eureka Prize for Excellence in Research by an Interdisciplinary Team" (Anonymous 2010). This modeling tool "seeks to predict consumer satisfaction at a cooked portion level" (Polkinghorne and Thompson 2010), moving the beef industry from "describing carcases to describing individual beef meals" (Polkinghorne and Thompson 2010) thereby providing a more accurate description of what the consumer requires and values.

The MSA grading model is detailed by Watson *et al.* (2008b). Briefly, it generates a numerical score for individual cuts by cooking method from a series of commercial inputs describing the animal and its treatments. The numerical score ranges from 0 to 100 for each reported cooking method. This is calculated for each cut of meat, such as knuckle, striploin, topside or tenderloin. The MSA score itself is based on a weighted average of consumer preferences associated with tenderness, juiciness, flavour and overall liking (Watson *et al.* 2008b). It is important to remember that the MSA model is a dynamic tool that should be continually updated as better methods and improved information become available (Watson *et al.* 2008b).

Ultimately it is the consumer's purchasing decision that determines the gross income available for distribution to each participant throughout the beef value chain (Polkinghorne 2006). Unfortunately, payment between participants within the Australian beef value chain are characterised by poor price communication (Gong 2008). Polkinghorne (2006) argues that, "payment and description at each end point of supply have at best, a very poor relationship to consumer satisfaction". In order to address this, it is important to firstly identify the variables from each component of the meat production process, namely on-farm animal characteristics, abattoir processing variables and consumer preparation methods. Understanding the interdependence earlier identified by Butler (1960), Friedlander (1964) and Everitt (1966) has been more thoroughly quantified in recent times by Meat Standards Australia (MSA) and outlined as a Palatability Analysis Critical Control Points (PACCP) pathway by Ferguson *et al.* (1999); Polkinghorne *et al.* (1999), Thompson *et al.* (1999a,b), Thompson (2002), Polkinghorne (2006) and Watson *et al.* (2008b).

The challenge is twofold, firstly, to maintain traceability of knowledge throughout the value chain to the primal when it is in a carton with other primals, so that it may be used as a marketing tool to help differentiate quality and other credence attributes, thereby increasing revenue. Secondly, to relate this information back to the live animal, so that management decisions can be made at the production level to more accurately meet market specifications, effectively allocate resources and reduce costs. By increasing revenue, decreasing costs and more effectively communicating the traits and specifications that enable this to be achieved, the whole supply chain could be optimised (Gheidar Kheljania *et al.* 2007). This should enable the participants of the beef value chain to remain competitive into the future.

The objective of this research was to overlay the PACCP approach to eating quality (Ferguson *et al.* 1999, Polkinghorne *et al.* 1999, Thompson *et al.* 1999a,b) with economic weights, thereby establishing a Financial Analysis Critical Control Points (FACCP) pathway. It is the author's contention that a complimentary financial framework is essential to facilitate effective change throughout the beef value chain. This will improve confidence to provide the long-term financial modelling necessary to secure future investment that will keep beef a competitive source of protein. This is a small but significant step in the progression toward a value based trading system.

Whilst this thesis will only focus on the economic weights associated with carcase yield and quality traits, there is a need to consider their impact on other value chain drivers associated with live animal production and consumer distribution. The common elements of labour inputs, yield changes, packaging, distribution and infrastructure costs are predominantly site specific and require constant monitoring at all segments of the value chain.

The live animal production considerations will likely focus on genetics, reproduction and feed conversion. In addition, the consumer distribution issues will likely focus on traceability, food safety and packaging. This expanded FACCP framework has the potential to provide a more accurate mechanism for appraising the required investments to ensure the beef industry is a competitive source of protein. With some foresight, the construction of this framework will create a synergistic trading environment that will enable participants to grow their businesses sustainably.

1.1 Thesis outline

A review of the relevant literature is presented in Chapter 2. Chapter 3 details the common experimental methods used for the analyses in Chapters 4 and 5. Chapter 4 investigates the most appropriate measure of carcase yield to best represent carcase value. The resultant measure is then used in Chapter 5 to partition the influence of quality and yield traits on carcase value. The results of this research are presented and discussed in detail, as are their interpretation and implications. Conclusions, limitations of the study, further research opportunities and application of the results, are outlined in Chapter 6.

2. LITERATURE REVIEW

Whilst significant research has been performed into all the individual aspects of the beef value chain, it has been problematic to link them all together. The author contends that reproductive efficiency, feed conversion, saleable meat yield percentage (SMY%) and meat quality are the four primary aspects that ensure the long-term sustainability of the beef industry. Selecting animals that satisfy any of these four pillars at the expense of the other will create a constraint at some point in the future that will limit further progress. Whilst it is beyond the scope of this thesis to cover all four aspects, the industry data being analysed in the proceeding analyses can be used to explore the understanding of meat quality and yield. This literature review will focus on how participants currently measure, communicate and value eating quality and SMY% throughout the beef value chain.

The prevailing industry paradigm is that the difficulty and associated costs to achieve individual cut traceability are prohibitive. Therefore, the research and development focus has been on studies that endeavour to predict the quality and yield of the carcase with minimal traceability of individual animals beyond the carcase. Measurements taken on the slaughter floor kill chain and/or at the point of chiller assessment are used in a number of ways, endeavouring to predict the components that will be generated from the carcase. This focus has largely been driven by the now out dated paradigm that beef quality can be judged at the carcase level. We now know that beef quality varies at the primal level and even within the primal, based on the cooking method being used (Polkinghorne *et al.* 2008b).

Given the advances in processing systems, computers and the supporting technology of barcodes and radio frequency identification, a new paradigm of traceability throughout the value chain is becoming apparent. Whilst processing facilities have become larger, more automated and throughput focused to decrease unit overhead costs, they have also maintained or increased the level of traceability. Originally this process was driven by food safety concerns and regulations. Increasingly, it is being driven by recognition of the inherent differences in quality and yield of primals. This traceability will ultimately facilitate the communication of value throughout the supply chain.

The following literature review covers five main areas of discussion.

- Section 2.1 reviews how previous studies have measured muscle, fat and bone proportions.

- Section 2.2 discusses how muscle is currently valued.
- Section 2.3 explores the communication of value signals between supply chain participants.
- Section 2.4 presents a case study.
- Section 2.5 is about integration into the value chain.
- Finally, section 2.6 highlights three opportunities associated with communicating value more effectively.

2.1 Measuring proportions of muscle, fat and bone

There has been a long history of scientific endeavour to effectively characterise and predict the proportions of muscle, fat and bone tissue that are generated when the carcase is boned. Research conducted by Murphey *et al.* (1960) was the basis of the United States Department of Agriculture (USDA) yield grade calculation that is still in use today. Johnson (1996) reviewed previous research outlined in Table 2.1.

Table 2.1: Prediction errors in the estimate of percentages of muscle, fat and saleable beef yield (SBY) (Reproduced from Johnson 1996)

Source	Measurements	Muscle	Fat	SBY
Crouse et al (1975)	CW + FT12 + EMA + KP Fat	N	N	1.79*
Charles (1977)	FT12	2.51	2.98	2.85
Kempster (1978)	Fat Class + CW	N	N	1.84
Johnson and Davis (1983)	FT10 + CW	2.11	3.00	N
	FT12 + CW	2.12	2.70	N
Ball and Johnson (1989)	P8	N	N	2.26
	FT12	N	N	2.14
Ferguson (1989)	P8	2.98	3.10	2.13
	FT12 + CW	2.71	2.45	1.97
Johnson and Ball (1989)	P8 + CW	N	N	1.46

Abbreviations: CW = carcase weight; EMA = eye muscle area; KP fat = kidney + pelvic fat; P8 = fat thickness at rump P8 site; FT10 = fat thickness at 10th rib; FT12 = fat thickness at 12th rib;

* Standard error of estimate of the mean (%)

N = not measured

Various combinations of carcase weight, subcutaneous fat (at 10/12th rib, or P8 or both) and a third regressor were investigated to better explain three measures of carcase yield percentages, namely estimated lean beef yield, carcase meat and saleable beef yield, as the dependent variable. Research performed by Crouse *et al.* (1975) shown in Table 2.1 highlights the regression equation developed by Murphey *et al.* (1960), which was the most accurate of those listed before 1989; hence its use as the basis for the USDA yield grade calculation.

Whilst logic leads us to identify the yield of saleable meat as an important contributor to carcase value, Ball and Johnson (1989) demonstrated a positive correlation between carcase fat percentage and saleable beef yield percentage. Because saleable beef yield percentage was being impacted more by the percentage of fat than the percentage of muscle in the carcase, Johnson (1996) contended it was “likely to be of limited value to genetic improvement”. Instead, Johnson advocated the measures of estimated lean meat yield and particularly carcase beef proposed by Charles (1977) to address confounded comparisons of yield because of the differences in the composition of muscle and fat. In essence this proposal supported earlier calls for “fat-corrected” carcase information by Everitt (1966). Despite these limitations, SMY% has remained the preferred measure of carcase yield.

Other carcase measures to reflect carcase yields have been investigated. Murphey *et al.* (1960) theorised that the percentage of kidney fat might be correlated to the amount of inter-muscular fat. Murphey *et al.* (1960) and Crouse *et al.* (1975) found that subcutaneous rib-fat measured at the 12th rib was the most useful carcase measure to predict yield. Dikeman *et al.* (1998) found that inter-muscular fat accounted for twice the variation explained by subcutaneous fat, confirming an earlier study by Seebeck and Tulloh (1968). However, measuring inter-muscular fat currently requires the full seaming of muscles and is impractical for a commercial processing facility. Further developments using x-ray technology such as computed axial tomography (CAT) scanning could be a viable alternative.

There has also been significant effort directed to establishing predictive relationships between the measure of one muscle and overall carcase yield. Orme *et al.* (1960) reported a 0.96 correlation coefficient for the weight of *M. biceps femoris* and the total weight of separable carcase yield and developed a regression equation that explained 92% of the variation in total separable carcase lean. Lunt *et al.* (1985) developed a two variable equation of adjusted fat thickness and *M. biceps femoris* that accounted for 88% of the variation in predicting the weight of lean meat on a carcase. Unfortunately, obtaining this muscle weight in a normal boning process is very difficult because the muscle is usually in two primals, the silverside (AUSMEAT reference code AM2020) and the cap of the rump (AUSMEAT reference code AM2080). Collecting this information requires a detailed carcase dissection that is relatively slow, labour intensive and therefore very expensive. Despite very good predictability, the practicality of obtaining the information needs to facilitate uptake of the technique.

Studies conducted by Berg and Butterfield (1976) found that muscle distribution was relatively fixed and conformation was altered by fat. More recently, studies in Europe by Conroy *et al.* (2010) assessed the ability of the EUROP classification system for carcase conformation and fatness (scale 1 – 15) to predict the proportions of meat, fat and bone in the carcase. This resulted in 0.73, 0.67 and 0.71 explanation of variance in the proportions of meat, fat and bone respectively. This was not as accurate as the combined measure using hindquarter meat (13 cuts generated from an 8-rib pistola), which explained 0.93, 0.87 and 0.89 of variance in the proportions of meat, fat and bone respectively, but the latter measure is much more laborious and painstaking to collect. Given the trade off between accuracy and time, it is envisaged the Irish beef industry will look to combine the EUROP classification with a video image analysis process to implement more effective payment systems based on meat yield without incurring the cost of whole carcase dissection (Conroy *et al.* 2010). Again, the practicality of obtaining the information is a major consideration to be effective in large-scale operations.

Whilst the USDA (1997) yield grade is a good indicator of carcase yield, Cannell *et al.* (2002) reported that the accuracy ranged from 0.39 using online graders operating at chain speed, 0.67 for expert yield graders with unlimited time to assign a yield grade and 0.65 for a combined system of video image analysis and grader input. Shackelford *et al.* (2003) reported that using the MARC video image analysis system to assign USDA yield grades explained 0.90 of the yield variance. Three video imaging systems trialled in Ireland explained 0.84, 0.85 and 0.87 of the variation in percentage yield (Allen and Finnerty 2000). Yield grade information needs to be accurate and significantly explain the variation of yield to be useful, but it is not cost effective to give graders unlimited time to obtain the information.

The Australian industry is characterised by abattoir feedback identifying gender, dentition, hot standard carcase weight and subcutaneous fat measurement at the P8 site. Sometimes this also extends to chiller assessment details on intra-muscular fat, meat colour, fat colour, eye muscle area and rib fat (usually at either 10th, 11th or 12th rib). This information is often used by processors as a selection tool to sort products for marketing and is therefore easier to provide as feedback. Whilst providing this feedback to producers may be deemed cost-effective by processors, it needs to be reliable and consistent. As highlighted above, the explained variation ranges from 0.39 in the estimation of yield by graders at chain speed (Cannell *et al.* 2002), 0.84 – 0.87 for yield assessed by video image analysis (Allen and Finnerty 2000) or 0.73 – 0.93 for meat by classification or classification and dissection in the study by Conroy *et al.* (2010). Feedback needs to be provided in a way that enables selection of higher performing animals while being cost effective. This underlies the move around the world to integrate computer based measurement systems with graders to provide more objective, repeatable data collection for more accurate calculation of yields at plant speed rates.

Johnson and Chant (1998) briefly highlighted the technologies being used attempting to improve the accuracy of carcase yield prediction. These were listed as real time ultrasound, velocity of sound, bioelectrical impedance, video image analysis and carcase density. Only video image analysis appears to remain in use on a commercial scale and even its uptake has been relatively limited. The move to more objective measurements rather than subjective human appraisal of carcase traits is driven by a desire to establish performance based pricing schedules. For these systems to be effective, there needs to be consistency in carcase classification to obtain the confidence of participants (Allen and Finnerty 2000).

In the research for accurate representations of carcase muscle proportions, the common threads have been that the measurement of traits needs to be reliable, rapid and inexpensive to collect (Crouse *et al.* 1975, Lunt *et al.* 1985) without “disrupting the normal product flow” (Gardner *et al.* 1997). Whilst this might be relevant to the processing sector, this paradigm needs to be challenged in the context of the entire value chain. The cost of collecting this information can be mitigated by the savings achieved through more effective resource allocation preventing over-fat carcases and improving yields of saleable meat within the confines of functionally efficient animals.

If we take the work of Murphey *et al.* (1960) as a reference point in time, it is now more than 50 years since these yield relationships became quantified and we have yet to implement an effective system of communicating yield throughout the value chain. Despite receiving some information on yield grade, it is defined in different ways that make it impossible to accurately compare between processors and often inconsistent between kill days within the same facility. This leads to information being provided as feedback that is unreliable for making selection decisions.

The scientific community largely agree on the methodology of estimated lean meat yield and carcase beef measures, but the commercial application as a tool for payment to producers has not resulted. It appears that these measures are confusing to producers and not easily communicated. None of the large-scale manufacturers has been willing to risk upsetting their supply lines by acting alone to bring about such a change. On the other hand, the term "saleable meat" has some resonance at every level of the value chain. Perhaps it is the definition of "saleable meat" that needs further standardisation to achieve the scientific rigor required for effective genetic selection.

The beef industry at large has become very efficient at following a process that is fundamentally flawed due to the limitations and self-imposed constrictions on the flow of relevant market information. Until this is addressed, only relatively minor incremental improvement will continue to be made whilst the terms of trade with other protein sources such as chicken and pork continue to decline due to their increasing production efficiency. Given this is such a fundamental driver of value, what has been the cost of not providing appropriate feedback? What has been the opportunity cost of restricting genetic improvement?

2.2 Current methods of valuing meat quality and yield

In Australia, current producer feedback and pricing systems are based on gender, dentition, carcase weight and subcutaneous fat (mm) at the P8 site. (The P8 site is defined as "the intersection of two imaginary lines: one passes from the dorsal tuberosity of the tuber ischii, parallel to the spinal axis, the other from the crest of the spinous process of the third sacral vertebra, meeting the first line at right angles." (Johnson and Ball 1989)). Less commonly it can also be defined as subcutaneous rib fat (mm) "measured mid-way between the 11th and 12th ribs, three-quarters of the distance from the medial to the lateral edge of *M. longissinlus thoracis et lumborum"* (Johnson and Ball 1989).

Australian meat yield is largely communicated through price variations surrounding hot dressed carcase weight and hindquarter (P8) fat measurements in grid pricing schedules. The ranges quoted are usually so large as to address only the extreme variation in yield, either very fat or very lean. Quality is usually interpreted as communicating marbling scores adjudged during chiller assessment the morning after slaughter.

Some specific markets have marbling criteria that pay premiums for AUSMEAT marble scores (AUS-MEAT 1998) in individual or grouped increments. However, Clarke *et al.* (2009a) found there "…was limited information quantifying carcase value to beef producers" and Polkinghorne (2006) argued that, "payment and description at each end point of supply have at best, a very poor relationship to consumer satisfaction".

In the United States of America animals are largely purchased on eight quality grades administered by the United States Department of Agriculture (USDA). These grades are listed in order of highest to lowest quality:

1. Prime
2. Choice
3. Select
4. Standard
5. Commercial
6. Utility
7. Cutter
8. Canner

Five yield grades (1-5) are also used on a voluntary basis. The yield grades were originally defined by the Federal Regulations 1965, and more recently the U.S. Department of Agriculture (USDA) Standards for Grades of Slaughter Cattle and Standards for Grades of Carcase Beef (USDA, 1996). Despite this system having the right intentions, a review of the EU carcase classification system found the USDA system to be relatively ineffective at predicting quality or yield with sufficient accuracy (AHDB 2008).

The classification system in the United Kingdom uses EUROP to make yield estimates and assumes that carcases produced within industry blueprint guidelines will have cuts of similar eating quality. This combination of yield and blueprint production creates carcases of uniform value. Whilst the United Kingdom has Quality Based Pricing in the industry, the current approach is regarded as "only partially successful" and rarely links to "strategic supplier improvement" (Hines *et al.* 2006).

Despite the Meat Standards Australia (MSA) grading system being designed to address the poor consumer relationship throughout the value chain, it has largely been implemented to comply with production considerations rather than consumer preferences. MSA delivers a score out of 100 for six cooking methods for each muscle that can result in one of four grades (Polkinghorne *et al.* 2008a):

- Ungraded <45.5
- 3 star 45.5<63.5
- 4 star 63.5<76.5
- 5 star >76.5

However, processors only distinguish whether or not carcases achieve the base MSA qualification and maybe one other higher quality group, paying producers and charging customers accordingly. It is unclear how much revenue is being forgone due to this unsatisfied demand.

Ultimately the Australian system is flawed. It values consumer preferences and volume of meat produced so broadly that it is very ineffective for identifying better performing animals, thereby stifling genetic improvement to a crawl. Whilst this explains the inability of the beef industry to make any significant productivity gains in meat quality or yield, it also means the opportunity is still available to do so.

2.3 Communicating value between supply chain participants

Value chains are most effective when the participants are aligned toward a common outcome. It is important to understand the expectations of the final consumer because the amount of money for distribution throughout a value chain is determined by the value perceived by the end-user and the price they are prepared to pay. In order to maximise this revenue, effective communication between the participants in the value chain is essential.

In a report to the New Zealand meat producers' board, the M.E.G.I.C. (1965) were quoted in Everitt (1966): "Efficient grading results in the producer being rewarded for the production of the grade of meat in greatest demand at particular times and in particular markets, and allows the product being bought on its grade mark without inspection". To achieve this result, communicating meat eating quality and yield throughout the value chain should focus on representing consumer value to all participants. The optimal result would remunerate producers in a way that effectively represents the return the animal makes for the processor and all stakeholders within the process.

Although trying to identify independent variables from each component of the meat production process, namely on-farm animal characteristics, abattoir processing variables and consumer preparation methods, the MSA modelling supported earlier work by Butler (1960), Friedlander (1964) and Everitt (1966) and found they were interdependent (Watson *et al.*

2008b). Despite this interdependence, anecdotal evidence suggests the provision of feedback to producers from the processing sector within the beef value chain is considered a cost. Subsequently this results in only the minimum feedback being provided with little regard for its relevance. This constrains the suppliers' ability to improve.

This poses a dilemma for most processors. Whilst a processor needs to maximise revenue, profitability is often determined by the labour cost associated with preparing these outputs and the overheads necessary for that production: minimising both creates their margin. Given the provision of feedback is usually viewed as an administrative overhead, processors usually provide the minimum required.

Those who control the grading system ultimately control the degree of differentiation presented to the consumer and therefore the total "welfare" available for distribution throughout the value chain (Ferrier 2005). Industry implementation of MSA has focused on individual components of the grading system that are broad-based targeting threshold components rather than fully separating ungraded, 3, 4 and 5 star product. Despite this limited implementation, MSA was estimated to have increased revenue by the equivalent of $0.32/kg hot standard carcase weight (HSCW) by Griffith *et al.* (2009) until 2007/08.

This was updated for the period up to 2010/11 to show $0.30/kg HSCW-increased revenue dissemination to the retailer, wholesaler and producer was estimated to have been $0.06, $0.11 and $0.13/kg HSCW respectively (Griffith and Thompson 2012). The proportion of extra revenue allocated to the producer was very similar to the 42% calculation within the Polkinghorne model (Polkinghorne 2006). Achieving 9% more revenue (Griffith *et al.* 2009) is a significant achievement that likely represents only the beginning of what can be achieved.

Consumer considerations

Consumers have a higher willingness to pay (WTP) when they have access to visual and taste attribute evaluations prior to purchase (Xue *et al.* 2010). The MSA method predicts the eating quality of individual beef cuts using critical control points in the production, processing and further processing sectors of the supply chain (Thompson 2002, Polkinghorne *et al.* 2008b). The assigned eating quality score falls into one of four categories of ungraded, 3, 4 or 5 stars. MSA has identified a series of critical control points throughout the value chain that impact on beef palatability (Ferguson *et al.* 1999, Polkinghorne *et al.* 1999, Thompson *et al.* 1999a,b, Watson *et al.* 2008b). This system can be linked to what consumers are willing to pay for various levels of eating quality (Lyford *et al.* 2010, Morales

2010). We now have an opportunity to build representative models of the beef value chain and inter-relate the financial critical control points, thereby creating a FACCP (Financial Analysis Critical Control Point). In doing so, we can more effectively communicate consumer value to participants at all levels throughout the value chain, particularly those in production and processing.

In order to understand the further potential of the MSA methodology from a consumer value perspective, Lyford *et al.* (2010) studied the WTP of 6,718 consumers in Australia, the United States of America, Japan and Ireland from data collected during large-scale consumer taste tests and surveys. The Lyford et al. (2010) results highlighted the unfulfilled demand for four and 5 star product, where Australian consumers were prepared to pay 1.5 times more than for 3 star and 2.1 times more than for 3 star respectively while Japanese consumers were prepared to pay 1.7 and 2.9 times more than for 3 star. Most other countries were grouped with Australian consumers in their WTP.

Broader WTP considerations were explored by Morales (2010) who investigated the characteristics of the potential demand for branded beef products across Australia. This study identified the opportunity for developing brands where "…the value of a brand is to become an extrinsic quality cue that can help to predict eating and credence quality dimensions" (Morales 2010). The study concluded that there was significant potential to sell branded beef products throughout Australia.

Selling more branded beef products has the potential to significantly increase the total revenue obtained from consumers. This will require better product presentation that effectively communicates the value consumers can expect before any premiums can be received. Improved product traceability, inventory management and information systems will be needed to ensure these expectations can be met. Hence, information throughout the value chain is crucial (Latvala and Kola 2000) and probably the most important driver to optimising the beef value chain.

Production considerations

Everitt (1966) stated that "Fat is in least demand by consumers; it affects the yield and distribution of lean meat; and at the same time it is energetically most expensive to produce. There seems little point, therefore, in the continuation of traditional breeding policies. Rapid growth rate, coupled with high feed conversion efficiency, leading to maximum muscle production represent parameters of greatest importance." This again highlights the need for a more integrated approach to understanding impacts of changes at one end of the value chain, such as growth rate, on the other end of the chain, such as meat yield at the possible expense of marbling.

Ongoing research has attempted to establish live animal assessments that reflect quality and yield traits. Perry *et al.* (1993) and Drennan *et al.* (2008) used live animal muscle and conformation scores to predict saleable meat yield (SMY), while Herring *et al.* (1994) matched live animal measures to carcase yield for selection of animals prior to slaughter, achieving the same accuracy as USDA yield grade. Hocquette *et al.* (2010) found that manipulating intramuscular fat (also known as IMF or marbling) independently from body fat depots using nutrition was more difficult to achieve than through genetic strategies. By finding live animal measures that accurately reflect quality and yield, management practices can be established to improve these traits.

Whilst there is a significant lead-time to change management practices in preparing animals for sale, the genetic potential is already set. To change genetic potential is very difficult. It can take a minimum of two and usually three years to see changes start, then a further four to six years for any genetic changes to be established in a commercial herd. Given that the definition of breeding objectives sets the direction of breeding programs (Kinghorn 1998), it is important to have stability of purpose and clearly defined breeding objectives.

Genetic improvement is an important avenue for producers to improve efficiency and obtain more profitable animals. Genetic selection based on carcase traits is possible with the heritabilities (h^2) for retail beef yield (RBY), intramuscular fat (IMF) and marbling (MARB) reported by Reverter *et al.* (2003b). The h^2 values for RBY, IMF and MARB were 0.57, 0.38, 0.17 and 0.50, 0.39, 0.25 for Temperate and Tropical breeds respectively. These moderate levels of heritability should facilitate genetic improvement.

The beef industry needs to provide feedback that enables genetic progress. The feedback being provided cannot be cost-effective over the long term if no genetic progress is being made (Johnson 1996). A limitation of the current system is the lack of knowledge about genetic progress: without an integrated approach and clear long term objective, no one really knows what amount the value chain as a whole is improving or deteriorating.

Processing considerations

Whilst understanding the relationship between some carcase components and their distribution over the carcase is well documented, it is not easily standardised. Each processing facility slightly varies from another due to the variations of skill and discipline of individuals boning and trimming the primals on the production line. Primals contain various combinations of the three primary tissues – muscle, fat and bone – according to the boning priorities of individual facilities and can range in value from $1/kg to $21/kg. With such large variations in value, it is important to specify the cutting lines and level of trim associated with each primal. To more effectively communicate these combinations, AUS-MEAT (AUS-MEAT 1998) and the North American Meat Processors (NAMP 1997) have developed detailed templates for standardising primal cutting specifications. The AUS-MEAT initiative has vastly improved communication and marketing of carcases and cattle in Australia (Johnson 1994).

Generally processors focus on how to maximise the amount of fat left on the primal to increase weight sold and therefore total revenue. The price per kilogram achieved is moderated by customers' WTP for excess fat. Effectively, selling fat at primal prices will always generate a higher return than selling fat as fat in the current Australian market. This principle is also true of bone being sold as bone-in primals rather than bone, although the market is aware of their problematic nature. Bone-in primals generally have a shorter shelf life as well as a higher tendency to burst vacuum packaging bags causing 100% product loss and are therefore priced accordingly. These strategies aim to improve the return of the fat and bone tissue, but they can ultimately detract from the return associated with muscle due to the "risk" discount applied by customers.

On the other hand, processors would like to receive higher yielding animals. Conroy *et al.* (2010) has described multiple regression equations to predict carcase proportions of meat, fat and bone using European carcase classification scores for conformation, fatness and hindquarter composition. Johnson (1996) advocated the carcase beef measure of yield outlined by Charles (1977) as a basis of trading animals. This was because it effectively combined the commercial acceptability associated with saleable beef yield while having the improved accuracy of estimated lean meat yield to be useful for genetic improvement. The other major benefit was that it could be estimated from the use of existing carcase measurements of carcase weight and subcutaneous fat at the sacral (rump P8), FT10 or FT12 site. Communicating any meat yield measures independent of quality is likely to encourage producers and processors to select for higher yielding animals with no consideration of any quality aspects or other equally important traits associated with calving ease and feed conversion. To be sustainable at the production end of the value chain, complete information needs to be translated back to the live animal to facilitate more effective selection decisions being made.

Processors are also mindful of purchasing animals on a liveweight basis because it requires estimating the dressing percentage of the animal. In this context, dressing percentage is important to carcase value. Animals that achieve a higher carcase weight relative to liveweight will be cheaper than those that are lighter carcases for the same liveweight. However, unless this higher carcase weight is generated by higher SMY (Butterfield 1966), it is of no value to the processor. Higher dressing percentage can be caused by higher fat yield. The carcase with the higher fat yield will have the better dressing percentage whilst causing more labour cost to trim the excess fat from the primal, which is a liability (Berg and Butterfield 1976) for the processor. High dressing percentage effectively selects animals with relatively small organs that may also impact negatively on production efficiency over time (John Thompson pers. comm. June 27, 2012).

According to Gardner *et al.* (1997), the evaluation of meat yield needs to be achieved without impeding product flow through the abattoir. Whilst this situation would be ideal, it should be tested within the context of value chain optimisation and the potential commercial implications of tracing the primal throughout the supply chain to the point of consumption for bio-security, food safety and most importantly, consumer eating satisfaction.

Traceability considerations

Logically, deboning the carcase, weighing the components produced, recording carcase measures and reporting the information generated as feedback to producers would provide the best communication. In reality, individual companies set management priorities that determine product specifications and available infrastructure that need to be managed within the ever-present constraint of time. As a result, carcase traceability is usually limited to a production day or, at best, a production shift. Also, the processes employed within a deboning operation will determine the traceability of carcase components. The vast majority of boning facilities around the world are based on a chain system that moves carcases from one station to the next, handling discrete components of the carcase at each station. The product is then trimmed and transferred to a centralised packing area via tubs or transfer conveyors. In these instances, collecting information on individual carcase components has largely been deemed as too expensive. There has been some uptake of DNA testing and bar-coded or radio frequency identification gambrels to assist in traceability of carcases (Finlayson 2012) but rarely any further on toward primals. Whilst there is some anecdotal evidence that two major processors have achieved traceability to the primal level, the author has not been able to validate this.

Without individual primal traceability, processors have used boning groups to identify quality grades for primal cuts. The standardised boning group approach used across Australia is a significant impediment to the full implementation of MSA for three main reasons:

1. This approach consolidates product, usually with a range of eating qualities above a pre-determined level. The result is that better quality product is given the same grade as the lowest common denominator to minimise the risk of failure.
2. The boning group approach limits the ability of processors to harvest cuts from their production. To utilise the full potential of MSA, processors need to be able to access particular cuts at defined quality levels that are set by the customers, not predetermined by external operators. The current application of MSA boning groups is not dynamic enough to work effectively with boning room production schedules and harvest cuts in response to customer demand.
3. The boning group approach limits the flexibility required to manage inventory and market product effectively when circumstances change, such as customers misinterpreting specifications or changing their mind.

Whilst there are significant logistical challenges involved, such as stock codes, labelling and inventory management, overcoming these challenges will clear the bottleneck limiting the full implementation of MSA throughout the value chain.

The expenses incurred are twofold, through the provision of processing facility infrastructure (both structural assets and information systems) and the labour required to achieve the traceability. Hence, the focus by industry has been on finding “an accurate and rapid dissection technique” (Johnson and Charles 1981) to be cost effective. By focusing on higher throughput, managers significantly reduce the unit cost to re-coup the initial investment and cover on-going maintenance costs. In a high volume, low margin environment, incremental change can be achieved, but it is harder to change fundamental paradigms of production to achieve traceability.

Whole value chain considerations

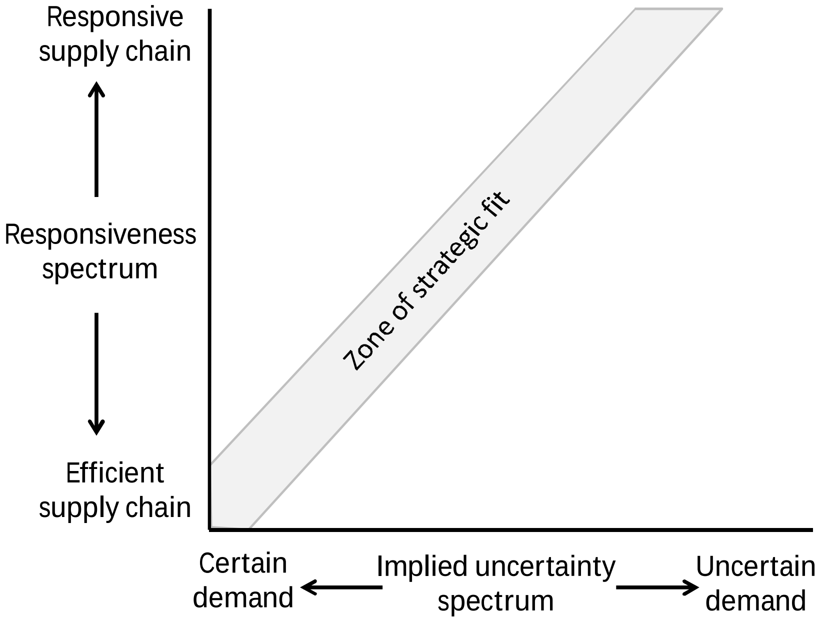
Creating awareness of the interrelationships amongst the various stages of the beef value chain should, in theory, enable modelling from alternative manufacturing and production industries to be applied to the beef value chain. In the manufacturing industry Gong (2008) found that “The bottleneck factor decides the level of system product mix flexibility.” In the beef industry, the “bottleneck factor” is undoubtedly the traceability from the carcase to the packaged primal. This traceability is fundamental to the ability of MSA to predict the various eating experiences possible at the consumer level. Without this traceability and communication established, the final entity preparing the product for the final consumer cannot be aware of the predicted eating outcome possibilities and therefore adjust preparation accordingly.

The global nature of the beef industry is very dynamic, subject to fluctuating demand and currency volatility. Businesses at all levels need to be flexible and able to respond to these ever-changing circumstances. Understanding these factors, incorporating consumer demand and producer supply considerations gives an opportunity to establish effective modelling tools. These models can provide useful insights on mitigating risks but also highlight opportunities.

A competitive strategy of a firm, according to Chopra and Meindl (2012), “defines, relative to its competitors, the set of customer needs that it seeks to satisfy through its products and services”. A supply chain strategy – how to structure the supply chain for the medium to long term – is derived from the competitive strategy and is based on the creation of a suitable strategic fit and scope for a particular product. The appropriate scope is an intercompany one, where the view is to maximise chain surplus (profitability) by all firms in the chain working together and sharing information.

Three steps are followed when establishing the zone of strategic fit for a supply chain: understanding the customer and supply chain uncertainty; understanding the supply chain capabilities; and achieving a strategic fit. In the case of the beef value chain, two decisions need to be made that correspond to the first two steps and lead to the third step: deciding on the degree to which consumer demand for the product in the chain is certain or uncertain; and deciding if a supply chain is able to respond to a wide range of quantities demanded, meet short lead times, handle a variety of products, build innovative products, meet a high service level and handle supply uncertainty (Chopra and Meindl 2012). The third step is to decide whether it should be a responsive supply chain or an efficient supply chain (one that operates at the lowest possible cost).

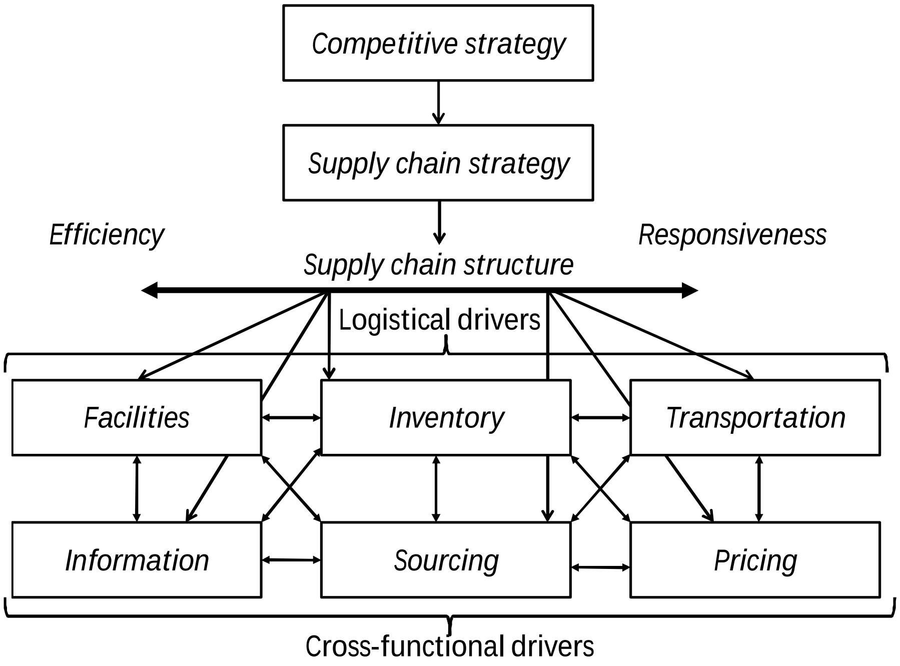
The zone of strategic fit is shown in Figure 2.1. First, the beef value chain has a high degree of implied uncertainty, defined by Chopra and Meindl (2012) as the uncertainty of consumer demand for a product "for only the portion of demand that the supply chain plans to satisfy based on the attributes the customer desires". In particular, knowledge is lacking of meat quality across all cuts of meat and what qualities consumers desire in each cut of beef. Second, participants in the supply chain need to be highly responsive to changing consumer tastes and preferences, which requires a high level of knowledge about consumer preferences to be transmitted to all stages in the chain between producers and consumers. In achieving a strategic fit, then, the aim of a firm is "to target high responsiveness for a supply chain facing high implied uncertainty" (Chopra and Meindl 2012).



Source: Chopra and Meindl (2012, p. 40).

Figure 2.1: Finding the zone of strategic fit

The role of each stage in the chain is aligned to support the supply chain strategy through the use of sets of logistical and cross-functional drivers. Figure 2.2 presents a framework for structuring these drivers in a supply chain. While all six drivers are relevant in influencing the performance of the beef value chain, the information driver is the one of most relevance to this study. Chopra and Meindl (2012) identify several components of information decisions that are prominent in a supply chain. One of these components, information technologies, is particularly valuable in the beef value chain and offers great scope to increase chain profitability by enabling a closer match of beef products to the preferences of consumers. To be capable of creating a profitable responsive supply chain, chain participants need timely and complex information. These enabling technologies can make producers and other chain participants more responsive to changing consumer preferences and thereby improve overall chain surplus (profitability).



Source: Chopra and Meindl (2012, p. 55).

Figure 2.2: Value chain decision-making framework

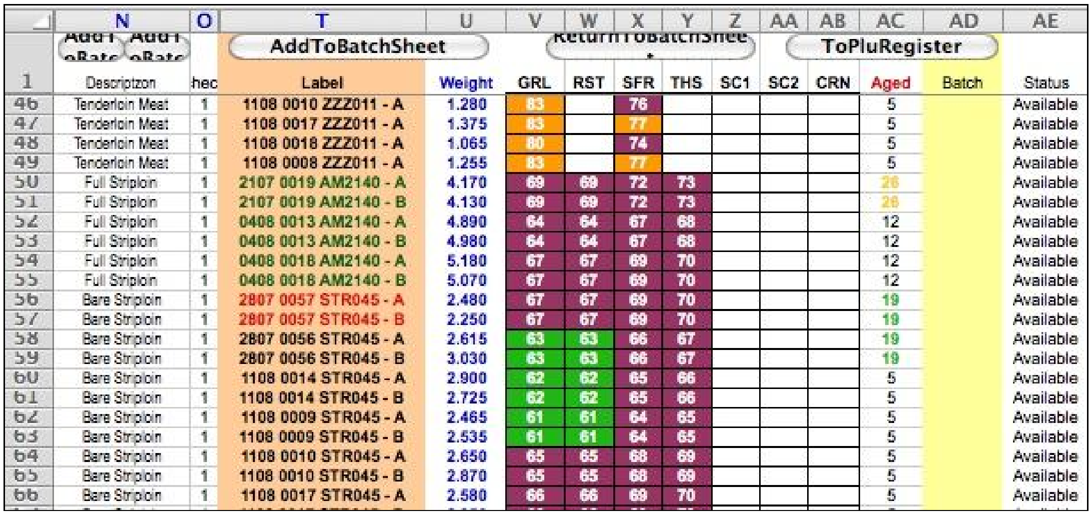
The opportunity is to integrate information and clarify the importance of individual eating quality and carcase yield traits. The traditional measure of quality has largely been attributed to the measure of intramuscular fat, also known as marbling. It has been assumed that increased intramuscular fat positively influences flavour, juiciness and tenderness (Hocquette *et al.* 2010). MSA research has highlighted the interconnectivity of pre and post-slaughter treatments and the traditional measurements of marbling, intramuscular fat and ossification on consumer palatability scores (Ferguson *et al.* 1999, Polkinghorne *et al.* 1999, Thompson *et al.* 1999a, Thompson 2002, Johnston *et al.* 2003a,b, Reverter *et al.* 2003a,b, Polkinghorne 2006, Polkinghorne *et al.* 2008b).

These results are supported by the findings of Berg and Butterfield (1976) that excess fat is detrimental to SMY% and not enough fat is detrimental to eating quality. By combining the influence of eating quality and yield traits into the decision making process, customers needs can be met more effectively whilst maximising profitability for the value chain participants. “While looking to manipulate growth in the quest for greater efficiency, we need to be mindful of the beef characteristics that make it demanded by consumers so that these are always retained” (Berg and Butterfield 1976). Having the priorities of all value chain participants aligned with our consumer is important for the long-term sustainability of the beef industry.

Even if initial models prove crude and in need of further development, the base methodology represents a new frontier in understanding the integrated nature of the beef value chain. What is often overlooked in discussions about MSA grading is the fact that it should remain a dynamic tool. As better information and new understanding is proven, it should be incorporated into this modelling (Watson *et al.* 2008b), thereby more closely aligning predictions with consumer expectations. There has been little modelling done on the financial aspects of these critical points, making it difficult to quantify their impact on the bottom line of participant’s in the beef value chain.

2.4 Processing case study – Polkinghornes value chain

The Polkinghornes value chain was built on full traceability from producer to consumer (Polkinghorne 2006, Polkinghorne *et al.* 2008a), requiring a purpose built database that also colour coded the scores to reflect one of four grades for individual portions for each cooking method (Figure 2.3). Red font on a white background indicated the portion scored <47.5 and was “UG” Ungraded. All graded product was distinctly recognisable with a white font on several backgrounds within the records cell. A green background indicated the portion scored ≥47.5 but <63.5 and was “3 star” eating quality for each of the six cooking methods. A purple background indicated the portion scored ≥63.5 but <76.5 and was deemed “4 star”. A gold background indicated the portion scored ≥76.5 and was deemed “5 star” eating quality. This database of primal information was essential to record processing yields accurately and maintain product traceability as it was transformed throughout the value chain.



	N	O	T	U	V	W	X	Y	Z	AA	AB	AC	AD	AE
1	Descriptzon	hec	Label	Weight	GRL	RST	SFR	THS	SC1	SC2	CRN	Aged	Batch	Status
46	Tenderloin Meat	1	1108 0010 ZZZ011 - A	1.280	83		76					5		Available
47	Tenderloin Meat	1	1108 0017 ZZZ011 - A	1.375	83		77					5		Available
48	Tenderloin Meat	1	1108 0018 ZZZ011 - A	1.065	80		74					5		Available
49	Tenderloin Meat	1	1108 0008 ZZZ011 - A	1.255	83		77					5		Available
50	Full Striploin	1	2107 0019 AM2140 - A	4.170	69	69	72	73				26		Available
51	Full Striploin	1	2107 0019 AM2140 - B	4.130	69	69	72	73				26		Available
52	Full Striploin	1	0408 0013 AM2140 - A	4.890	64	64	67	68				12		Available
53	Full Striploin	1	0408 0013 AM2140 - B	4.980	64	64	67	68				12		Available
54	Full Striploin	1	0408 0018 AM2140 - A	5.180	67	67	69	70				12		Available
55	Full Striploin	1	0408 0018 AM2140 - B	5.070	67	67	69	70				12		Available
56	Bare Striploin	1	2807 0057 STR045 - A	2.480	67	67	69	70				19		Available
57	Bare Striploin	1	2807 0057 STR045 - B	2.250	67	67	69	70				19		Available
58	Bare Striploin	1	2807 0056 STR045 - A	2.615	63	63	66	67				19		Available
59	Bare Striploin	1	2807 0056 STR045 - B	3.030	63	63	66	67				19		Available
60	Bare Striploin	1	1108 0014 STR045 - A	2.900	62	62	65	66				5		Available
61	Bare Striploin	1	1108 0014 STR045 - B	2.725	62	62	65	66				5		Available
62	Bare Striploin	1	1108 0009 STR045 - A	2.465	61	61	64	65				5		Available
63	Bare Striploin	1	1108 0009 STR045 - B	2.535	61	61	64	65				5		Available
64	Bare Striploin	1	1108 0010 STR045 - A	2.650	65	65	68	69				5		Available
65	Bare Striploin	1	1108 0010 STR045 - B	2.870	65	65	68	69				5		Available
66	Bare Striploin	1	1108 0017 STR045 - A	2.580	66	66	69	70				5		Available

Figure 2.3: Inventory database screen snapshot showing primal description, check field, label information, weight of primal, seven cooking method (GRL – grill; RST – roast; SFR – stir-fry; THS – thin-sliced; SC1 – slow cook for one hour; SC2 – slow cook for two hours; CRN – corned), Aged: days aged since kill date; Batch: batch assigned when taken from inventory for further processing and invoiced; Status: eating quality scores calculated daily using individual cut ageing coefficients.

To limit the risk of supplying a poor eating experience to the consumer, a group of muscles with differing eating qualities, such as the rump primal, were rated according to one of the lower eating qualities of its components (Polkinghorne *et al.* 2008a). This component is signified as the “Deem Cut” i.e. deemed to most effectively represent the primal to achieve this risk mitigation objective.

Inventory utilisation and value

Consistent with the base principle of traceability, all the products generated from further processing were recorded. Furthermore, the yield of each product produced was also recorded as well as the price received for each product. These products were marketed direct to company-owned retail stores or wholesaled to external businesses.

“For example, the *M. rectus femoris* could be fabricated and sold primarily as either steaks or a roast. Steak preparation typically yielded 78% of the muscle as steaks with 5% sausage trim, 12% fat and a 4% cutting loss. In comparison, an 89% roast yield was obtained with 7% sausage trim, 3% fat and 1% cutting loss. If the primary objective was to produce stir-fry or casserole cubes, further yield mixes would apply. The return from the muscle was dependent on the combination of the weight of the primary and secondary products and on their respective prices. The eating quality of this muscle is affected significantly by cooking method (MSA model estimates) with typical results being a 4 star roast but only 3 star steak. As retail pricing was based on grade, the overall return for *M. rectus femoris* from an average carcase was $31.89 when prepared as steak in contrast to $42.25 when prepared as roasts. Consequently, sale as a roast was planned wherever possible to optimise return. A similar decision process was followed for other carcase portions." (Polkinghorne *et al.* 2008a).

The traceability throughout the processing stages facilitated communication of information throughout the value chain. Because of this traceability and record keeping, a value for each primal could be established. The "live" inventory value, yield and eating quality information created the opportunity to optimise the return of primals by choosing how they would be processed on any given day. This traceability facilitated the flexibility necessary for the business to respond to changing consumer demands requiring alternative inventory utilisation, isolating quality assurance breaches and most importantly, translating value between each participant of the supply chain.

Supply and pricing to the retail store

Demand for retail products was driven by customer sales at the retail store. The inventory of primal cuts was then further processed into the required retail-ready items or sold into the wholesale market. Those cuts processed into retail-ready items were done so in batches and full yield records were obtained. This information included primary and secondary items produced from each primal batch being processed, as well as any associated trims and waste. The cutting loss or gain was calculated as the deduction of all other quantities from that of the source material (Polkinghorne *et al.* 2008a).

By combining the retail price paid by consumers and the processing yields recorded at each step of the process, a unique pricing methodology was established. Polkinghorne (2006) assessed the market supply and demand forces to establish 65% as a reasonable and sustainable price point. This is characterised by Figure 2.4.

The wholesale primal prices used were calculated as 65% of the retail value achieved for the cut depending on the quality grade achieved, namely ungraded (UG), 3, 4 or 5 stars. The value calculation was a function of retail price by the quantity of retail ready product, trim, fat and bone generated during the preparation of the item. Wherever possible the first marketing priority was to sell through the company owned retail outlet. If this was not possible, wholesaling to other MSA outlets was pursued before using the broader wholesale market. Appendix 1 outlines the retail products and their pricing for each of the quality grades.

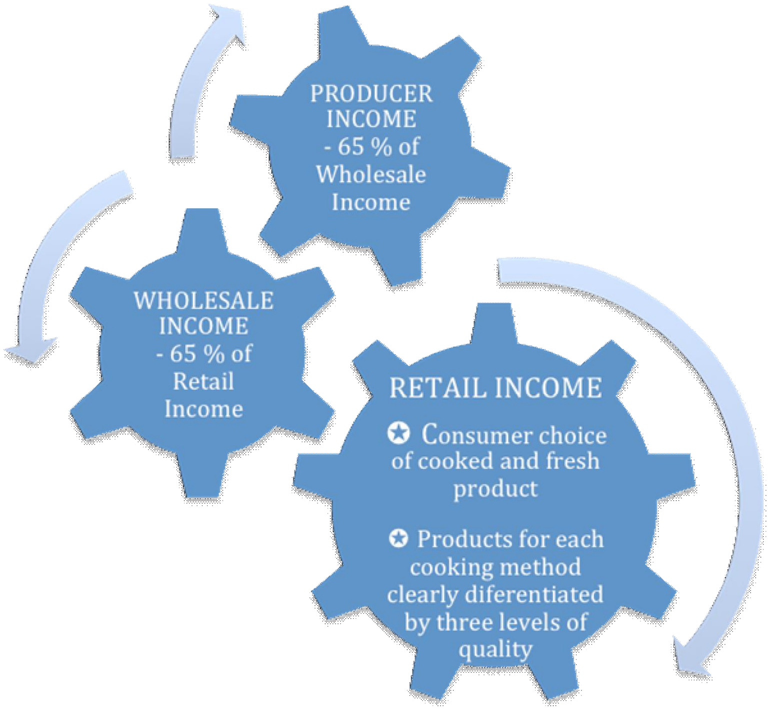


Figure 2.4: Polkinghornes value chain characterisation

A value for each primal at each of the four quality grades could be determined over a defined period of time. Depending on cut utilisation strategies employed for different quality grades, primal returns could vary significantly. The value for each primal was calculated individually for each of the four quality grades. Appendix 2 outlines an example of primal prices used in subsequent chapters of this thesis for each of the four quality grades used to calculate carcase value.

The prices paid for each 3 star primal ranged from $2.94 per kilogram for *M. gastrocnemius* (OUT029) to $17.03 per kilogram for *M. psoas major* (TDR062). Carcase value was determined by summing the total value of the relevant component primals, trim, fat and bone each animal was boned into. This method provided a direct market signal from retail consumers throughout the value chain because of the custom-built traceability and feedback systems.

This case study represented a new value chain paradigm. The methodology employed provided a framework that delivered a consumer-focused product that was highly responsive to changing consumer demands, tailored to suit their needs. This value chain also addressed traceability concerns to guarantee food safety whilst simultaneously communicating accurate eating quality and carcase yield through value based payments. The alignment of participants throughout the value chain meant consumer feedback could be used to facilitate genetic improvement, thereby closing the feedback information loop.

2.5 Effective beef value chains

Value translation throughout any supply chain should communicate the contribution of individual components toward achieving a desired outcome, where the desired outcome has been outlined and requested by the ultimate consumer. By “beginning with the end in mind” (Covey 1989) there is an opportunity to create an alignment of individual goals and vastly improve the effectiveness of the supply chain. This was evident when the two original objectives for implementing a grading and classification system for beef carcases were outlined as first, to develop uniform grading standards that could report market pricing; and second, to provide feedback to suppliers about market requirements (Harris *et al.* 1988). Whilst the original objectives were noble, they have proved elusive over the past 109 years since Herbert Mumford first proposed them in a series of bulletins entitled "Market Classes and Grades of Cattle with Suggestions for Interpreting Market Quotations” (Harris *et al.* 1988).

Typically, institutions established voluntarily or by regulation tend to run their course and slowly become less relevant. Australia’s implementation of the AUSMEAT language in 1987 for carcase description was to accurately describe gender, dentition (as a measure of age) and carcase weight because the definition of “carcase quality” varied depending upon the customer and destination (Polkinghorne and Thompson 2010). Also, “the USDA quality grades were never intended to provide point estimates for expected beef palatability” (Smith *et al.* 2008). In both Australia and the United States of America, implementing effective communication throughout the value chain “has been subject to a similar history of local, state and national political interference” (AHDB 2008). The United Kingdom experience reflects that of Europe as a whole, suffering from a lack of transparency, poor product description between value chain participants and feedback unduly influenced by a focus on subsidies and market support rather than consumer requirements (AHDB 2008). None of these existing structures adequately provides the feedback necessary for increasing compliance or productivity.

The two primary objectives of beef carcase grading systems are to estimate SMY% and determine the eating quality of the meat (Indurain *et al.* 2009). Given the value chain as a whole is a system, and the value chain in its parts are the components (Gow *et al.* 2003), it follows that there needs to be understanding "about the impact of selection for any given trait on other economically important traits such as carcase yield, quality, feed conversion or fertility so that there are no unfavourable correlated responses to selection" (Clarke *et al.* 2009b). Unless we understand these interactions, we cannot incorporate the outcomes into daily management decisions.

The calls by Pethick *et al.* (2010) for a new wave of structured research should be vigorously supported. However, it should also be recognised that this is not a new approach, rather it re-ignites previous calls for a more coordinated research focus outlined recently by Polkinghorne (2006) that "concerted application of meat science research findings would assist in delivering consistent quality products to the consumer. These must be augmented by industry procedures, which can apply the science in a working commercial environment and achieve balanced clearance of all carcase components. The commercial incentive to adopt such changes must come from the adoption of systems, which relay accurate information and directly link price to consumer value at all trading points." This approach was also supported by Everitt (1966) when he quoted Friedlander (1964), "The first important factor (in meat production and research) is the necessity of breaking down the barriers previously existing between primary production, processing and marketing so that one can have a direct line of communication." Study of isolated components of this integrated system is probably one further reason for our lack of progress for "accuracy of appraisal decreases at each processing point along the chain from dinner plate to the live animal." (Butler 1960).

This is as relevant today as it was 45 years ago except now the industry can access the MSA methodology representing the best existing total quality management approach for improving beef quality and palatability (Smith *et al.* 2008). The challenge is to effectively implement this system and meet consumer demand by actively redefining the linkages between the value chain participants.

2.6 Opportunities

There are three distinct opportunities to change the way participants within the beef value chain culminate in delivering a contemporary consumer product:

1. Continue to develop MSA, to incorporate validated research findings
2. Utilise traceability to address food safety and provide marketing flexibility
3. Close the information loop, providing effective feedback throughout the value chain on eating quality and SMY%

First, there is an opportunity to expand and evolve the MSA methodology. It is important to remain focused on the consumer implications of any action by analysing the inter-related effects of treatments performed in one section of the value chain on those participants upstream or downstream. The Palatability Analysis Critical Control Point (PACCP) methodology developed by MSA (Ferguson *et al.* 1999, Polkinghorne *et al.* 1999, Thompson *et al.* 1999a,b) was the first methodology to address the beef value chain with this approach.

The industry must avoid isolating this body of knowledge accumulated within the MSA methodology. It cannot confine it to a "box", believing the job is done and the knowledge is complete. History has taught us that knowledge evolves and gains clarity over time. Knowledge should only be truly accepted after being thoroughly tested. The development of MSA is an appropriate example of an evolving system that started grading whole carcases as one quality grade to now grading 37 individual cuts by six different cooking methods; from grading all cattle breeds as equals to currently assigning fixed effects related to *Bos indicus* content; from not identifying animal treatments to recording whether or not they are treated with hormonal growth promotants. It is important to maintain a questioning mentality that continually tests and re-tests the underlying assumptions fundamental to the workings of the model: this is the essence of the entire system. Should subsequent studies disprove the current assumptions and coefficient values, the model itself should be updated and modified accordingly. The ability to manage this process effectively will determine whether or not it can remain dynamic, evolve with our understanding and thereby maintain its relevance.

Second, traceability of retail product to the point of origin achieves two important functions (a) food safety, and (b) marketing flexibility.

(a) Food safety is of paramount importance to the consumer and the entire beef value chain is facing increased regulatory demands after the bovine spongiform encephalopathy (BSE) outbreaks in the United Kingdom and Japan, foot and mouth disease in Argentina and other South American countries and E. coli issues in ground beef within the United States of America. With a systematic approach to traceability established, problematic inventory can be rapidly and accurately isolated and quarantined from the food supply channels. This should enable continued market access, retention of consumer confidence and minimise the imposition of any further regulation.

(b) Marketing flexibility is obtained by maintaining the eating quality information of primals up to the final point of retail sale. To facilitate the passage of this information, systems are required that maintain product traceability to translate information up to the point of sale so that decisions on product presentation at the retail level can be made with confidence. The majority of people presenting beef to the ultimate consumer are often confronted with limited information, despite it being of paramount importance at the point of final sale. For example, the round primal (also known as knuckle or AUSMEAT code AM2060) is often prepared as a barely acceptable grilling steak after passing through a tenderiser, when it could alternatively be presented as an above average roast, cut into stir-fry portions or diced for use in a casserole. The bottleneck is that insufficient information is available to accurately determine which primal is appropriate for each presentation. By addressing this communication breakdown, there is an opportunity to increase revenue, or at the very least satisfy the consumer need more effectively, thereby increasing the likelihood of a repeat purchase. Essentially, resolving these process logistics will unlock the full potential of MSA.

Third, closing the information loop by improving the systems providing product traceability can provide effective feedback to all value chain participants. By incorporating more detailed eating quality and SMY% information with traceability, feedback systems to producers would be vastly improved. The logical progression would enable the extended development of integrated modelling between live animal growth and carcase dissection as demonstrated by Slack-Smith (2009), as well as valuable genetic feedback. Such developments could generate significantly improved efficiencies in the beef industry normally associated with the dairy and pork industries.

The importance of carcase meat yield in its various forms as a measure of carcase performance has been investigated by many previous studies such as Murphy *et al.* (1960), Crouse *et al.* (1975), Charles (1977), Johnson and Charles (1981), Lunt *et al.* (1985), Johnson (1994) and Conroy *et al.* (2010) to name but a few. The important point to note is the lack of a yield measurement to provide commercial information. The limitation to providing this has been the capital infrastructure and process flow necessary to collect the information, and the labour required to do it. Nevertheless, selecting for carcase yield in isolation of quality traits will likely be detrimental to functional aspects of beef production and the long-term ability of the value chain to respond to changing consumer preferences. The rise in mortality during transport to the slaughter house that accompanied selection for increased muscle (Berg and Butterfield 1976) combined with anecdotal evidence of higher yielding carcases with “bland” eating quality in the pork industry should be noted to ensure this is avoided in the beef industry.

For more inspiring examples, the Australian dairy industry has adopted a component payment system for volume, milk fat and milk solids. Annual production per cow has increased by 91% over the past 30 years from 2,848 litres in 1979–80 to 5,445 litres in 2009–10p (Anonymous 2011). A Canadian pork cutout trial in 1992 (Anonymous 1992) highlighted a 6–7% improvement in lean meat yield compared with an earlier trial in 1978 and attributed 50% to genetic improvement. Also, the average Canadian hog carcase increased from 79.3kg in 1990 to 94.0kg in 2010 (Anonymous 2010). Such changes significantly decrease the fixed processing costs per litre of milk or per kilogram of pork produced respectively. These results demonstrate the significant improvement that can be made with better feedback throughout the value chain, thereby increasing total revenue, through better asset and labour utilisation within these value chains.

In order to capture these gains in the ongoing search for improved processes and efficiency, it is likely the beef industry will need to look externally at how this has been achieved in other industries. Hines *et al.* (2006) describes a combined Target-Kaizen costing approach applicable to lean manufacturing enabled businesses. The target price represents the maximum allowable at the start of the product lifecycle whilst the Kaizen costing is the price point toward the end of the product life cycle, usually expressed as a percentage. This price change can then represent the change in the cost of production over time, leading to the application of lean manufacturing principles. This combined approach has been taken from the Japanese automotive industry where it plays a central part in the achievement of the quality, cost and delivery goals stipulated in customer specifications (Hines *et al.* 2006). It is but one approach requiring further investigation for its appropriateness to the beef value chain.

When the linkages between value chain participants are effective, confidence builds and longer-term decisions are more likely to be made. The more defined or predicted an outcome is, the better chance of managing the ramification or influence it has. MSA provides an avenue to understand and segment customer specifications in terms of quality that, when combined with traceability, can be expanded to include cost and delivery goals. Collected correctly, this information can be invaluable to manage product margins and more effectively set prices that reflect consumer demand.

2.7 Summary

Value chains represent a line of communication between the ultimate consumer and the original producer. When price is based on weight or volume criteria alone the “rational response would be to produce a high volume of very large (but often poor tasting) product” (Hines *et al.* 2006). This can be avoided by the beef industry if it incorporates the quality considerations identified by MSA, namely tenderness, juiciness, flavour and overall liking.

We now have an opportunity to build representative models of the beef value chain and inter-relate the financial critical control points, thereby creating a FACCP. In doing so, we can more effectively communicate consumer value to participants at all levels throughout the value chain, particularly those in production and processing. This communication has the potential to significantly increase the total revenue obtained from consumers, but the ramifications of such a change throughout the value chain are unclear.

This opportunity highlights the need for a more integrated approach to understanding impacts of changes throughout the chain. By finding live animal measures that accurately reflect quality and yield, management practices can be established to improve these traits. A limitation of our current system is the lack of knowledge about genetic or management progress: we do not know if it is improving or deteriorating.

Whilst the AUS-MEAT initiative has vastly improved communication and marketing of carcases and cattle in Australia (Johnson 1994), it was established to standardise specifications using current traits, not to facilitate genetic improvement directly. Communicating any meat yield measures independent of quality is likely to encourage producers and processors to select for higher yielding animals with no consideration of any quality aspects or other equally important traits associated with calving ease and feed conversion. To be useful at the production end of the value chain, this information needs to be translated back to the live animal.

Translating back to the live animal requires traceability and communication. This traceability can also empower the person preparing the product for the final consumer, making them aware of the predicted eating outcome possibilities and therefore adjusting preparation accordingly. Modelling the various options at their disposal can provide useful insights on mitigating risks and also highlight opportunities. There has been little modelling done on the financial aspects of these critical points in the beef value chain, making it difficult to quantify their impact on the participant’s profit.

Traceability of retail product to the point of origin achieves two important functions of (a) food safety, and (b) marketing flexibility. It should enable continued market access, retention of consumer confidence and minimising the imposition of any further regulation. Essentially this is a purely logistical, process issue to resolve.

The calls by Pethick *et al.* (2010) for a new wave of structured research should be vigorously supported. The challenge is to effectively implement the MSA system and meet consumer demand by actively redefining the linkages between the value chain participants. The industry must avoid isolating the body of knowledge accumulated within the MSA methodology. The ability to manage this process effectively will determine whether or not it can remain dynamic, evolve with our understanding and thereby maintain its relevance.

Closing the information loop by improving the systems providing product traceability can provide effective feedback to all value chain participants. This could significantly improve beef industry efficiencies normally associated with the dairy and pork industries. Significant improvement can be made with better feedback throughout the value chain, thereby increasing total revenue, and asset and labour utilisation within these value chains.

To capture the gains in the ongoing search for improved processes and efficiency, the industry will likely need to look externally at how this has been achieved in other industries. Each approach requires investigation for its appropriateness to the beef value chain. When the linkages between value chain participants are effective, confidence builds and longer-term decisions are more likely to be made. Collected correctly, this information can prove invaluable for managing product margins for more effective price setting given consumer demand.

Taking care with the design of an effective pricing system can prevent undue distortion by suppliers, in terms of the quality of product they produce and supply, and through the strategies and tactics they employ (Hines *et al.* 2006). To be sustainable and effective, the appropriate scope is an intercompany one, where the view is to maximise chain surplus (profitability) by all firms in the chain working together and sharing information. By overlaying a financial model (FACCP) to the PACCP-based principles of the MSA grading method and incorporating carcase yield, we have the opportunity to encourage transactions between participants and effectively communicate consumer needs to all levels of the beef value chain.

3. EXPERIMENTAL METHODS

3.1 Introduction

A commercial dataset of information was collated in a retail environment on animals (n=3,735) over an eight-year period from 2001–2008. The retail system described the eating quality of the product offer using a matrix of the Meat Standards Australia (MSA) palatability scores by cooking method rather than traditional cut names. The general principle of the supply chain was to work backwards from the consumer to the producer and identify the most effective point in time to undertake any process that would deliver the appropriate consumer outcome.

Comprehensive commercial data was collected from on farm management and genetic details, to abattoir slaughter floor, MSA grading, boning yield information on individual carcases and individual cut yields processed into retail ready products. This required the extensive development of Microsoft Excel based spreadsheet databases enabled with Visual Basic scripting. The latter was necessary to interface with the multitude of platforms utilised throughout the chain and facilitate the necessary traceability for full yield reconciliation, product invoicing and process validation.

The methodology and processes constructed to collect the information used in this thesis was largely detailed by Polkinghorne (2006) and Polkinghorne *et al.* (2008a). Thompson (2002) outlined the critical control points that underpin MSA grading eligibility. The following description is largely based on these preceding papers and outlines the common materials and methods used in the following two chapters.

The materials and methods outline contains four sections:

1. Livestock sourcing
2. Livestock processing
3. Boning and fabrication
4. Supply and pricing to the retail store.

3.2 Materials and methods

3.2.1 Livestock sourcing

Livestock were sourced from suitably accredited MSA producers. This ensured consistency of preparation prior to slaughter regarding lairage times of less than 24 hours from original property departure, access to water until the final stages of preparation for slaughter and quiet animal handling (Thompson 2002). Cattle were all consigned directly from the property to the abattoir.

3.2.2 Livestock processing

Livestock processing was contracted at an MSA accredited abattoir with a set of agreed procedures. The philosophy and incentive to enhance eating quality was translated to detailed lairage standards, tenderstretch carcase suspension by the obturator foramen (pelvic bone) wherever possible and adjustment of low voltage electrical stimulation and chilling to achieve a desired pH-temperature relationship. Each carcase was fully traceable to the producer and was processed according to the MSA grading protocols (Ferguson *et al.* 1999, Thompson *et al.* 1999a, Polkinghorne 2006) for pre and post-slaughter handling. Several pre-conditions were met for carcases to be eligible for grading:

- Slaughter the day after dispatch
- Direct movement from farm to slaughter
- No mixing of cattle groups in the period prior to transport from the property and in the lairage
- Processing requirement that the loin (*M. longissimus dorsi*) reach a pH of 6.0 whilst the loin temperature is >12°C and <35°C (plant specific accreditation, not individual carcases)
- Subcutaneous rib fat ≥3mm (carcases <3mm were measured and recorded but not eligible to receive MSA accreditation)

The MSA model requires inputs for gender (castrate male or female), whether or not hormone growth implants have been used (Yes or No), carcase weight, skeletal ossification (using the USDA standard), marbling (using the USDA standard), subcutaneous rib fat depth, ultimate pH, carcase suspension method (AT – achilles tendon; TS – ligamentum; TX – obturator foramen) and days ageing by muscle. These inputs are used directly and interactively to generate eating quality predictions for each cooking method for individual muscles as opposed to grading the whole carcase (Polkinghorne 2006). Traceability of information was paramount for this to be achieved.

Carcase identification used a combination of cattle ear tags and electronic National Livestock Identification System (NLIS) tags correlated to the abattoir body number for each particular kill date. Hot carcase weight was defined according to the Handbook of Australian Meat (AUS-MEAT 1998). Carcases were graded by MSA trained and accredited graders. At the completion of grading, the live animal identification, slaughter floor, chiller and MSA grade information were collated and emailed directly to the fabrication facility where the carcases were being transported for boning.

Given the industry generated nature of the dataset, the distribution of both fixed effects and continuous variables was not balanced and some results need to be treated with caution. One area to note was the limited number of achilles tendon (AT) hung carcases (n=14) with no female representation, compared to tenderstretched carcases (n=1,223). The tenderstretched carcases were-hung through the obturator foramen (TX n=1,032) and sacral ligament (TS n=191). For the purpose of this analysis, these were all grouped together as TX. Figure 3.1 shows the distribution of carcase weight for each suspension method. Thirteen of the AT hung and twenty-five TX animals were over 300kg HSCW. Whilst there were limited numbers of AT animals, there was sufficient overlap for analysis. The caution necessary when interpreting these results is whether or not the differences remain consistent over a wider range of carcase weights.

There were 1,199 animals with an estimated percentage of *Bos indicus* (EPBI) of 0%, compared to 38 with 18.5% *Bos indicus* content animals. These animals were from one supplier and were very similar in mean carcase weight, shown in Figure 3.2. The 0% EPBI averaged 241kg and the 18.5% EPBI 240kg. The SMY% was 0.5% higher for 18.5% EPBI at 61.9% compared to 61.4% for 0% EPBI. The marbling scores (Umb) were very similar at 309 for 0% EPBI and 303 for 18.5% EPBI. The ossification scores (Uoss) were slightly higher for the 0% EPBI at 140 compared to 132 for the 18.5% EPBI. This could be partially explained by the lack of any females in the 18.5% EPBI.

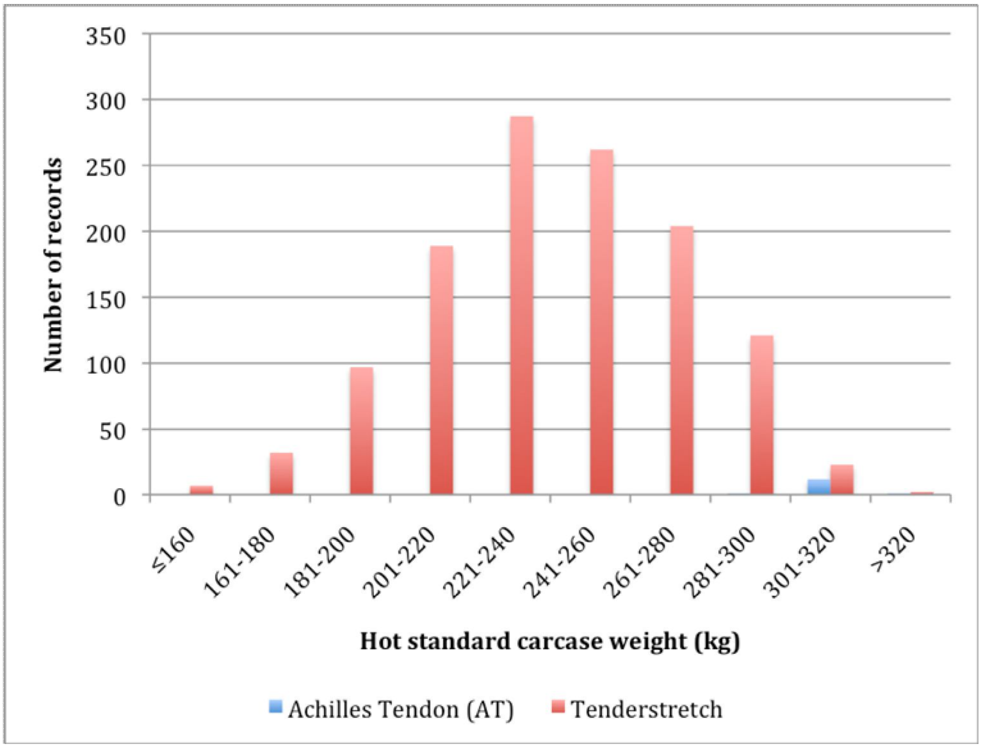


Figure 3.1: Distribution of carcase weight for each suspension method (achilles tendon and tenderstretch)

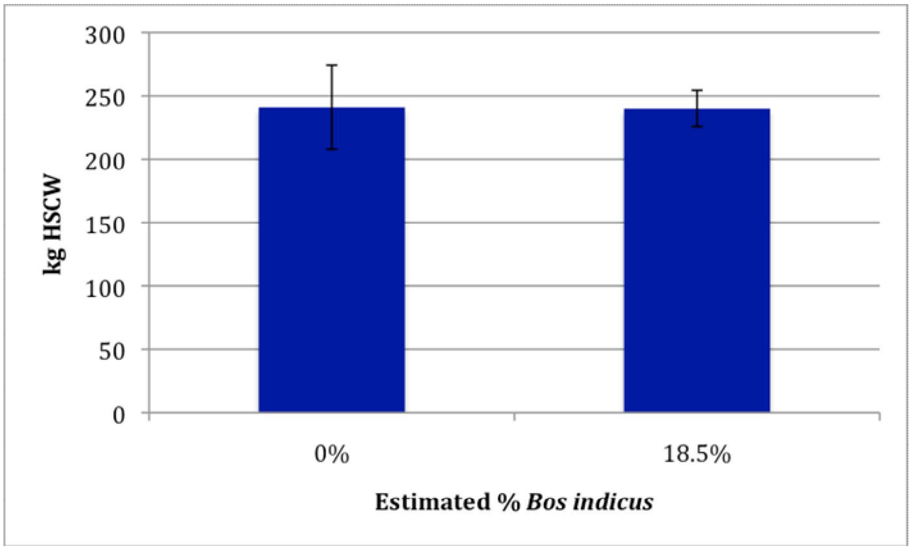


Figure 3.2: The average hot standard carcase weight (HSCW) for estimated percentage *Bos indicus* groups (0% and 18.5%).

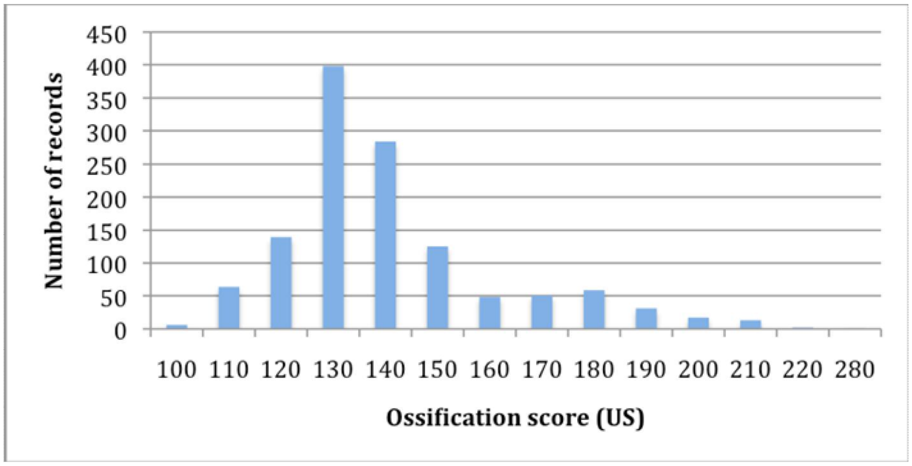


Figure 3.3: Distribution of ossification scores within the dataset (n=1,237)

The skewed distribution of Uoss is shown in Figure 3.3. Uoss had a mean of 141 and a range of 100–280. Females had higher Uoss (161 compared to 133), Umb (324 compared to 303) and subcutaneous rib fat (6.8mm compared to 6.1mm), as opposed to castrated males respectively. Castrated males did have a higher average carcase weight of 249kg compared to females averaging 220kg. These gender differences are largely as expected.

Umb was assessed using the USDA standard for intramuscular fat in 10-point increments. In this system, a score of 330 approximately equates to an AUS-MEAT marble score 1,430 AUS-MEAT marble score 2, 530 AUS-MEAT marble score 3 and so on. The Umb scores within the data were skewed as shown by Figure 3.4.

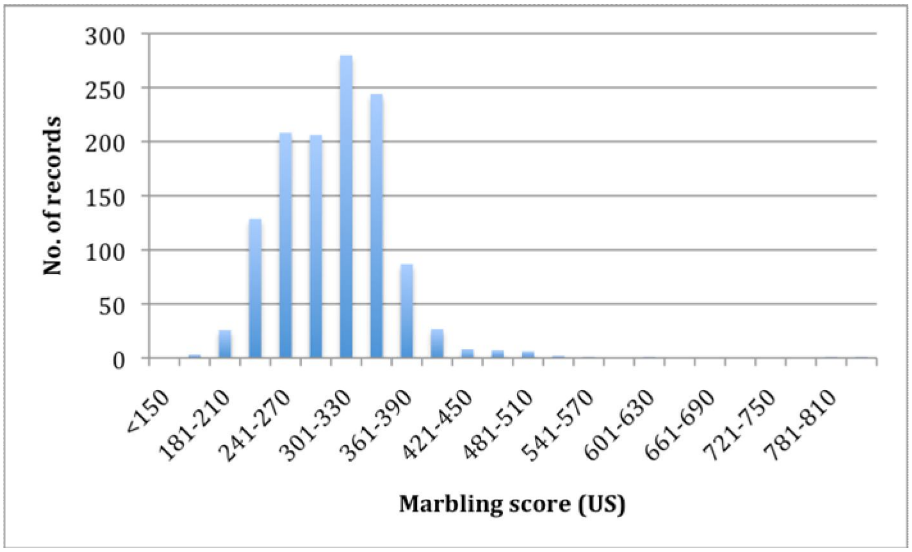


Figure 3.4: Distribution of marbling scores (US)

3.2.3 Boning and fabrication

Primals were trimmed to commercial specifications (AUS-MEAT 1998) and weighed individually. All weights of trims, waste, fat and bone were also recorded for each individual animal and stored in a purpose built inventory database to maintain product traceability to point of origin as a live animal.

To differentiate primal records for traceability throughout the process, AUSMEAT cut references were utilised. Where there was no specific AUSMEAT reference available, the Meat Standards Australia (MSA) reference was utilised, and where there was no specific MSA reference, a Polkinghornes (POLK) defined cut reference was utilised as individual stock-keeping units (SKUs).

This inventory of cuts was then further processed into retail ready items or sold into the wholesale market. Those processed into retail ready items were done so in batches and full yield records were obtained. This information included primary and secondary items produced from each primal batch being processed, as well as any associated trims, bone, fat, waste and loss. The cutting loss or gain was calculated as the deduction of all other quantities from that of the source material (Polkinghorne *et al.* 2008a).

3.2.3.1 Boning stratification groups and boning interval

The 25 primal cuts recorded in common amongst all boning stratification groups are listed in Table 3.1. Where possible, specific muscle identification is provided as well as the AUSMEAT primal reference that details where the cut is derived from (AUS-MEAT 1998).

A boning stratification group consisted of animals dissected to the same primal specification, and therefore contained the same list of SKUs. Table 3.2 lists the six primal cuts that differentiate the boning stratification groups. Boning stratification columns with cuts listed as a “1” have had that cut identified as an SKU for that particular group. These differences in boning specifications identify the various primal combinations used as fixed effects for the analysis of yield measurements. Boning stratification number 224 is the only one that recorded all 31 cuts identified in Table 3.1 and Table 3.2 signified by “1” against each individual cut.

There were 10 variations of boning stratification groups. Cuts listed as “0” have not been identified as a separate SKU for that boning stratification, instead being processed into trim, bones or waste and fat as appropriate.

Table 3.1: The primal cuts collected on all carcases (n=1,237)

Cut Description	**Muscle**	**AUSMEAT Primal Ref**	**Primal**	**MSA or *POLK* Cut Ref**
Tenderloin Fillet	*M. psoas major*	AM2150	Tenderloin	TDR062
Tenderloin Meat	*Combination of muscles*[a]	AM2150	Tenderloin	*ZZZ011*
Bare Striploin	*M. longissimus dorsi*	AM2140	Striploin	STR045
Rump Cap	*M. biceps femoris*	AM2080	Rump	RMP005
Rump D Muscle	*M. gluteus medius*	AM2080	Rump	RMP131
Rump Eye Muscle	*M. gluteus medius (eye portion)*	AM2080	Rump	RMP231
Rump Tail (Tri Tip)	*M. tensor fasciae latae*	AM2080	Rump	RMP087
Outside Flat	*M. biceps femoris*	AM2020	Silverside	OUT005
Eye Round	*M. semitendinosus*	AM2020	Silverside	EYE075
Osso Bucco	Combination of muscles[b]	AM2360	Hind Shank	*ZZZ004*
Eye of Knuckle	*M. rectus femoris*	AM2060	Thick Flank	KNU066
Knuckle Undercut	*M. vastus intermedius*	AM2060	Thick Flank	KNU098
Knuckle Cover	*M. vastus lateralis*	AM2060	Thick Flank	KNU099
Knuckle Side	*M. vastus medialis*	AM2060	Thick Flank	KNU100
Topside (Cap Off)	Combination of muscles[c]	AM2000	Topside	AM2001
Topside Cap	*M. gracilis*	AM2000	Topside	TOP033
Denuded Cube	*M. longissimus dorsi*	AM2220	Rib Set	CUB045
Spinalis	*M. spinalis dorsi*	AM2220	Rib Set	SPN081
Bolar Blade	*M. triceps brachii caput longum*	AM2300	Blade	BLD096
Oyster Blade	*M. infraspinatus*	AM2300	Blade	OYS036
Rodz Pieces	Combination of muscles[d]	AM2561	*n/a*	*ZZZ001*
Trim 75VL	Combination of muscles[e]	AM2561	Trimmings	*BfTr75*
Trim 85VL	Combination of muscles[e]	AM2561	Trimmings	*BfTr85*
Bones	n/a	n/a	*n/a*	*BonesO*
Waste & Fat	n/a	AM2565	Trimmings - fat	*WstFat*

[a] Tenderloin meat consisted of *M. psoas major*; *M. psoas minor*

[b] Osso Bucco consisted of *M. peronaeus tertius; M. extensor digitorum longus; M. extensor digiti tertii proprius (pedis)*

[c] Topside (Cap Off) consisted of *M. adductor femoris; M. semimembranosous; M. pectineus*

[d] Rodz Pieces consisted of *M. psoas major*; *M. longissimus dorsi*; *M. biceps femoris*; *M. spinalis dorsi*; *M. infraspinatus* only when they achieved Meat Standards Australia MQ4 score of >63.5 for grilling

[e] Trim 75VL & Trim 85VL consisted of 75% visually lean and 85% visually lean body trim respectively

Table 3.2: Primal cuts that differentiate the boning stratification groups

Cut Description	AUSMEAT Primal Ref	Primal	Cut Ref	Boning Stratification Groups									
				157	188	191	195	199	203	212	216	220	224
Heel	AM2020	Silverside	OUT029	0	1	1	1	1	1	1	1	1	1
Thin Flank	AM2200	Thin Flank	AM2200	0	0	0	0	0	0	1	1	1	1
Chuck Tender	AM2310	Chuck Tender	CTR085	0	0	0	0	1	1	0	1	1	1
Brisket	AM2320	Brisket	AM2320	0	0	0	1	0	1	0	0	1	1
Fore Shin	AM2360	Fore Shin	FQshin	0	0	0	0	0	0	0	0	0	1
Polk Chuck	AM2260	Chuck	ZZZ002	1	0	1	1	1	1	1	1	1	1

Note: "1" signifies the cut was taken and recorded as a separate stock-keeping unit (SKU)

Table 3.3 shows two-thirds of the animals were boned using stratification 220, which separated all the muscles except forequarter shin (Cut Description "Fore Shin" in Table 3.2). Another 11% used stratification 216 where the forequarter shin and brisket were not separated. The balance of animals were distributed through the remaining eight stratifications that did and did not segregate the heel muscle (OUT029), thin flank (AM2200) chuck tender (CTR085), brisket (AM2320), forequarter shin (FQshin), Polkinghorne specified chuck (ZZZ002) and RODZ®(ZZZ001) outlined in Table 3.2. The unbalanced nature of the industry-generated data is highlighted by the skewed distribution of records in Table 3.3.

Table 3.3: Boning stratification group numbers

Boning stratification group	Number of carcases
157	24
188	22
191	65
195	26
199	18
203	62
212	22
216	143
220	826
224	29
n	1237

Figure 3.5 shows the percentage of carcases boned each day after their slaughter. Over two-thirds of the animals were boned within a week of slaughter and 97% within eleven days. Boning Interval numbers dropped considerably after 11 days post slaughter with only 3% of animals boned between 11–17 days (inclusive) and therefore better considered as one group.

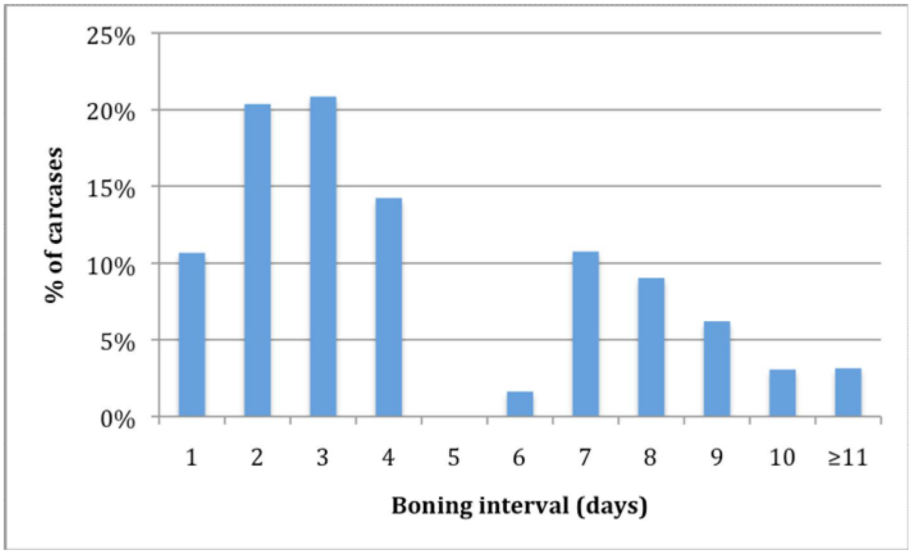


Figure 3.5: The percentage of carcases boned per day post kill date (boning interval)

3.2.3.2 Fabrication Inventory

When carcases were graded, an eating quality score (MQ4) was calculated using the MSA grading model (2004 vs 1.0) for each muscle, at five days ageing for each of six cooking methods (GRL – grilling; RST – roasting; SC2 – slow cooking for 2hrs; SFR – stir-frying; TSL – thin-slicing; CRN – corning). This information was loaded into a purpose built Excel database.

Consistent with the base principle of traceability, the yield all products generated from further processing was recorded through to invoice, enabling pricing information to be captured.

3.2.3.3 Inventory utilisation and value

For the purpose of these analyses, the utilisation was standardised for each primal. In Table 3.4, each row represents the yield of primary and secondary product, trim, bone, fat and waste cutting loss for each primal and sums to 100%.

The traceability throughout the processing stages facilitated communication of information throughout the value chain. Because of this traceability and record keeping, a value for each primal could be established. This enabled value translation between each participant of the supply chain.

Table 3.4: Yield allocation for processing primals into retail ready products

Cut Description	Cut Reference	Cooking Method[a]	Primary Yield %[b]	Secondary Yield %[c]	Trim %	Bone %	Fat %	Waste Cutting loss %
Tenderloin Fillet	TDR062	Grill S	95.4	2.8[1]			1.8	
Butt Tenderloin	AM2170	Grill S	79.5		9.8		1.9	8.8
Tenderloin Meat	ZZZ011	Grill R	93.0		5.2		1.8	
Bare Striploin	STR045	Grill S	91.0		6.6			2.4
Rump Cap	RMP005	Grill R	34.5	50.8[2]	12.5			2.2
Rump D Muscle	RMP131	Grill S	79.2	8.3[3]	11.0			1.5
Rump Eye Muscle	RMP231	Grill S	82.1		15.7			2.2
Rump Tail (Tri Tip)	RMP087	Stir-Fry	74.5		22.5			3.0
Outside Flat	OUT005	Roast	69.1		29.4			1.5
Eye Round	EYE075	Roast	78.3		19.0			2.7
Heel	OUT029	Stir-Fry	97.5		1.4			1.1
Osso Bucco	ZZZ004	Slow cook	73.4	11.2[4]			14.5	0.9
Eye of Knuckle	KNU066	Roast	82.5	4.4[3]	12.2			0.9
Knuckle Undercut	KNU098	Stir-Fry	67.6		30.7			1.7
Knuckle Cover	KNU099	Roast	70.8	4.4[5]	23.6			1.2
Knuckle Side	KNU100	Stir-Fry	72.2		26.1			1.7
Topside (Cap Off)	AM2001	Roast	71.0	7.1[5]	20.0			1.9
Topside Cap	TOP033	Slow cook	72.6		26.5			0.9
Thin Flank	AM2200	Stir-Fry	62.8		33.1			4.1
Denuded Cube	CUB045	Grill S	81.0		17.1			1.9
Spinalis	SPN081	Grill S	81.6		18.9			-0.5
Bolar Blade	BLD096	Grill S	43.5	19.4[5]	36.1			1.0
Oyster Blade	OYS036	Grill R	21.9	60.8[2]			14.8	2.5
Chuck Tender	CTR085	Slow cook	67.4		31.4			1.2
Brisket	AM2320	Slow cook	36.4		61.7			1.9
Fore Shin	FQshin	Slow cook	80.0		10.0		8.0	2.0
Polk Chuck	ZZZ002	Slow cook	68.3		29.6			2.1
Rodz Pieces	ZZZ001	Grill R	46.9	31.3[2]	17.0			4.8
Trim 75VL	BfTr75	N/A			100.0			
Trim 80VL	BfTr85	N/A			100.0			
Trim 85VL	BfTr80	N/A			100.0			
Bones	BonesO	N/A				100.0		
Waste & Fat	WstFat	N/A						100.0

Where cooking method[a]: Grill S = Grilling steak cut 25mm thick; Grill R = RODZ pieces 20mmX20mmX75mm; Roast = whole portions suitable for oven roasting; Slow Cook = 20mmX20mmX20mm diced cubes of meat suitable for casserole cooking; Stir-fry = 10mmX10mmX75mm pieces of meat suitable for stir-frying; N/A = no cooking method applicable for this cut;

Primary yield[b]: primal was cut to optimise yield of product with associated cooking method;

Secondary yield[c]: second priority product - [1]RODZ grill; [2]Grill K = diced kebab cubes 20mmX20mmX20mm; [3]Stir-fry; [4]Gravy beef 20mmX20mmX20mm diced cubes; [5]Casserole diced cubes 20mmX20mmX20mm

3.2.4 Supply and pricing of retail cuts

The value calculation was a function of retail price by the quantity of retail ready product, trim, fat and bone generated during the preparation of the item. Appendix 1 outlines the retail products and their pricing for each of the quality grades.

The wholesale prices used were calculated as 65% of the retail value achieved for the cut, based on the methodology outlined in Polkinghorne (2006) and Polkinghorne *et al.* (2008a) as a reasonable and sustainable price point by assessing the market forces of supply and demand. Whilst 65% was applicable specifically for the Polkinghornes business, it may need to be varied for other supply chains. Prices paid for each primal ranged from $2.94 per kilogram for *M. gastrocnemius* (OUT029) to $17.03 per kilogram for *M. psoas major* (TDR062) as outlined in Appendix 2 for each primal to calculate carcase value. Carcase value was determined by summing the total value of the component primals, trim, fat and bone each animal was boned into.

3.2.4 Data analysis

In subsequent chapters, only animals dissected into the specific primal SKUs outlined in Table 3.1 and Table 3.2 that had retail yield information records, were kept for analyses (n=1,626). This data was screened for outliers (n=23), ungraded carcases (n=9) and obvious errors were removed from the dataset. Total carcase yields less than 95% (n=1) and exceeding 102% (n=2) were removed; a further 355 records were incomplete, not having a boning date and therefore no boning interval. This left 337 females and 900 castrated males remaining (n=1,237) that were processed into ten boning stratifications.

Animals within the dataset were processed from 16th September 2002 to 4th September 2006 (inclusive). In order to test interactive effects, the Julian day was scaled back equating 16th September 2002 to day "1" through to 4th September 2006 as "1,450". There were 114 kill dates within the dataset usually consisting of one supplier per day.

4. THE EFFECT OF YIELD ON CARCASE VALUE

4.1 Introduction

The total revenue of an animal is determined by the quantity and price per kilogram of its components. While the offal, hide, blood, bones, tendons etc. are important contributors to revenue for the processor, they are rarely discussed unless market forces have had a large impact on processing returns and an adjustment is made to their payment systems. The revenue from these components is usually averaged over all animals and embedded in the slaughter charge. Therefore, the revenue provided by the carcase is essentially driven by the yield of saleable products derived from the carcase in the form of primals, trims, fat and bone.

The measures of yield vary according to their definition of meat, trim, fat, bone and loss constituting the numerator tissue of interest, and generally carcase weight as the denominator. Whilst other studies by Charles (1964), Berg and Butterfield (1976) and Ball and Johnson (1989) have looked at the accuracy of tissue measures reflecting measures of carcase yield, they have not investigated how these tissues reflect carcase value. This chapter examines the relationship between six measures of carcase yield and carcase value after adjustment for fixed effects by gender, boning stratification group and boning interval.

The six yield measures investigated were percentage of:

- bone (BoneYld)
- yield lost (LossYld)
- primal yield (PrimYld)
- trim yield (TrimYld)
- waste and fat trim (WstFat)
- saleable meat yield (SmyYld)

It was thought saleable meat yield percentage (SMY%) would be a more stable measure than either of the two components (PrimYld and TrimYld) given the interchange between them. Whilst there are a number of ways yield can be communicated, these particular measures have discrete definitions that enable their measurement within large-scale processing facilities. Plant specific situations may make it easier to measure all waste off a carcase; or all bone off a carcase; or all primals off a carcase. By investigating the contribution each measure is likely to provide, we can determine whether or not they are appropriate.

Measuring each of the five components of carcase yield (BoneYld; LossYld; PrimalYld; TrimYld; WstFat) pose different challenges relating to the collation of information and traceability back to the individual carcase. Whilst the calculation of yield lost (LossYld) may appear easy, everything else generated from the carcase needs to be traced and deducted from the original carcase weight for this yield measure to be generated. Both the trim yield (TrimYld) and waste and fat (WstFat) yields require all primals are weighed to be accurate and meaningful.

Determining the most effective measure of yield in relation to carcase value has significant implications for commercial enterprises. The boning process flow, workspace design, packaging, labelling and software needed to capture the necessary information in a timely way are different depending on the outcome required. This will impact the infrastructure needed that in turn influences the level of capital expenditure required.

The yield definition used needs to reflect carcase value. When a yield measurement is used in grid payment systems to determine the carcase value, the information and market signal need to be correct to have the desired impact on the behaviour of supply chain participants over the longer term. Understanding the definition of yield and its relationship with value is very important. Producer payments will be impacted, management practices adjusted and genetic performance of breeding stock evaluated (Drennan *et al.* 2008) thereby impacting future returns.

The objective of this analysis was to identify the combination of primals, trim, waste fat, bone and loss, expressed as a percentage of the carcase, which most effectively described the value of the carcase. This measure of yield will be used in subsequent chapters as a covariate with carcase quality traits to partition out the relationships between value and eating quality compared to value and yield.

4.2 Materials and methods

The data used in these analyses has been described in detail in Chapter 3. Briefly, this data contained on-farm management and genetic details, abattoir slaughter floor details, MSA grading, boning yield information on individual carcases, as well as individual cut yields processed into retail ready products. In addition, there were six yield measurements analysed. The carcase weight was grouped into five component "tissues of interest" (Pomar *et al.* 2007), namely primals, trims, waste and fat, bone and loss. The sum total of these five yields was always 100%, when expressed as a percentage of carcase weight because the loss percentage was calculated as 100% less the sum of primal, trim, waste bone and fat percentages. This was calculated by dividing the tissue of interest in kilograms (numerator) by hot dressed carcase weight in kilograms (denominator).

These five yield measures were chosen because of their discrete segregation of carcase components and industry wide application and understanding. Saleable meat yield (SMY%) was the sixth yield percentage tested, generated by dividing the combination of primal and trim yields in kilograms (numerator) by hot dressed carcase weight in kilograms (denominator).

For this analysis, retail product prices outlined in Appendix 1 were related back to wholesale by a fixed margin of 0.65 in keeping with the broad methodology outlined in Polkinghorne (2006) and Polkinghorne *et al.* (2008a). These retail product prices were used in conjunction with standardised yield percentages for retail product, trimming, fat and bone outlined in Table 3.4 generated during preparation. The resulting wholesale primal price per kilogram ($/kg) was outlined in Appendix 2. This price was then multiplied by the relevant primal weight to determine a total primal value. By combining the primal values with the value of carcase trims, fat and bone, a total carcase value was determined. Dividing the total carcase value by the carcase weight resulted in the $/kg value used as the dependent variable.

Statistical analysis

A generalized linear model (SAS 1997) was used to analyse the value trait ($/kg HSCW) as the dependent variable. The model consisted of fixed effects for gender, boning stratification, supplier, estimated percentage *Bos indicus* (EPBI) and boning interval. The model also had covariates for kill day (as both linear and curvilinear effects) with one of the six measures of yield (SMY percent, primal yield percent, trim yield percent, bone yield percent, waste yield percent, loss yield percent).

Logically, suspension method was not significant in any model (P>0.05) and therefore not included in the final model. Whilst suspension method changes the shape of some primals and therefore cutting lines, it should not impact volume by any measure.

The unbalanced nature of the industry dataset restricted the testing of many interactions. For example there were no females hung by the achilles tendon (AT) and two boning stratification groups consisted only of castrated males with a third group containing very low numbers which precluded the testing of a gender x hang interaction. However, as yield was measured with each animal, first order interactions using each yield measure as the nominated covariate were tested.

4.3 Results

Mean data for the traits used in the analyses are summarised in Table 4.1. Anecdotal evidence suggested the range of carcase weight, ossification (Uoss), marbling (Umb) and rib fat were representative of animals processed for the Australian domestic market. The average carcase was 241kg, two-thirds of the animals between 208 and 274kg HSCW and averaged 6.3mm of subcutaneous rib fat. Carcase Uoss averaged 140 and Umb averaged 309, roughly equating to 0.9 AUSMEAT marble score.

Table 4.1: Means, standard deviation (stdev) and range for carcase traits used in the analysis (n=1,237)

			Range	
Variable	Mean	Stdev	Min	Max
HSCW (kg)	241	32.62	129	333
Ossification score	141	21.43	100	280
Marbling score	309	57.73	150	820
Rib Fat (mm)	6.3	2.45	3	18
Ultimate pH	5.58	0.08	5.31	5.70
Wholesale value ($/kg HSCW)	5.44	0.30	4.64	6.58
Julian kill day	656	411	1	1450

At the average carcase weight there was a $468 difference between the minimum and maximum value, a range of $1.94/kg HSCW or 36%. Given the producer payment was 65% of wholesale value, this equated to $1.26/kg HSCW or $304 at the producer level.

The mean, standard deviation and range of the six measures of yield recorded in the dataset are shown in Table 4.2. There was a large range in each measure of yield. SMY% had the lowest coefficient of variation at 5.5% compared to 8.1%, 13.6%, 6.6%, 23.9% and 58.3% for primal, trim, bone, waste and fat and loss yields respectively.

Table 4.2: The mean, standard deviation (Stdev) and range of the six carcase yield percentages analysed

			Range	
Yield Measure	Mean	Stdev	Min	Max
Saleable meat yield	61.5	3.4	52.6	70.8
Primal yield	33.5	2.7	23.9	40.3
Trim yield	28.0	3.8	17.7	39.0
Bone yield	21.1	1.4	16.0	26.7
Waste yield	16.3	3.9	6.2	27.4
Loss yield	1.2	0.7	-2.0	3.7

Table 4.2 shows the model containing the SMY% as a covariate explained the most variation with the full model having an R^2 value of 0.85 and root mean square error of 0.12. SMY% was highly significant ($P<0.001$) and clearly the most influential variable accounting for over 90% of the explained variation within that model. The waste yield percentage model had the second highest R^2 value of 0.72, followed by the trim yield and primal yield models with R^2 values of 0.69 and 0.42 respectively. The SMY% is a combination of the trim and primal yields and was much more effective when considered as one number than either of the two individual components. Table 4.3 outlines the *F*-ratios associated with the discrete and continuous variables.

Table 4.3: The *F*-ratio for the significance of fixed effects (gender, boning stratification, supplier, estimated percentage of *Bos indicus* and boning interval) and covariates (linear and curvilinear effects for kill date), along with different yield measurements on carcase value ($/kg).

	NDF,DDF	***F*-ratios**					
Discrete variables:							
Gender	1,1246	64.01***	94.44***	1.15 N.S.	10.87**	0.08 N.S.	0.35 N.S.
Boning strat no.[1]	9,1246	22.12***	12.26***	22.34***	24.54***	3.71**	3.57**
Supplier	21,1246	9.82***	6.21***	10.92***	16.04***	15.70***	15.16***
EPBI[2]	1,1246	6.81**	0.51 N.S.	0.00 N.S.	0.46 N.S.	2.07 N.S.	2.50 N.S.
Boning interval	12,1246	2.39**	3.37**	3.54**	1.11 N.S.	2.15*	3.29**
Continuous variables:							
Saleable meat yield %	1,1246	4628.43***					
Waste yield %	1,1246		1877.46***				
Trim yield %	1,1246			1540.12***			
Primal yield %	1,1246				279.25***		
Loss yield %	1,1246					11.10**	
Bone yield %	1,1246						0.01 N.S.
Julian kill date	1,1246	236.48***	146.72***	67.00***	58.01***	31.34***	31.18***
JulKill*JulKill[3]	1,1246	53.64***	44.98***	15.16**	41.86***	27.84***	27.18***
Coefficient of Determination (R^2)		0.85	0.72	0.69	0.42	0.29	0.28
Root Mean Square Error		0.12	0.16	0.17	0.23	0.26	0.26

N.S.,*, **, *** not significant, p<0.05, 0.01, 0.001 respectively

Boning Strat No.[1] (Boning stratification number); EPBI[2] (Estimated percentage *Bos indicus*); JulKill*JulKill[3] (Julian kill day curvilinear covariate);

The data for Julian kill date (P<0.001) was confounded with other terms in the model and could only be presented adjusted for gender and including SMY% as a covariate. The predicted means for each kill date are shown in Figure 4.1 with the curvilinear effect that best fits the data. Carcase value decreased over time when adjusted for gender and at the same SMY%.

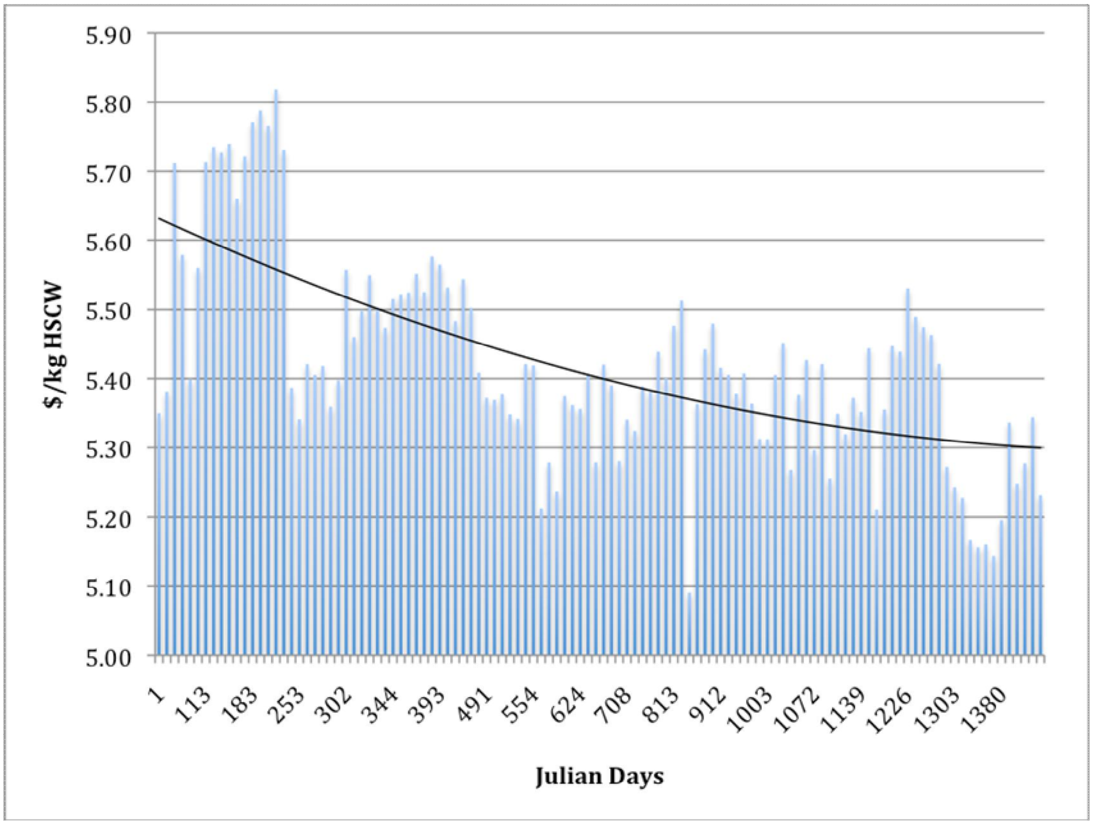


Figure 4.1: Predicted mean values in $/kg hot standard carcase weight for each of the 114 kill dates during the 1,450 Julian day time range. Predicted means adjusted for gender as a fixed effect and saleable meat yield percentage as a covariate.

Using the SMY% model, Figure 4.2 shows females were worth $0.08/kg HSCW more than castrated males and Figure 4.3 shows animals with 0% *Bos indicus* were worth $0.06/kg HSCW more than those with 18.5% *Bos indicus*. Whilst the *Bos indicus* result is significant, the limited number (n = 38) of 18.5% *Bos indicus* animals would require further validation with a balanced experimental design.

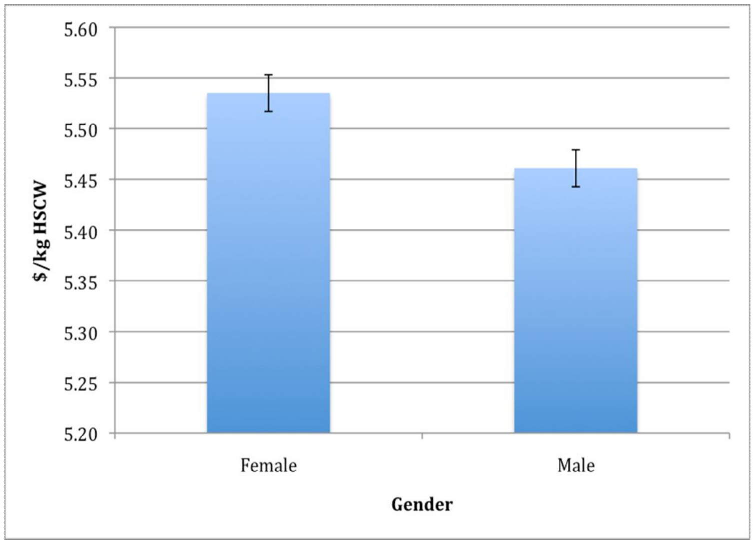


Figure 4.2: Predicted mean value of gender in $/kg hot standard carcase weight adjusted for fixed effects (boning stratification group, supplier, estimated percentage of *Bos indicus*, boning interval) and covariates (saleable meat yield percentage, linear and curvilinear effects for Julian kill day).

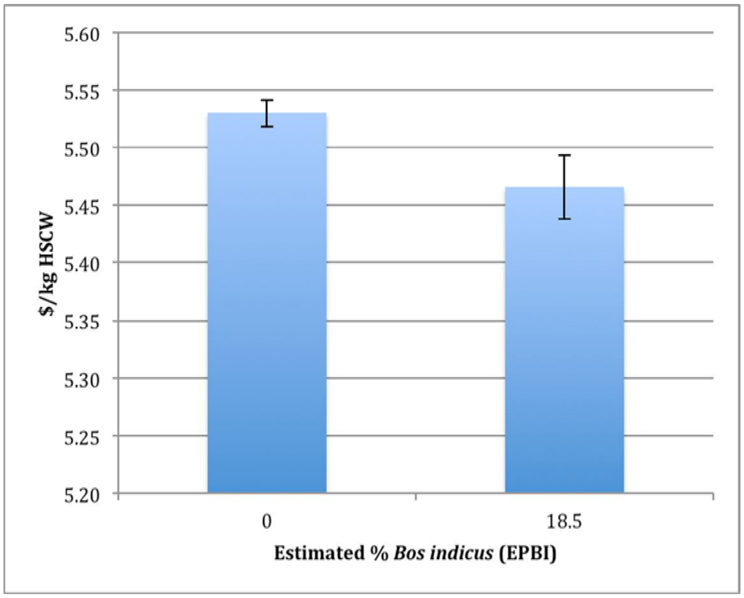


Figure 4.3: Predicted mean value of estimated percentage *Bos indicus* (EPBI) in $/kg hot standard carcase weight adjusted for fixed effects (gender, boning stratification group, supplier, boning interval) and covariates (saleable meat yield percentage, linear and curvilinear effects for Julian kill day).

There were significant differences between suppliers, Figure 4.4 shows the $0.55/kg HSCW range between the highest and lowest producer least square means after adjusting for other terms. This variation is likely due to a combination of genetic and environmental factors influencing yield and value.

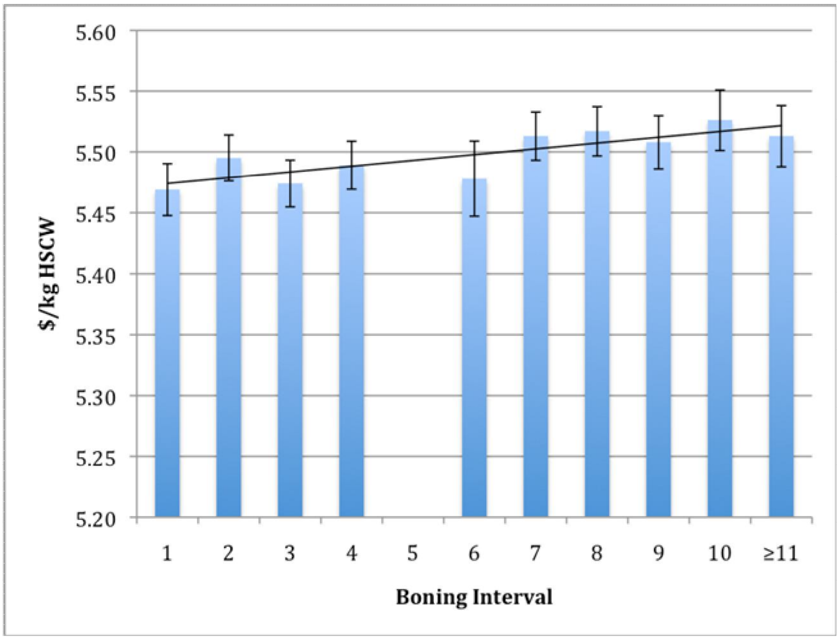


Figure 4.4: Predicted mean value of suppliers in $/kg hot standard carcase weight adjusted for fixed effects (gender, boning stratification group, estimated percentage of *Bos indicus*, boning interval) and covariates (saleable meat yield percentage, linear and curvilinear effects for Julian kill day) with fitted trend-line through the means.

Whilst the *F*-ratio of supplier effect was relatively small, it was significant (p<0.0001) with 22 degrees of freedom. The boning interval *F*-ratio was less than a third of the estimated percentage *Bos indicus*, with lower significance (p<0.01). When compared to SMY%, the supplier, *Bos indicus* and boning interval traits were of relatively little consequence in the overall description of carcase value.

Boning interval was significant (p<0.01), but with the lowest *F*-ratio of 2.59. When considering the highest *F*-ratio was SMY% (p<0.001) at 4628.43, it is a relatively small contribution to the predictive capacity of the final model. Figure 4.5 shows predicted means for boning interval. There was a positive trend for value of the carcase to increase with increased boning interval.

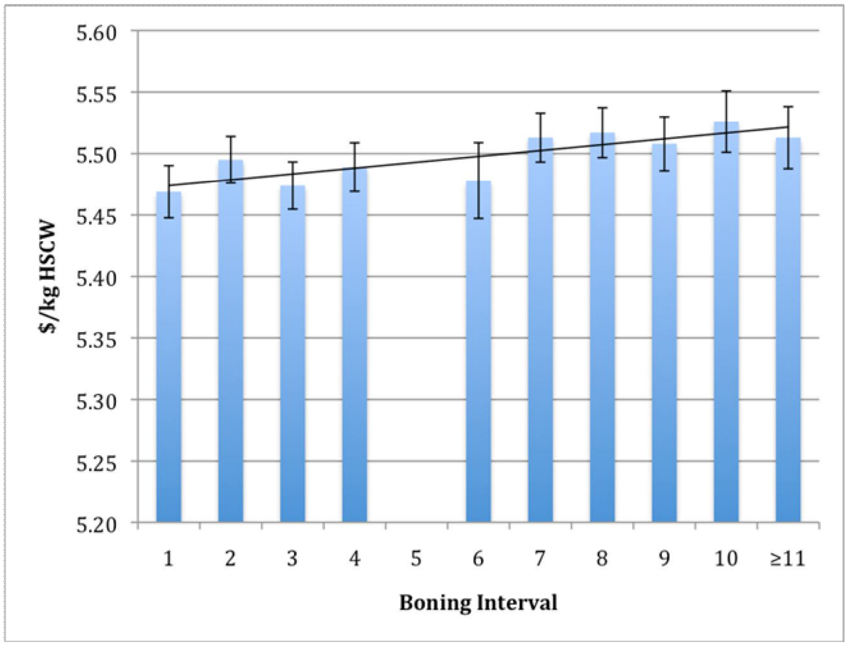


Figure 4.5: Predicted value means in $/kg hot standard carcase weight for boning interval (days) adjusted for fixed effects (gender, boning stratification group, supplier, estimated percentage of *Bos indicus*) and covariates (saleable meat yield percentage, linear and curvilinear effects for Julian kill day) with fitted trend-line through the means.

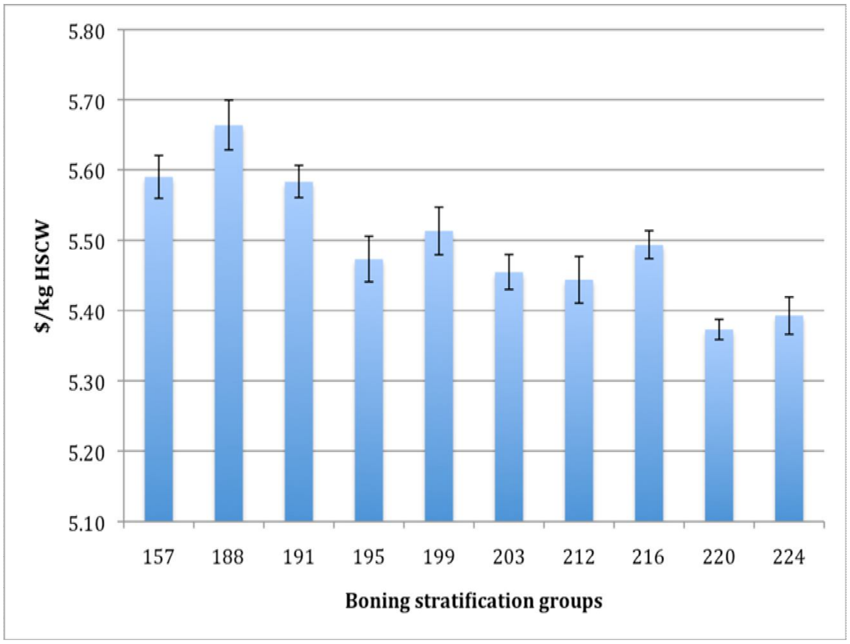


Figure 4.6: Predicted mean values in $/kg hot standard carcase weight for boning stratification groups adjusted for fixed effects (gender, supplier, estimated percentage of *Bos indicus*, boning interval) and covariates (saleable meat yield percentage, linear and curvilinear effects for Julian kill day).

The predicted means for boning stratifications shown in Figure 4.6 represent the relative change in value between different boning specifications. The least square means range from $5.37 for group 220 to $5.66 for group 188. The changes between boning stratification represent differences in how the carcase was broken down and the subsequent differences in value.

4.4 Discussion / further work

SMY% had the strongest relationship with carcase value ($/kg HSCW) when compared to other measures of yield. Given SMY% is such a significant determinant of value, there is a compelling need to ensure it is communicated throughout the value chain.

Despite measuring the SMY% of a production run being achieved relatively easily, assigning it to individual animals is difficult because it involves tracing the weight of all primals and trims to their original carcase. To collect this data, systems were purpose built and a collective will to obtain the information allowed it to become a natural part of the culture. SMY% information was routinely collected and in this analysis was valued at $0.09 per percentage point SMY%. This equated to a difference of $0.58/kg HSCW or $140 for one standard deviation either side of the mean (61.5% SMY) for the average carcase (241kg).

Measurement of SMY%

The SMY% covariate is a combination of carcase primals and trims. The primal and trim yields were expressed as a percentage of HSCW. They are negatively correlated, as one increases the other decreases. By looking at the overall combination using SMY% a more stable measure was obtained as evidenced by the lowest coefficient of variation.

The three primary components of the beef carcase are muscle, fat and bone tissue. A limitation of this dataset was the unknown fat content within the SMY%. Previous studies found that as the subcutaneous fat thickness increased on the carcase, so to did the percentage of fat in SMY% (Ball and Johnson 1989, Johnson 1996). However, in this study the dependent variable was calculated using the actual value of each primal and therefore, even if it were available, the fat component of the SMY% was not considered relevant to these analyses. Further work could investigate the threshold values of fat within individual primals that would influence purchasing decisions.

Julian kill date

Due to the confounded nature of the data for Julian kill date, it is difficult to identify any confident explanation. One plausibile explanation of animal value decrease over time could be the changing personnel, and their interpretation and application of boning procedures. If this information was available it would have been included as a fixed effect, but the data was unavailable. While this effect is not fully understood, it was included as a covariate due to its significance ($p<0.0001$).

Gender

Gender had a significant impact on value when adjusted to the same SMY%. Entire males develop relatively higher proportion of lower value forequarter primals compared to castrated males and females while females fatten at lighter weights compared to males (Berg and Butterfield 1976). Small effects of gender on tissue distribution within the carcase is a possible explanation for females being worth $0.07/kg more than castrated males, after adjusting for SMY%.

Boning stratification groups

The objective is to always maximise the total revenue generated from a carcase. To ensure effective utilisation of capital infrastructure and labour, decisions on carcase allocation for particular boning groups have to be made in a timely and effective manner. These decisions require knowledge of anticipated primal demand as well as the dissection possibilities, usually combined with the chiller assessment information. Based on anticipated demand, carcases are grouped together to form “runs” that will be boned out into the same primal specifications.

The fundamental difference in the Polkinghorne methodology was an unlimited combination of boning stratification groups compared to the standardised boning groups implemented across Australia. This allowed unlimited flexibility to break down the carcase into the most efficient primal variants for further processing considerations, such as retail roast preparation, diced casserole cubes for kitchen meal production or retail stir-fry strips for example.

This analysis showed the predicted means for boning stratification groups ranged $0.28/kg HSCW. The differences in predicted means represent the value between different boning stratifications. For example, boning stratification 216 has all the cuts listed as a “1” in Table 3.1 and Table 3.2 with a predicted mean of $5.49/kg HSCW shown in Figure 4.6. Boning stratification 212 has a predicted mean of $5.44 and has the same cuts as boning stratification 216 except the chuck tender (CTR085), it was not processed into a separate SKU. Therefore, processing the chuck tender into a separate SKU has increased the predicted mean by $0.05/kg HSCW.

The yield inter-relationships between the primary "mother" primal grouping and subsequent "daughter" derivatives produced from it need to be more closely understood. If this is a linear relationship, between each step of the process, ultimately to the final consumers fork, adjustments could be made to a standard point of reference. This would facilitate effective modelling and enable benchmarking or indexing opportunities to provide more accurate feedback to suppliers at each step of the value chain.

Estimated percentage of Bos indicus

Animals with 0% *Bos indicus* content were worth $0.06/kg HSCW more than those with 18.5% *Bos indicus* content. Whilst this effect is significant, this result should be treated with caution and used as a guide only given the limited number of records (n=38) and the fact they were from one supplier. A balanced design experiment covering a wider mix of *Bos indicus* content animals is required to validate this finding.

Boning intervals

The reason boning interval is positive is that it is adjusted to the same SMY%. If SMY% is left out of the analysis the coefficient for boning interval is negative, i.e. the longer the interval before boning the more weight is lost and therefore value as a % of HSCW decreases. It is apparent that the losses in weight across the carcase are not uniform. When adjusted to the same SMY% those carcases which had a longer boning interval are more valuable. This can be explained if the losses in carcase weight with time were greater in the lower value cuts than high value cuts. Whilst there may be some exceptions in individual primals, the weighted average loss is higher in cuts of lower value than those of higher value when adjusted to the same SMY%.

The extended boning intervals represent the commercial considerations of the specific supply chain providing the information. At this facility, priority was given to processing daily orders for delivery ahead of the boning process. In large scale processing facilities, the majority of animals would be boned within 24 hours of slaughter. Whilst the effect of boning interval on value is worthy to note, it is not a commercial consideration.

4.5 Conclusion

The analysis in this chapter clearly highlights the importance of using SMY% to explain carcase value in this supply chain. Given the significance of SMY% and the potential revenue improvement, it is almost inconceivable that there are no large-scale operations incorporating this trait into carcase payment systems as effective feedback to their suppliers for potential improvement.

5. THE INFLUENCE OF QUALITY AND YIELD ON CARCASE VALUE

5.1 Introduction

The Australian beef industry has world-leading infrastructure to enable value-based communication amongst supply chain participants. However, to make value-based trading a reality, a significant paradigm shift that recognises and values the interdependence of value chain participants as part of an integrated production system will be required to capitalise on this opportunity. Unfortunately, the current beef value chain is constrained by price averaging systems that characterise each transaction. Only the very marginal outliers are penalised and the balance usually paid a relatively flat rate whether it by $/head, $/kg liveweight or $/kg hot standard carcase weight (HSCW). The Meat Standards Australia (MSA) grading system provides an opportunity to grade individual cuts in the carcase on eating quality, but as yet there is little information on the economic weights of the grading model inputs.

It is generally accepted that carcase quality and yield traits are important within the beef value chain. Under conventional pricing models these factors usually play a very small role in determining carcase value. Whilst the HSCW is the basis of trade, the relationship between eating quality and quantity with carcase meat yield and carcase value is limited and unclear, providing little incentive to produce either (Clarke *et al.* 2009a). Clarke *et al.* (2009a) also found there "…was limited information quantifying carcase value to beef producers". Latvala and Kola (2000) highlighted the crucial role of information in the marketplace, supporting the earlier work of Akerlof (1970) who argued, "if good quality products cannot get a price premium, thus only bad quality products will be offered for sale". Therefore it is vital that correct information be disseminated throughout the value chain, particularly from consumers to producers.

Whilst carcase revenue is essentially driven by the yield of saleable products, value is determined by how well these products meet the needs of the final consumer (Polkinghorne 2006) and their willingness to pay (WTP) for having these needs met (Lyford *et al.* 2010). In order to extract this value, we need to effectively describe and present product to the final consumer.

Describing and presenting beef products in a way that reflects consumer sentiment has until recently been relatively unreliable. The development of Meat Standards Australia (MSA) methodology provides a more integrated view of the value chain, using consumer scores to grade cuts instead of carcases (Ferguson *et al.* 1999, Polkinghorne *et al.* 1999, Thompson *et al.* 1999a,b, Polkinghorne *et al.* 2008a,b, Watson *et al.* 2008a,b).

The MSA model uses a range of variables (including but not limited to: carcase suspension, ossification, marbling, rib fat, carcase weight, ageing) and external treatments (for example hormonal growth promotants) that affect cuts independently and interactively (Watson *et al.* 2008b). Essentially, the success of cuts-based grading requires traceability of information for individual cuts. However, the tendency in the processing sector has been to group cuts within a band of eating quality using Australia-wide boning groups.

The application of boning groups was to streamline production into efficient runs of carcases to be processed to similar specifications. Unfortunately the way it has been implemented there are severe limitations to product differentiation and therefore revenue generation because cuts are bulked into categories with the score of the lowest eating quality cut setting the baseline. Recently, this method of segregating cuts on eating quality has been shown to be grossly inefficient (McGilchrist *et al.* 2012).

The current situation is a perfect analogy of the “chicken and the egg, which comes first”. Consumers cannot provide a price signal until they have been offered a distinct choice whilst retailers are waiting on the price signal to justify presenting any further choice. The current implementation of MSA grading is largely driven by graded or ungraded carcase description rather than the four distinct quality levels, namely ungraded, 3, 4 and 5 star qualities. Payment is still based on the conventional approach to calculating value where primals from different animals are still paid the same. This approach also makes it difficult to partition out the value to the various contributing factors, particularly carcase eating quality and yield. It also makes it difficult for suppliers in the value chain to refine their output and increase their returns because the price signals only reflect total quantity produced rather than genetic potential, and marginally reward resource allocation to improve marbling or improve growth rates to reduce ossification.

Investment will be required to address this impasse and remove the bottlenecks, updating infrastructure, processes and data management systems. Attracting the necessary investment funding requires modelling the likely returns that could be generated. This modelling process would benefit from developing economic weights for the MSA grading model inputs that could be used to assess the value possibilities with various MSA implementation strategies. Providing this information as feedback throughout the value chain would realign stakeholders toward a common goal, thereby facilitating more effective decision-making.

In Chapter 4 of this thesis, relationships between six measures of carcase yield percentages (saleable meat, primal, trim, bone, waste and fat, loss) and carcase value were assessed. Saleable meat yield percentage (SMY%) was clearly the most effective predictor of carcase value. The following analyses use both conventional pricing and MSA premium pricing estimated by Lyford *et al.* (2010), with and without SMY% as a covariate. It is important to compare and contrast the conventional pricing methodology with the proposed MSA pricing methodology to understand the signals and nuances that are provided and assess their effectiveness.

This chapter will partition out the contribution made by eating quality and quantity components to generate economic weights for the conventional and MSA pricing model inputs.

5.2 Materials and methods

The data used in these analyses have been described in detail in Chapters 3 and 4 and outlined in previous papers by Polkinghorne (2006) and Polkinghorne *et al.* (2008a). Briefly, these commercial data (n=3,735) contain information collated throughout the value chain including on-farm management and genetic details, abattoir slaughter floor details, MSA grading, boning yield information on individual carcases, as well as individual cut yields processed into retail ready products. Graded carcases, excluding outliers that were boned within one of ten boning stratification groups formed the subset of data (n=1,237) used in the following analyses.

Two forms of pricing methodology were analysed. Firstly, cuts were priced using conventional prices irrespective of eating quality for all carcases, as outlined in Chapter 4. Secondly, cuts were priced using the differential MSA pricing based on the premiums reported by Lyford *et al.* (2010). In their study, they reported the premiums for Australian consumers of 0.50, 1.51 and 2.10 times the base 3 star retail product value for 2 (ungraded), 4 and 5 star product, respectively (Lyford *et al.* 2010). This resulted in the retail price grid outlined in Appendix 1.

As outlined in Chapter 3, the retail prices were adjusted to the wholesale proportion of 65% and for yield losses associated with the retail preparation process outlined in Table 3.4. The resultant primal prices for each quality grade are outlined in Appendix 2. Each cut was then assessed using the MSA 2004 model (version 1.0) to calculate a grade and applicable price per kilogram. Total carcase value was then calculated as a function of primal price by quantity and summing the component value of primals, trim, fat and bone from each carcase. The total carcase value in dollars ($) divided by HSCW in kilograms (kg) provided the dependent variable ($/kg HSCW).

Statistical analysis

The following analyses examined relationships between carcase traits and carcase value using a conventional pricing scale or quality based pricing using the MSA premiums estimated by Lyford *et al.* (2010). The relationships between carcase traits and carcase value were examined with and without adjustment for SMY%.

The dependent variable ($/kg HSCW) for each carcase was analysed using a generalized linear model (SAS 1997) (Stata Version 12). The fixed effects in the model were gender, boning stratification, supplier, estimated percentage *Bos indicus* (EPBI), boning interval and carcase suspension method (hang). The model also contained covariates for ossification (Uoss), marbling (Umb) and kill day as both linear and curvilinear effects. SMY% was either excluded or included in the analyses to partition value between eating quality and quantity components.

5.3 Results and discussion

A summary of the data used was presented in Table 4.1. To reiterate briefly, carcases averaged 241kg ranging from 129kg to 333kg HSCW, the average Uoss score was 141 ranging from 100 to 280, Umb averaged 309 ranging from 150 to 820 and rib fat averaged 6.3mm ranging from 3mm to 18mm.

Tables 5.1 and 5.3 show the *F*-ratios for the effect of fixed effects and covariates on carcase value, with or without SMY% included in the analyses, using the conventional and MSA premium pricing models respectively.

Tables 5.2 and 5.4 show the model regression coefficients for continuous variables, with and without SMY% as a covariate, using the conventional and MSA premium pricing models respectively.

Table 5.1: The *F*-ratios for the significance of fixed effects (gender, boning stratification, supplier, estimated percentage of *Bos indicus*, hang and boning interval) and covariates (linear and curvilinear effects for kill date, ossification, marbling, hot standard carcase weight (HSCW) pH and rib fat) on carcase value ($/kg HSCW) when priced using conventional prices without saleable meat yield % and with saleable meat yield % included as a covariate.

	No Saleable Meat Yield		With Saleable Meat Yield	
	NDF,DDF	*F*-ratio	NDF,DDF	*F*-ratio
Discrete variables				
Boning stratification	9,1187	4.34***	9,1186	21.09***
Supplier	3,1187	10.24***	3,1186	9.70***
Est. % *Bos indicus*[1]	1,1187	1.11 N.S.	1,1186	4.98*
Gender	1,1187	1.50 N.S.	1,1186	22.41***
Boning interval	12,1187	4.37***	12,1186	1.98*
Hanging method[2]	1,1187	0.16 N.S.	1,1186	0.09 N.S.
Continuous variables				
Saleable meat yield[3]	-	-	1,1186	3818.33***
Ossification[4]	1,1187	4.20*	1,1186	6.26*
Marbling[5]	1,1187	40.68***	1,1186	4.30*
HSCW[6]	1,1187	0.02 N.S.	1,1186	1.43N.S.
Rib fat	1,1187	110.58***	1,1186	0.12 N.S.
UpH[7]	1,1187	1.01 N.S.	1,1186	7.04**
Julian kill date	1,1187	63.66***	1,1186	235.72***
JulKill*JulKill[8]	1,1187	45.37***	1,1186	54.34***
Model				
Coefficient of determination (R^2)		0.39		0.86
Root mean square error		0.24		0.12

N.S.,*, **, *** not significant, $p<0.05$, 0.01, 0.001 respectively

Est. % *Bos indicus*[1] (Estimated percentage *Bos indicus*); Hanging method[2] (carcase suspension method); Saleable meat yield[3] (Saleable meat yield percentage); Ossification[4] (US ossification); Marbling[5] (US marbling); HSCW[6] (Hot standard carcase weight); UpH[7] (ultimate pH); JulKill*JulKill[8] (Julian kill date curvilinear variable);

Table 5.2: Model regression coefficients ($/kg HSCW) for continuous variables in the conventional pricing model with and without saleable meat yield (SMY) as a covariate

	Without SMY		With SMY	
Variable	Coefficient	Std Error	Coefficient	Std Error
Saleable meat yield/%[1]	-	-	0.085***	0.001
Ossification/100 points[2]	0.10*	0.050	0.06*	0.024
Marbling/100 points[3]	-0.09***	0.015	-0.02*	0.007
HSCW/kg[4]	-0.00 N.S.	0.000	-0.00 N.S.	0.000
Rib Fat/mm	-0.04***	0.004	-0.00 N.S.	0.002
UpH[5]	-0.100 N.S.	0.098	-0.13**	0.048

Saleable meat yield/%[1] (Saleable meat yield percentage); Ossification[2] (US ossification); Marbling[3] (US marbling); HSCW[4] (Hot standard carcase weight); UpH[5] (ultimate pH);

Table 5.3: The *F*-ratio for the significance of fixed effects (gender, boning stratification, supplier, estimated percentage of *Bos indicus*, hang and boning interval) and covariates (linear and curvilinear effects for kill date, ossification, marbling, hot standard carcase weight (HSCW) pH and rib fat) MSA grade pricing of carcase value ($/kg) including saleable meat yield percent.

	No Saleable Meat Yield			With Saleable Meat Yield		
	NDF,DDF	*F*-ratio	Rank	NDF,DDF	*F*-ratio	Rank
Discrete variables						
Boning stratification	9,1187	3.98***	4	9,1186	15.49***	3
Supplier	3,1187	9.25***	2	3,1186	7.74***	5
Est. % *Bos indicus*[1]	1,1187	0.28 N.S.	6	1,1186	24.70***	2
Gender	1,1187	0.53 N.S.	5	1,1186	11.41**	4
Boning Interval	12,1187	4.29***	3	12,1186	1.36 N.S.	6
Hanging method[2]	1,1187	15.52***	1	1,1186	41.83***	1
Continuous variables						
Saleable meat yield[3]				1,1186	3102.41***	1
Ossification[4]	1,1187	96.31***	2	1,1186	407.40***	2
Marbling[5]	1,1187	24.78***	5	1,1186	363.60***	3
HSCW[6]	1,1187	1.23 N.S.	7	1,1186	1.72 N.S.	7
Rib Fat	1,1187	120.73***	1	1,1186	1.07 N.S.	8
UpH[7]	1,1187	3.35 N.S.	6	1,1186	16.07***	6
Julian kill date	1,1187	44.77***	3	1,1186	139.00***	4
JulKill*JulKill[8]	1,1187	32.69***	4	1,1186	25.53***	5
Model						
Coefficient of determination (R^2)		0.44			0.85	
Root mean square error		0.24			0.13	

N.S.,*, **, *** not significant, $p<0.05$, 0.01, 0.001 respectively

[1,2,3,4,5,6,7,8] Refer to table 5.1 for full details;

Table 5.4: Model regression coefficients ($/kg HSCW) for continuous variables in the MSA pricing model, with and without saleable meat yield as a covariate

	Without SMY		With SMY	
Variable	Coefficient	SE	Coefficient	SE
Saleable meat yield/%[1]	-	-	0.085***	0.152
Ossification/100 points[2]	-0.50***	0.051	-0.54***	0.027
Marbling/100 points[3]	0.07***	0.015	0.15***	0.008
HSCW[4]	0.00 N.S.	0.000	0.00 N.S.	0.000
Rib fat	-0.04***	0.004	-0.00 N.S.	0.002
UpH[5]	-0.18***	0.101	-0.21***	0.053

[1,2,3,4,5] Refer to table 5.2 for full details;

Fixed effects and continuous variables in both the conventional and MSA pricing models

The Julian kill date (linear and curvilinear) terms were significant ($P<0.001$) in both the conventional and MSA pricing models, with or without SMY%. As described in Chapter 3 and discussed in Chapter 4, the effect was not well understood, but significant and therefore these adjustments were included.

Ultimate pH

In both the conventional and MSA pricing models, UpH was significant when adjusted for SMY%. Table 5.2 showed UpH was not significant without SMY% in the conventional model. UpH is used in the MSA model as both a threshold effect (i.e. carcases with a pH>5.7 are not graded) and a predictor of eating quality for those carcases with a pH<5.7 (Watson *et al.* 2008b). The latter effect was for high pH (below 5.7) to have a small negative effect on eating quality (Watson *et al.* 2008b). This effect of UpH on eating quality was evident in the current analysis of carcase value where carcases with a higher pH had a slightly lower value.

In the conventional models, the UpH coefficient was approximately half the magnitude of the models using the MSA premium pricing, becoming significant when SMY% was included as a covariate, with a reduced error. This suggests the effect was independent of SMY% and the pricing methodology. Where the negative effect could be explained in the MSA pricing model, the reasoning for the conventional pricing model was not as simple because that pricing did not take Uph into account. However, in the context of factors that impacted on carcase value in the MSA pricing model (including SMY%), the effect was rather small with the extremes in UpH in this study accounting for only $0.04/kg.

Boning interval

Figure 5.1 shows the effect of boning interval on carcase value with and without SMY% included as a covariate in the conventional pricing model. As boning interval increased without adjustment for SMY%, the value of the carcase decreased in a linear fashion. This was expected as carcases lost weight the longer they were held over for boning. However, when SMY% was included in the model this effectively reversed the trend and boning interval had a positive relationship with carcase value. The effect was similar for the MSA pricing model. This was outlined in more detail in Chapter 4. Briefly, it is proposed that the proportional average weight loss was greater in lower value cuts then those of higher value when adjusted to the same SMY%. This results in carcases with a longer boning interval having more value when adjusted for SMY%. However, this is not a commercial consideration as most animals are boned out within 24 hours of slaughter.

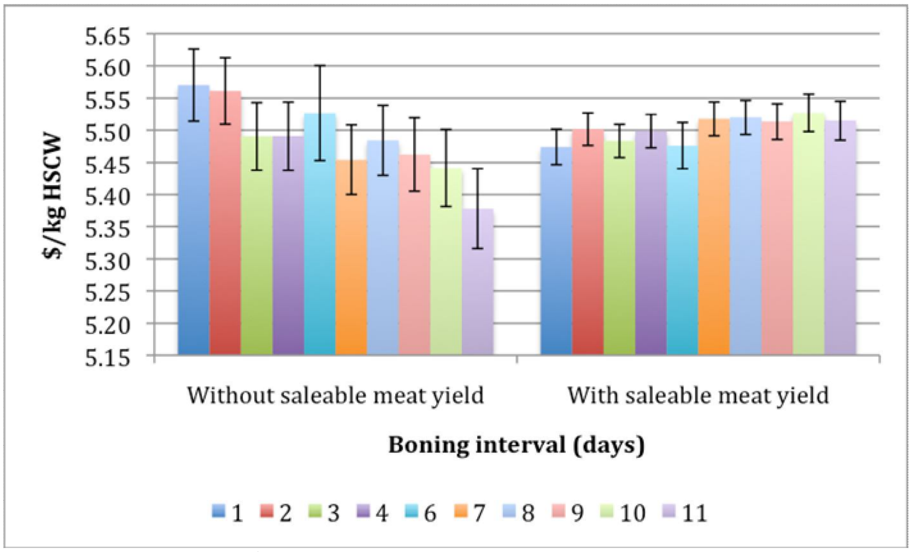


Figure 5.1: Predicted means ($/kg HSCW) for boning interval using the conventional pricing model, showing standard errors, with and without saleable meat yield as a covariate.

Supplier

The predicted means for the supplier effect are shown in Figure 5.2, with and without SMY% as a covariate in the conventional pricing model. Whilst the ranges are $0.59 without SMY% and $0.58 with SMY% in the model, the standard errors of individual suppliers were much smaller and variation between suppliers was reduced from ±0.16 to ±0.11. In addition, the correlation between supplier means that were or were not adjusted for SMY% was 0.18. This was not significant (P>0.05).

The predicted means for the supplier effect with and without SMY% as a covariate in the MSA pricing model are shown in Figure 5.3. Whilst the range was $0.55 without SMY% and $0.60 with SMY% in the model, the variation between suppliers was reduced from ±0.16 to ±0.12. In addition, the correlation between supplier means that were or were not adjusted for SMY% was 0.19. This was not significant (P>0.05).

These results suggest that the majority of the variation between suppliers in carcase value using either conventional or MSA pricing models was due to SMY%. This would suggest processors could mitigate a lot of supplier variation by implementing SMY% based payments. Figure 5.2 shows the predicted mean for supplier 1 using conventional pricing at $5.70 and $5.31 with and without SMY% respectively. Figure 5.3 shows the predicted mean for supplier 1 using MSA pricing at $5.62 and $5.23 with and without SMY% respectively. In both models, there is a $0.39 difference in predicted means. Being able to communicate this more effectively to suppliers would provide very significant motivation to continue providing the preferred type of animal.

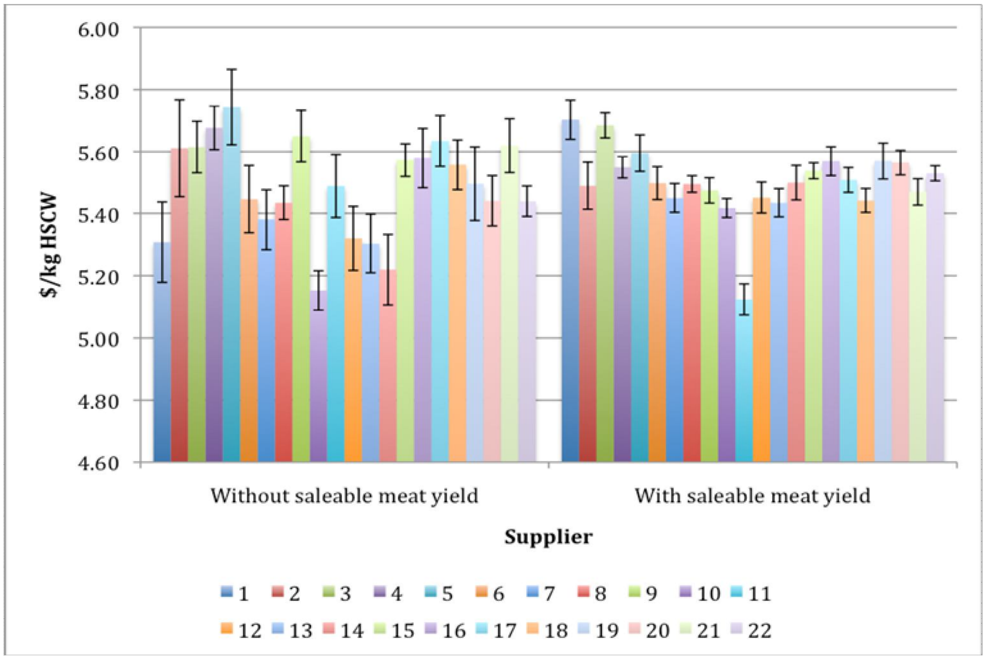


Figure 5.2: Predicted means ($/kg HSCW) for suppliers using conventional pricing with and without saleable meat yield as a covariate

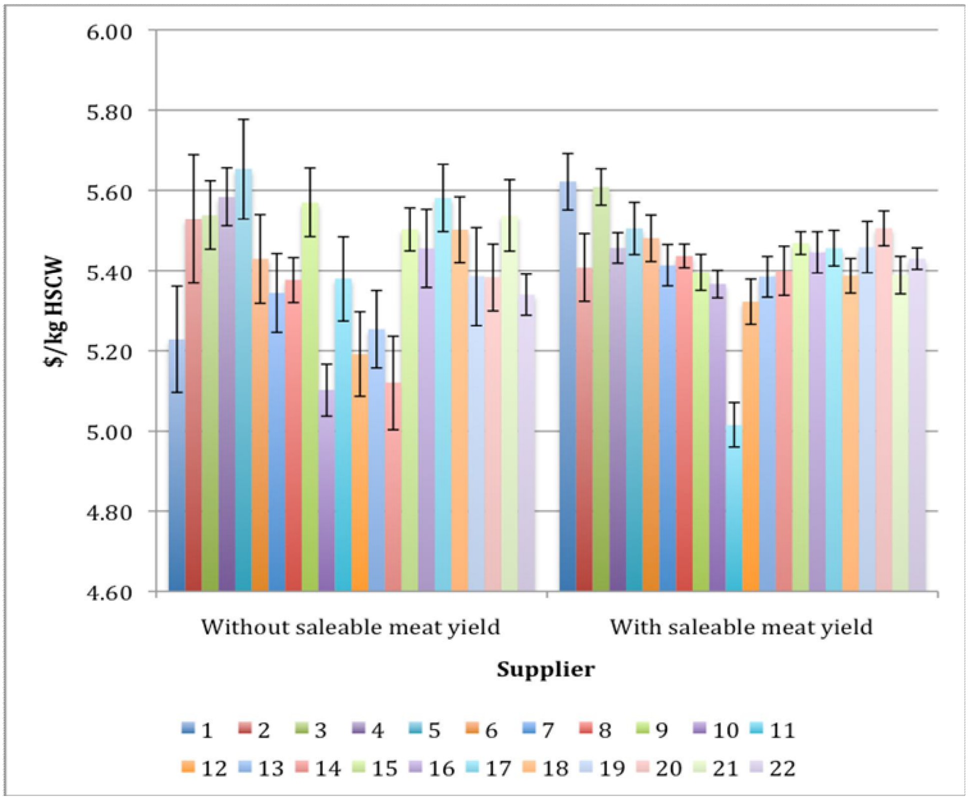


Figure 5.3: Predicted means ($/kg HSCW) for suppliers in the MSA pricing model with and without saleable meat yield as a covariate

The predicted means for boning stratification with and without adjustment for SMY% for the conventional pricing model are shown in Figure 5.4 and the MSA pricing model in Figure 5.5. The different boning stratifications only involved subtle changes in boning procedure. Some primals were broken down into different sub-components, which were priced differently, outlined earlier in Chapter 3, Table 3.2. Effectively this would have only had a small impact on carcase yield and a slightly greater impact on carcase value. Hence, differences in carcase value would have largely been unaffected by adjustment for SMY% as evidenced by the predicted means shown in Figure 5.4 for the conventional model and Figure 5.5 for the MSA pricing model. This is supported by the high correlation of 0.78 between the boning stratification predicted means using the conventional pricing model with and without adjustment for SMY% and 0.73 using the MSA pricing model with and without adjustment for SMY%. Therefore the differences are due to the different cuts utilised by different boning stratifications shown previously in Table 3.2.

This analysis showed the predicted means for boning stratification groups ranged ca. \$0.28/kg HSCW using the conventional pricing model and ca. \$0.23/kg using the MSA pricing model. The differences in predicted means represent the value difference between different boning stratifications. For example, boning stratification 216 has all the cuts listed as a “1” in Table 3.1 and Table 3.2 with a predicted mean of \$5.41/kg HSCW for the MSA model pricing including SMY% shown in Figure 5.5. Boning stratification 212 has a predicted mean of \$5.36 shown in Figure 5.4, and has the same cuts as boning stratification 216 except the chuck tender (CTR085) was not processed into a separate SKU. Therefore, processing the chuck tender into a separate SKU has increased the predicted mean by \$0.05/kg HSCW.

This value difference has to cover the extra labour, packaging and overhead costs associated with maintaining an extra stock-keeping unit for that particular business. By providing these value differences, boning room operators would have the ability to justify whether or not they should further process each primal into sub-primals of more uniform eating quality.

Logically, the differences between boning stratifications should be related and additive, as discussed in more detail in Chapter 4. Briefly, boning stratification groups are used to form “runs” of carcases that will generate the same primal groupings with the objective of maximising carcase revenue and minimising the associated labour, packaging and overhead costs. While the considerations are the same for each site, they are site specific.

Boning groups were originally created to streamline production into efficient “runs” of carcases to be processed to similar specifications. Product generated from these “runs” is usually packed into cartons with other carcases from the same boning group. Traceability of its origin and individual eating quality attributes is lost. Therefore cuts within boning groups are assigned the lowest eating quality within the group. This creates marketing problems because differentiating product quality to increase revenue is severely limited. Recent studies by McGilchrist *et al.* 2012 has shown the Australia wide implementation of these MSA boning groups to be grossly inefficient at harvesting 4 and 5 star cuts.

By contrast, the Polkinghorne methodology was based on traceability of primals throughout the value chain from carcase to primal; from primal to sub-primal; from sub-primal to final retail processing batch. This enabled an unlimited combination of boning stratification groups and provided full flexibility to break down the carcase into the most efficient primal variants for futher processing considerations. Further work is required to determine when this was, and was not, appropriate for increasing overall profitability when labour, packaging and overhead considerations are factored in.

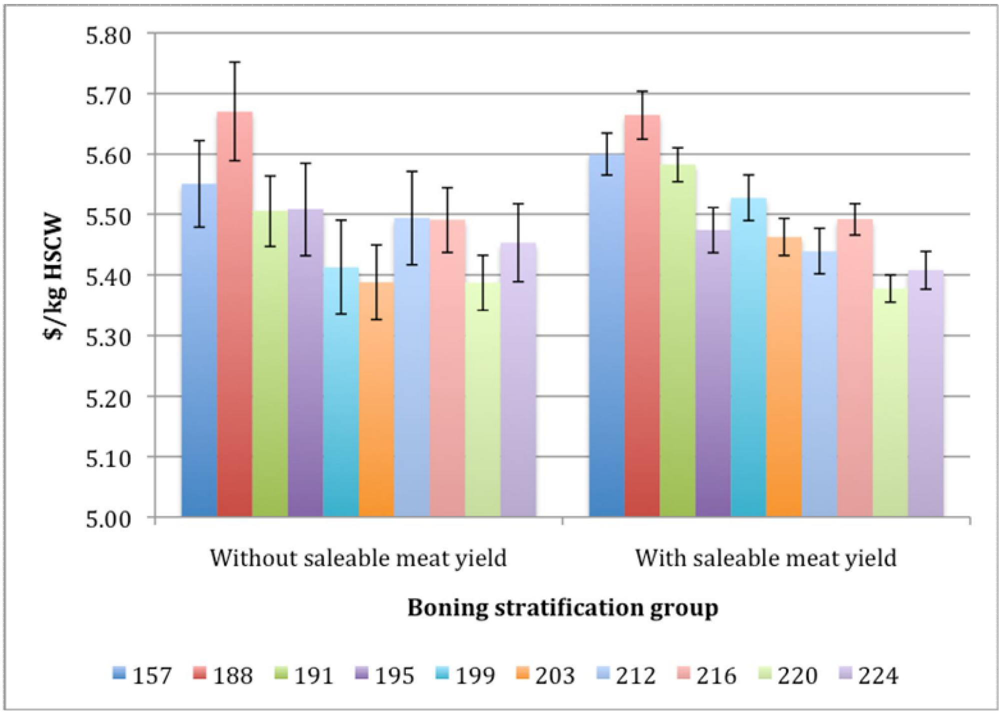


Figure 5.4: Predicted means ($/kg HSCW) for boning stratification group using the conventional pricing model with and without saleable meat yield as a covariate

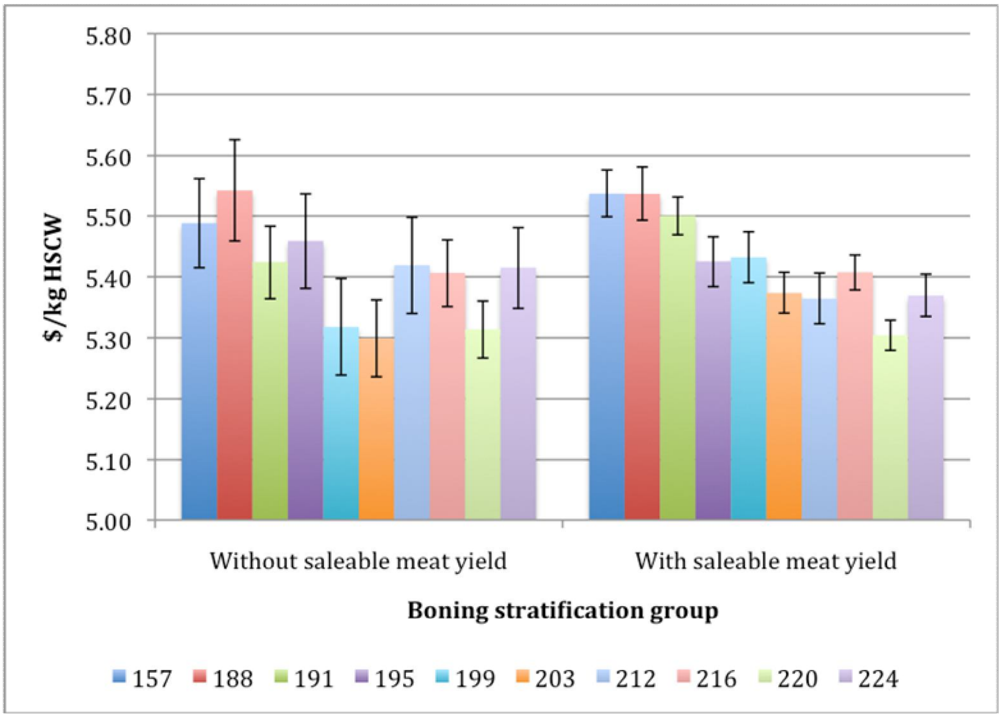


Figure 5.5: Predicted means ($/kg HSCW) for boning stratification groups of the MSA pricing model with and without including saleable meat yield as a covariate

As reported in Chapter 4, gender was only significant when SMY% was included in both the conventional and MSA pricing models. After taking into account standard errors, the predicted means for the corresponding models with and without SMY% using conventional and MSA pricing models were similar. When including SMY% as a covariate, the female value advantage over castrated males increased from $0.03 to $0.06/kg (see Figure 5.6) using the conventional pricing model and $0.02 to $0.05/kg (see Figure 5.7) using the MSA pricing model.

In both pricing models without SMY%, the difference in value was attributed to slightly favourable distribution in muscle being offset by a lower SMY% (61.5% average for castrated males, 61.1% average for females). When adjusted to the same SMY% the difference in value increased to ca. $0.06. It is proposed that this would have been largely due to small differences in tissue distribution despite the findings by Berg and Butterfield (1976) not reporting differences between females and castrated males, only between entire males and females. This result indicates the difference is independent of pricing methodology and is contrary to the industry standard price grids that discount females, usually by $0.05 – $0.10/kg HSCW in favour of castrated males (Danny Wilkie pers. comm. September 18, 2011).

If we work through an example based on the following assumptions:

- A representative domestic carcase is 240kg;
- The average SMY% of castrated males used in this study was 61.5% and females were 61.1%. This equates to approximately 1kg of saleable meat, using the average price of \$9/kg, translates to approximately \$0.04/kg HSCW that can be justified on SMY% differences;
- Figure 5.6 shows that females were worth \$0.03/kg more than castrated males without SMY% as a covariate in the conventional model;
- Figure 5.6 shows that females were worth \$0.06/kg more than castrated males with SMY% included as a covariate in the conventional model;
- Figure 5.7 shows that females were worth \$0.02/kg more than castrated males without SMY% as a covariate in the MSA premium pricing model;
- Figure 5.7 shows that females were worth \$0.05/kg more than castrated males with SMY% as a covariate in the MSA premium pricing model;

Hence, the biggest discount females should receive in models without SMY% is \$0.01/kg under the conventional pricing model, and \$0.02/kg using the MSA pricing model. However, when SMY% is used as a covariate in these models, Figure 5.6 shows females should actually receive \$0.06/kg more than castrated males in the conventional pricing model and \$0.05/kg more than castrated males in the MSA pricing model. Therefore, there is no justification for penalising females \$0.05 – \$0.10/kg HSCW.

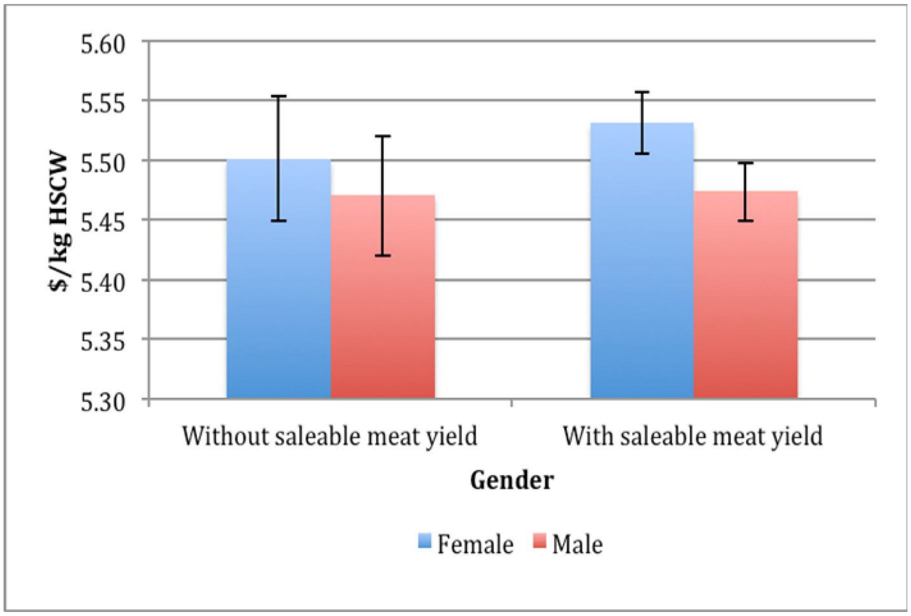


Figure 5.6: Predicted means (\$/kg HSCW) of gender in the conventional pricing model with and without including saleable meat yield as a covariate

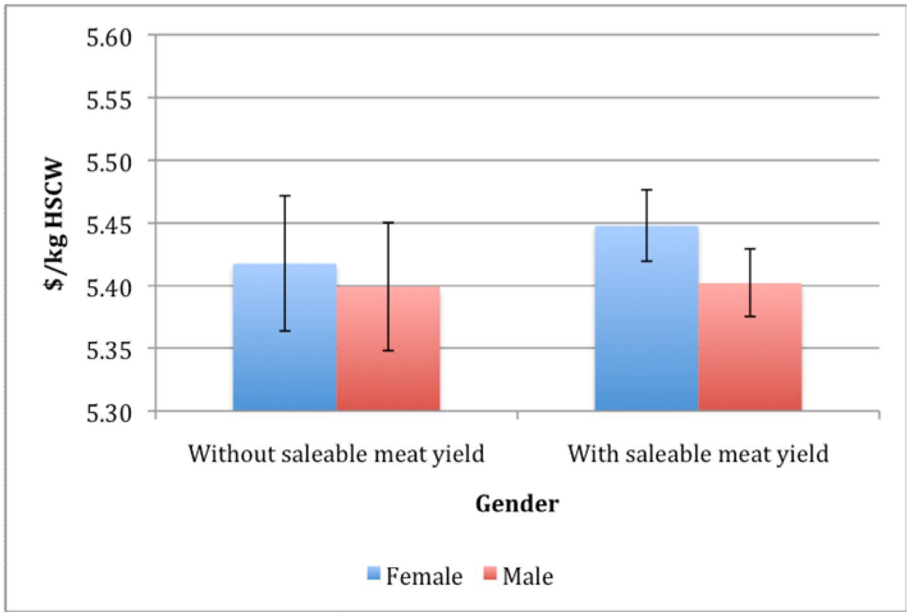


Figure 5.7: Predicted means ($/kg HSCW) for gender using the MSA pricing model with and without including saleable meat yield.

The fixed effect of estimated percentage *Bos indicus* (EPBI) was only significant in either pricing model when SMY% was included as a covariate. This is explained by the 0.5% higher average SMY% for 18.5% EPBI compared with the 0% EPBI carcases, discussed earlier in Chapter 3 and supported by the study conducted by Ball and Johnson (1989). This study found a 1 – 3% difference of saleable beef yield in favour of Brahman cross carcases over Herefords. Figure 5.8 shows that although the EPBI effect was not significant in the conventional pricing model unadjusted for SMY%, there was a trend that the higher EPBI carcases had a higher carcase value. However after adjustment for SMY% this trend was reversed with the 18.5% EPBI having a $0.05/kg lower value than the 0% EPBI, a $0.10/kg turnaround.

When SMY% was included as a covariate in the MSA pricing model, the predicted mean difference also increased $0.10/kg from $0.03 to $0.13/kg HSCW as shown in Figure 5.9. Whilst this was consistent with the negative impact of EPBI on eating quality outlined by Watson *et al.* (2008b) in the MSA pricing model, this would suggest that the value contribution of SMY% for 18.5% EPBI animals was masking the impact of EPBI within conventional and MSA pricing methodologies. The difference must be due to slight variance in tissue distribution between 0% and 18.5% EPBI carcases. Whilst these results are significant, they need to be treated as indicative due to the study limitations outlined previously in Chapter 3.

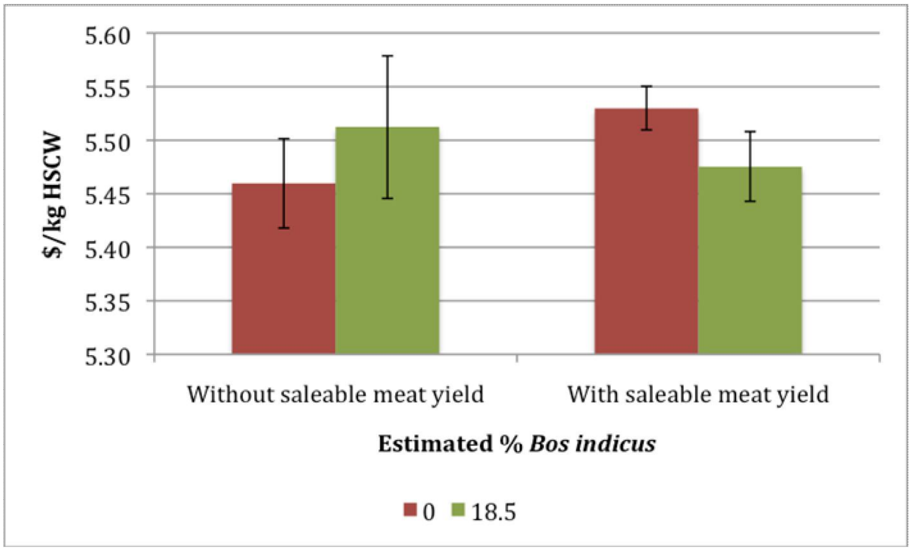


Figure 5.8: The predicted means ($/kg HSCW) for estimated percentage *Bos indicus* in the conventional model including saleable meat yield as a covariate

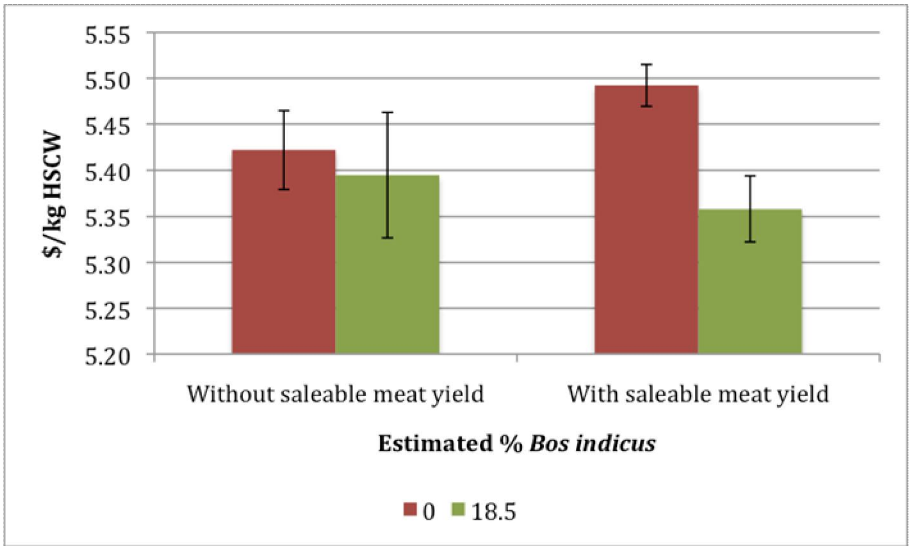


Figure 5.9: Predicted means ($/kg HSCW) for estimated % *Bos indicus* in the MSA pricing model with and without saleable meat yield as a covariate

Carcase value calculated using the conventional pricing model

The results in Table 5.1 show that supplier, boning stratification and boning interval all had significant (P<0.001) effects on carcase value in the conventional pricing model without SMY%. Hanging method, estimated percentage *Bos indicus* content and gender had no significant effect on carcase value priced using the conventional pricing model (P>0.05). Of the continuous variables, rib fat explained the largest proportion of variance in value (P<0.001) followed by Umb (P<0.001). The relative importance of fixed and continuous terms in describing carcase value changed considerably with the addition of SMY% as a covariate, halving the root mean square error of the model from $0.24 to $0.12.

As expected, the hanging method effect was not significant ($P>0.05$) with or without adjustment for SMY% in the conventional pricing model. Of more interest was the change in magnitude of the regression coefficients for carcase traits using the conventional pricing model with and without adjustment for SMY%. Without adjustment for SMY%, an increase in Uoss score was worth $0.10/100 units, compared with $0.06/100 units after adjustment for SMY%. This 40% reduction in the magnitude of the regression coefficient indicates that increased Uoss score was correlated with SMY%.

Similarly, using the conventional pricing model that contained no premiums for Umb, the regression coefficient for Umb indicated an increase in Umb score resulted in a lower value with a decline of $0.09/kg HSCW. The magnitude of this negative coefficient for Umb score was reduced by ca. 80% when SMY% was included as a covariate. This suggests that most of the variance in carcase value attributable to Umb score was associated with SMY% in the conventional pricing model. This result was supported by the negative phenotypic correlations between intramuscular fat and Umb with retail beef yield reported by Reverter *et al.* (2003b).

Rib fat as a covariate within the conventional pricing model without SMY% had a negative coefficient with carcase value of $0.04/kg HSCW, although effectively this relationship was no longer important when adjusted for SMY%. HSCW was not related to value with and without adjustment for SMY%.

Carcase value calculated using MSA price premiums

In the MSA pricing model without SMY%, hanging method had the largest effect (Table 5.3, $P<0.001$). Supplier, boning interval and boning stratification effects were also significant ($P<0.001$), whilst EPBI and gender were not significant ($P>0.05$). Rib fat provided the largest explanation of variance in carcase value ($P<0.001$), whilst Uoss explained more than three times that of Umb ($P<0.001$).

When SMY% was included as a covariate in the MSA model, the model's explanation of variance (R^2) increased from 44% to 85% and the error almost halved from $0.24 to $0.13, consistent with the changes observed in the conventional pricing model. The fixed effects associated with hanging method and boning stratification remained significant ($P<0.001$) whilst boning interval did not ($P>0.05$). EPBI and gender became significant ($P<0.001$).

The hanging method was the largest fixed effect explanation of variance in the MSA pricing model. The predicted means for the MSA model in Figure 5.10 show the $0.32/kg HSCW difference in predicted means favouring tenderstretching (TX) over Achilles tendon (AT) without SMY% in the model. Whilst this was reduced to $0.27/kg and the standard error was halved when SMY% was included as a covariate in the model, there is no real difference when standard errors are taken into consideration. Given returns of this magnitude on a fixed effect are so rare, it is hard to imagine why any MSA graded animals processed for the Australian domestic market would not be tenderstretched.

Whilst there is an argument that tenderstretched carcases are “not the same” from butchers in the trade, the fact is they aren’t the same – they have primals set in different shapes, particularly the topside (AM2000) and rump (AM2080). These differences in shape can manifest as longer flatter primals that require the operator to make the necessary adjustments to cutting lines for boning and retail product preparation. This in turn involves a degree of change that some operators are uncomfortable to make. Hence, some operators avoid using tenderstretched primals let alone paying the premium based on eating quality that they deserve, hence the demand has not been created for such cuts.

Processors are faced with the same issue of change management, due to the change in processes and difference in hanging profile. The process changes are usually implemented after the kill floor by rehanging the carcase by the obturator foramen (TX). This can be done with a system of hydraulic, pneumatic or manual lifting mechanisms. Some processors also have a double hook system, one through the obturator foramen and one under the sacral ligament (TS) as an alternative should the pelvic bone break. The pelvic bone is particularly susceptible to breaking when carcase splitting has not been even, leaving one side with a bone that is too thin to take the weight of the side. It is also why some processors have enforced a 300kg HSCW threshold on the grounds that it poses an unacceptable occupational health and safety risk for their staff. Another issue with the TS application is the damage caused by the hook on the medial surface of the rump primal (AM2080). This can cause some bruising and subsequent yield loss or primal downgrade to trimmings.

The TX carcase results in the hind shank pointing at right angles to the spine, increasing the effective width of the carcase and lifting it up further from the floor. In some plants this can cause issues moving carcases around hallways, through doorways and into chillers. Often, rail spacing is too narrow and sides of beef overlap and at worst interlock, making movement difficult. Whilst none of these issues are insurmountable, they can be problematic depending on the management approach to their solution. The economic equation of ca. $0.30/kg for animals valued with the MSA pricing premium equates to $72 for the average 240kg carcase, should amply recover any extra costs incurred to implement if product is being sold on eating quality.

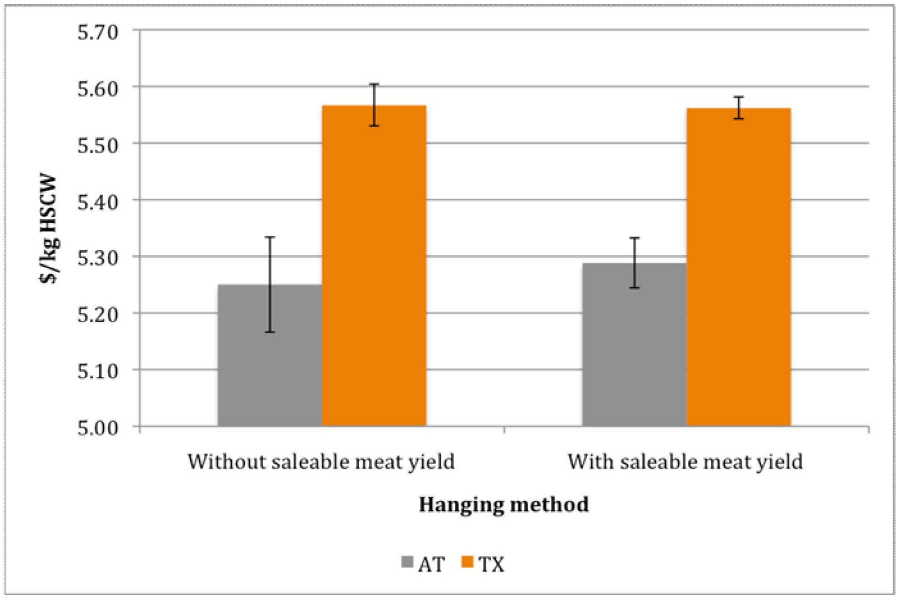


Figure 5.10: Predicted means ($/kg HSCW) for hanging method (carcase suspension) – Achilles tendon (AT) and tenderstretch (TX), using the MSA pricing model, with and without saleable meat yield as a covariate.

HSCW was not related to value in either the conventional or MSA pricing models, without and with adjustment for SMY%. This was not surprising given Berg and Butterfield (1966) have shown that bone and muscle are early maturing and fat is late maturing in the carcase. Hence, as a primal consists of muscle and fat, the early maturing pattern of muscle is counteracted by the very late maturing pattern of fat so that increases in carcase weight have little impact on carcase value.

As expected, SMY% was the largest contributor to explaining variance in carcase value when cuts were priced using the MSA premiums ($P<0.001$). Rib fat joined HSCW as not significant ($P>0.05$), whilst Uoss, Umb and UpH were all significant ($P<0.001$).

Table 5.4 shows the negative effect associated with Uoss increased -$0.50/100 points to -$0.54/100 points when SMY% was included in the MSA pricing model. This is not significantly different when standard errors are considered. This result indicated Uoss was independent of SMY%.

The coefficient for Umb in Table 5.4 showed the effect of Umb increased more than 200% from $0.07 to $0.15/100 points when SMY% was included in the model. The increase in the coefficient for marbling can be explained by removing the variance associated with SMY%, given the negative correlation between marbling and SMY% (Reverter *et al.* 2003b). After adjusting for SMY%, the relationship is simply with quality and so it is expected to be higher.

To investigate the relative value of continuous variables in the MSA pricing model that included SMY% as a covariate, value elasticities were calculated at the means with a linear model in *Stata Version 12.0*. Table 5.5 shows the relative contributions of the continuous variable traits in the MSA pricing model (including SMY%) to consumer value, reported in percentage terms at the mean $/kg HSCW. The percentage change in value of the mean MSA price for a 1% change of each variable is reported.

Table 5.5: Elasticities of continuous variables in the MSA pricing model including saleable meat yield percentage

Variable	Elasticity
Saleable meat yield percentage	0.95
Ossification	-0.14
Marbling	0.09
Hot Standard Carcase Weight	0.02
Ultimate pH	-0.24
Rib Fat	0.00

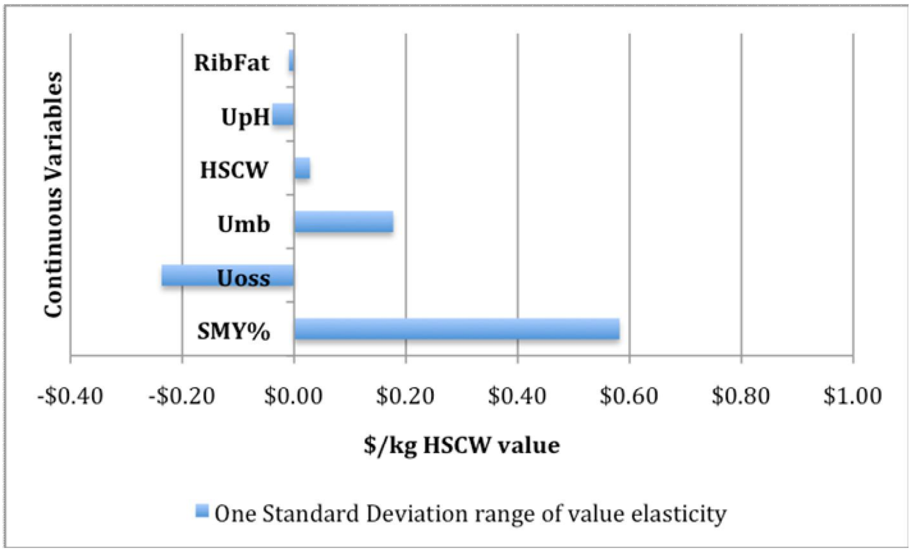


Figure 5.11: Range of value impact ($/kg HSCW) across one standard deviation from the mean of continuous variables (excluding Julian kill day) in the MSA pricing model including saleable meat yield percentage as a covariate.

Figure 5.11 shows the effective range of pricing over ± one standard deviation from the mean. The predominant variables were SMY%, Uoss and Umb with $0.58, $0.24 and $0.18/kg HSCW potential value variation in absolute terms, respectively. These figures represent a significant opportunity to adjust resource allocation and management decisions to capture increased value.

These economic weights provide clear pricing information that can be utilised in downstream optimisation models, such as the feedlot growth model developed by Slack-Smith (2009). Such models can be adapted to focus on specific markets.

5.4 Implications

These results highlight the importance of looking at the beef value-chain as an interconnected whole rather than the industry tendency to view components in isolation (Everitt 1966). Despite Johnson and Charles (1981) reporting the most effective way of predicting carcase components was by measuring primal weight and to a lesser extent fat thickness at the 12th/13th rib, relatively little progress has been made in the past 30 years communicating this feedback to suppliers in a way that facilitates long-term improvement. As stated by Johnson (1996) “Some form of yield must be measured or implied in any attempt to evaluate carcase merit because, for a particular market, yield is commercially valuable and subject to genetic manipulation (Ball and Johnson 1989).”

This study demonstrated five distinct insights. First, SMY% was the clear differentiator of value, with a $0.09/kg impact on value for every percentage change in SMY% when carcases were valued using conventional pricing and the MSA price premiums. Figure 5.11 showed this represented a $0.58/kg HSCW range of value impact for animals within one standard deviation of the mean 61% SMY% (58% - 65% SMY). This equated to $140 per average carcase of 241kg HSCW.

Including SMY% as a covariate in both the conventional and MSA pricing models, rendered rib fat insignificant due to their high correlation. However, the coefficient for UpH became significant in the conventional model and remained so in the MSA pricing model, but the coefficient remained largely unchanged

To collect the SMY% information, thorough cut traceability systems had to be established. Although this method of cut traceability provided carcase SMY% information, it also facilitated the wider business objectives. Maintaining cut traceability, and that of any subsequent derivative products, facilitated management objectives by tracking cost-of-goods changes (Polkinghorne *et al.* 2008a). In addition, this traceability enabled more effective food safety protocols that could isolate the impact of a product recall with a high degree of confidence.

When all these aspects of cut traceability are considered, it would appear illogical not to communicate this information throughout the value chain. However, experience has shown this is not as straightforward as it seems. This dataset was unique in that each cut was traced to an individual carcase. This was made possible by adopting a traceability paradigm from the outset and required purpose built software to achieve this aim.

Large-scale plants have vast resources and infrastructure focused solely on throughput efficiency and batch level traceability. Changing this paradigm will require significant investment toward reconfiguring process flows of equipment, labour, packaging and communication. These investment decisions require a financial framework and strategic fit (Chopra and Meindl 2012) to be justified. This study provides some economic values that could be used to assess the market potential of adopting this methodology. After making the decision to adopt such a paradigm shift, the most important factor is the implementation teams' leadership capability to align the people involved toward the vision (Covey 1989). Whilst not impossible, it should not be underestimated.

Second, Tables 5.2 and 5.4 showed the coefficient for Uoss was similar in the conventional or MSA pricing models, regardless of whether it was adjusted for SMY%. This indicated that Uoss was independent of SMY%. Figure 5.11 showed the effective range of Uoss to be worth $0.24/kg HSCW, $58 per carcase using the MSA pricing and SMY%. In contrast, Table 5.21 showed Uoss had reduced significance ($P<0.05$) and explained much less of the variation in the conventional model with or without SMY%. Information on Uoss is rarely available outside the MSA grading system, despite being one of the keys to producing better quality meat and a better indicator than dentition (Polkinghorne *et al.* 2008b). The independence of Uoss from SMY% suggests there is an opportunity to select lower Uoss animals with higher SMY%.

Third, Tables 5.2 and 5.4 showed the Umb coefficient changed significantly in the conventional and MSA pricing models with and without adjustment for SMY%. This indicates Umb is negatively correlated with SMY%, supporting the findings of Reverter *et al.* (2003b). Figure 5.11 shows the effective UMB range of value is $0.18/kg HSCW or $43 per average carcase using the MSA price premiums and SMY%. In contrast, the conventional pricing model discounted Umb with and without SMY%.

Unless SMY% is incorporated into a value based marketing scheme, much of the value of increased eating quality due to increased marbling will be lost. When SMY% is not used, the effect of Umb is masked and therefore difficult to use as a selection tool. Table 5.4 shows the coefficient for Umb more than doubled from $0.07/kg to $0.15 when SMY% was included in the model. Given existing markets discount animals for fat, animals that marble have become collateral damage.

Unless this is addressed, there is no real incentive to produce higher marbling animals in the mainstream beef production due to the negative impact it has on producer returns. The exception will remain in the very high marbling markets based on Japanese derived Wagyu and Korean Hanwoo (yellow) cattle where carcase payments are focused on marbling. Supply will be limited without mainstream adoption. This in turn limits the supply of higher quality product to participants further down the value chain and ultimately the consumers that want to purchase it.

Fourth, the hanging effect was worth ca. $0.30/kg HSCW with or without SMY% in the MSA pricing model, worth $80 per carcase at the average carcase weight of 241kg. It is rare to generate such a high return on a fixed effect. Given the impact tenderstretching has on carcase value, and the limited real investment required for implementation, it is likely that all carcases graded for MSA domestic markets will be tenderstretched.

In order for tenderstretching to become the norm rather than the exception, a management paradigm shift is the single biggest impediment. Whilst significant investment in infrastructure modifications may be necessary for some facilities, it is usually not required (John Thompson pers. comm. June 27, 2012). These modifications entail process changes to handling of carcases, possible changes to the width of rail spacing and hallways to handle the altered carcase profile. They will also require cutting line adjustments to accommodate the different primal shapes, particularly the topside (AM2000) and rump (AM2080). Chiller rail heights also impact on access to the quartering site that may require process changes for chiller assessment. From past experience this will also require sound communication with upstream chain participants, educating them on cutting line differences and how this may impact on the shape of their retail presentation. These changes can easily be justified for the increased return that will be received.

Fifth, contrary to current industry discounts for females of $0.05 to $0.10/kg HSCW, this study found females were worth more than castrated males. Given these results are presented at the wholesale level to retail, the production sector would only receive c.a. 65% of this. Without SMY% included as a covariate, a discount of $0.01/kg HSCW could be justified to account for the average difference in SMY% in both the conventional and MSA premium pricing models.

Even adjusting for SMY% difference between castrated males and females and using the conventional pricing model, there should be no discount for females. If this were to be adopted by processors, it would have significant ramifications throughout the industry not only as carcases but also on the value of females traded as weaners, yearlings for backgrounding, grass fattening and feedlotting.

These insights are useful toward the development of a value based marketing system that provides effective information to each participant in the value chain. Understanding the relationship and interaction of SMY%, Uoss and Umb in this context has the potential to align the objectives of participants and synergistically improve overall chain profitability (Chopra and Meindl 2012).

These results show that effective economic weights can be derived for the beef value chain. These are most effective when MSA grading is used to present product to consumers in three distinct quality levels, priced according to the WTP research of Lyford *et al.* 2010. Increased returns can be achieved by using MSA pricing premiums and SMY% if higher marbling, higher yielding carcases with lower ossification are supplied. Whilst outside the scope of this thesis, the practical considerations of reproductive efficiency and feed conversion and their impact on these results needs to be investigated further if they are to be sustainable practices for the wider value chain. The combination of MSA pricing and SMY% maximises the communication throughout the value chain. This method provides a less distorted, repeatable method of calculating carcase value that can establish consistent priorities for all stakeholders.

5.5 Conclusion

This study shows the importance of combining saleable meat yield percentage and MSA quality traits, particularly Uoss and Umb, in the explanation of carcase value ($/kg HSCW). Whilst the coefficient of determination (R^2) was similar for both the conventional and MSA priced models, explaining the variance of value ($/kg HSCW) at 0.86 and 0.85 respectively, the importance of individual variables was significantly different.

The results generated by this study show SMY% is worth $0.09/kg HSCW for every percentage change in SMY% in the MSA model; females were worth $0.02 to $0.06/kg HSCW more than castrated males regardless of pricing methodology; tenderstretching was worth $0.30/kg HSCW in the MSA pricing model; marbling and ossification were worth $0.15 and $0.58/kg/100 points respectively in the MSA pricing model including SMY% as a covariate.

Without communicating carcase value through this combination of measurements, distorted and biased information will continue to be used by suppliers and progress will continue to be stifled. It is important to communicate carcase value through a combination of carcase measurements – namely, SMY%, Uoss and Umb – within a pricing framework that clearly reflects consumer quality grades to generate meaningful feedback for value chain participants.

Meaningful feedback creates a functional exchange of information capable of spawning a plethora of opportunities. These opportunities have the potential to simultaneously increase the revenue and decrease costs by aligning value chain participants with consumer expectations.

6. SUMMARY

In this concluding chapter, Section 6.1 will provide a review of this study, Section 6.2 will highlight the limitations of the study and highlight opportunities for further research, while Section 6.3 will suggest applications of the results.

6.1 Review of the study

The beef value chain consists of many components that together form an integrated system. These components have been studied in isolation thereby limiting progress (Friedlander 1964, Everitt 1966). Progress has been further hampered because the feedback throughout the chain does little to communicate value (Polkinghorne 2006, Clarke *et al.* 2009a). The development of the Meat Standards Australia (MSA) grading model (Thompson 2002, Polkinghorne *et al.* 2008b) represents the best existing total quality management approach for improving beef quality and palatability (Smith *et al.* 2008).

The MSA model is a consumer grading system that seeks to “define or predict consumer satisfaction with a cooked meal” (Polkinghorne and Thompson 2010) as opposed to traditional classification or grading system. Using the MSA model has provided an opportunity to differentiate the beef quality, providing consumers with the capacity to express choice. By assigning pricing differences to the quality grades, financial incentives can be provided to suppliers in line with consumer expectations.

However, the value equation would not be complete without also considering the contribution of quantity. To determine the most effective measure of value, six alternative measures of carcase yield were analysed. The most effective measure was SMY%.

Because MSA grading is focused on describing consumer eating quality independent of carcase meat yield, it was necessary to evaluate conventional and MSA price premium models with, and without SMY% as a covariate. Figure 6.1 summarises the coefficients of significant covariates and differences in predicted means for fixed effects in each of the four models explored in Chapter 5.

Figure 6.1 demonstrates the importance of pricing methodology and its influence on communicating the relative value of individual traits to participants of the value chain. The wide range of results is a likely reason why participants are at times confused and perplexed.

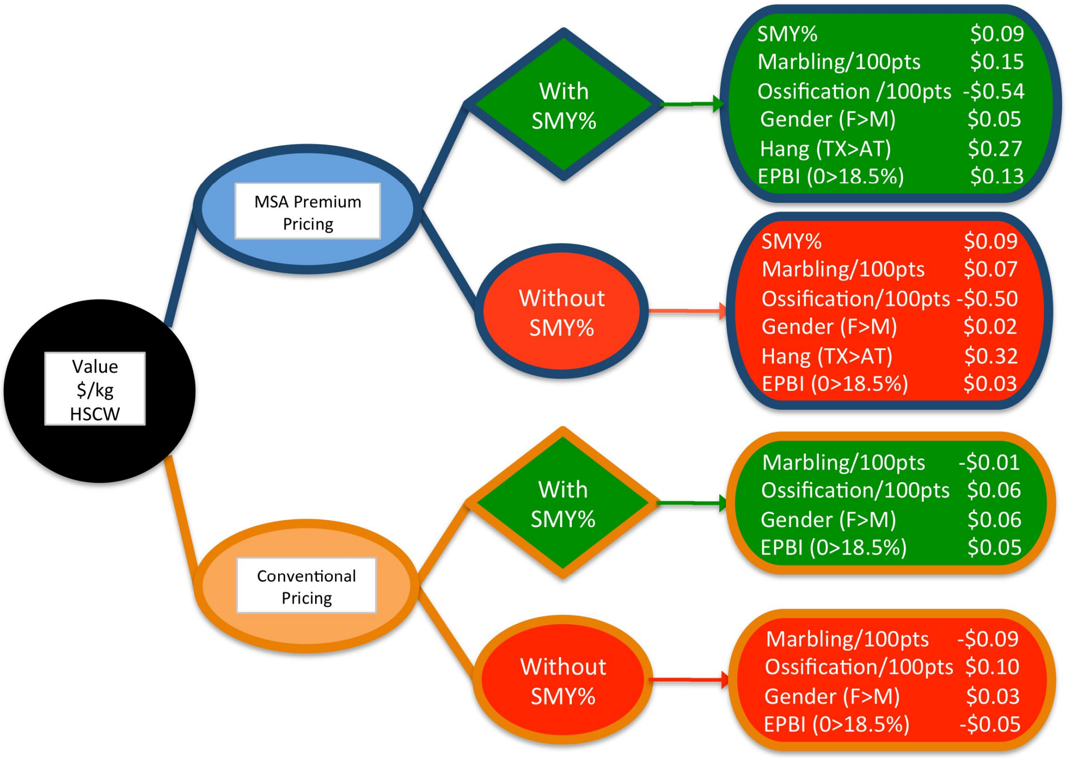


Figure 6.1: Coefficients and predicted mean differences ($/kg HSCW) for terms within the conventional and MSA pricing methodologies, each with and without saleable meat yield percentage (SMY%) in their model

This study showed:

- SMY% is the single most important determinant of value in a beef carcase with an economic weight of $0.09/kg HSCW per one percent change in SMY%, using either the conventional or MSA premium pricing models. The effective range of value impact across one standard deviation from the mean (58% – 65%) was worth $0.58/kg HSCW, $140 per carcase at the average carcase weight of 241kg.

- Ossification was worth $0.54/kg HSCW/100 points in the MSA premium pricing model including SMY%. The effective range of value across one standard deviation from the mean (120-160) was worth $0.24/kg HSCW or $58 per average carcase.

- Marbling value coefficients ranged from -$0.09 through to $0.15/100 points/kg HSCW. This range is due largely to the negative correlation between marbling and SMY%. By valuing the carcase using a combination of eating quality and SMY%, their relative impact on carcase value can be put into perspective. Without using SMY%, the coefficient for Umb was $0.07/kg HSCW, less than half the coefficient of $0.15/kg HSCW when SMY% was incorporated into the MSA price premium model.

- Tenderstretching is important when using MSA premium pricing, worth ca. $0.30/kg HSCW. Up until now it has not been possible to quantify the economic effect of carcase suspension. It is envisaged that the magnitude of this effect could result in every carcase processed for the Australian domestic market being tenderstretched.
- Regardless of pricing methodology, the effect of gender was found to be opposite to conventional thinking. Females were worth between $0.02 and $0.06/kg HSCW more than castrated males. Females should only receive a $0.01/kg HSCW discount in payment systems that do not incorporate SMY%, rather than the current discount of $0.05 to $0.10/kg HSCW they currently receive in commercial transactions.

The most effective price signals are obtained when pricing premiums are applied to the 3, 4 and 5 star MSA quality grades in conjunction with SMY%. Whilst independent of carcase yield measures, MSA grading is not totally unrelated to SMY% due to the negative relationship of rib fat and marbling on SMY% (Reverter *et al.* 2003b). Without SMY% included as a covariate the effect of Umb was masked, limiting the potential contribution of eating quality to a value based marketing system.

It is important that eating quality and carcase yield information be considered within the same pricing methodology to provide a more complete picture of the beef value chain and the interdependent relationships of which it is constructed. The MSA premium pricing levels used within this study represent market premiums for quality when traceability is maintained throughout the value chain to provide product differentiation. Consumer demand signals can then be accurately communicated throughout the value chain.

This research has demonstrated economic weights can be derived for the saleable meat yield percentage (SMY%) of carcases and their MSA grading model inputs for a range of fixed and continuous variables using conventional and MSA premium pricing models. These economic weights can contribute toward the establishment of a broader financial model (FACCP), overlaying the Palatability Analysis Critical Control Point (PACCP) pathway used as the basis for the development of the MSA technology (Ferguson *et al.* 1999). This is a small but integral part of a value based marketing model for beef.

6.2 Limitations of the study and opportunitites for further research

The limitations of this study largely result from the industry nature of the dataset and lack of balance in the experimental design. This is particularly relevant to the EPBI results that were significant but which do not cover the full range of *Bos indicus* content percentages or even the females for 18.5% EPBI content. Therefore, the results presented here are regarded as indicative.

The boning stratifications presented also suffered from the experimental design and need to be investigated further. Whilst the data presented 10 boning stratifications, there are myriad possibilities for various primal combinations.

The SMY% measure used in this study was a combination of the primal and trim yields. This was not adjusted for fat within these two yield measures. Further work could be done to investigate whether or not there are threshold levels of fat within individual primals that would influence purchasing decisions.

There is a need to further investigate a wider range of EPBI content as well as the management and environmental variations associated with multiple suppliers using a balanced experimental design.

Within the meat processing sector, a more complete understanding of the "mother daughter" relationships between each primal, sub-primal and sub-sub-primal through to retail-ready product would further enhance the use of these economic weights. Shadow pricing could be developed for different outputs, highlighting their worth at various points along the value chain.

For this information to be relevant, the labour, packaging, distribution and infrastructure considerations need to be considered at each point of further processing. The increased return of each primal subject to further processing needs to cover the labour and packaging costs as well as any product yield losses. These economic weights could then be used in an optimisation control model for maximising net revenue.

6.3 Application of results

The ultimate application of these results would be as part of wider, value based marketing system that incorporated the whole beef value chain. The MSA grading model provides the opportunity to communicate the consumer quality of the product to each participant of the value chain, aligning everyone toward a common goal. For this to be successful, sound feedback, planning and coordination among all entities in the supply chain is required (Gheidar Kheljania *et al.* 2007).

Providing effective feedback is considered to be the key performance driver in the supply chain due to the direct influence on all other drivers (Chopra and Meindl 2012). Improving information systems inevitably requires improved software and integration of independent systems to provide better decision-making tools. The economic weights and methodology highlighted in this thesis are a small but significant step toward developing a value based marketing model.

Such a model would integrate consumer demand, MSA grading information, SMY% and on-farm supply considerations. One application of this information would be to maximise the overall value chain net revenue using total supply chain optimisation, as outlined by Gheidar Kheljania *et al.* (2007). Integrating with resource allocation and risk mitigation programs that further assist decision-making would be a logical extension of this.

For processors, another application could be creating a live, fully tailored, predictive sorting system that provides real-time information on the kill floor allowing carcases to be organised into newly defined boning groups based on individual customer needs and just-in-time inventory principles. The underlying traceability processes would be required to manage the logistical challenges associated with tracking multiple primals in cartons, on pallets and throughout a distribution network.

The traceability of primals can also improve processing efficiency in domestic businesses. Traditionally, the domestic market has been constrained to using smaller carcase weights that are more expensive to process. Heavier carcase weights could be utilised to supply domestic consumers if they are selected for equivalent meat quality levels. McIntyre in Johnson (1994) referred to supermarket carcase weight specifications as being driven by consumer preferences. The traditional carcase weight specification represents a pseudo indicator of portion size due to the influence of carcase weight on primal size. An alternative is the further dissection of primals into their smaller sub-components. Not only does this address the issue of primal size, it has the added benefit of providing a product that eats more uniformly throughout the resultant primal (Polkinghorne *et al.* 2008a).

For producers to obtain effective feedback, processors need to recognise the interdependence of the beef value chain and actively engage with producers, providing improved feedback about eating quality and saleable meat yield. Providing more effective producer feedback would assist them to make decisions about alternative breeding and management strategies. Communicating SMY% and quality to suppliers would enable them to modify their management practices to influence the level of carcase fatness and could reduce their input costs as well as redeploying these resources to other avenues that could further increase their returns. The relative value of females may also increase in the commercial market place by the removal of current discounts imposed on suppliers.

By viewing these results as part of an expanded FACCP framework, there is potential to provide a more accurate mechanism for appraising investments in the beef value chain. Ongoing investment is essential to ensure the beef industry is a competitive source of protein. With some foresight, the construction of this FACCP framework will create synergies between beef value chain participants to improve their competitiveness and grow their businesses sustainably.

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8. APPENDICES

		Willingness To Pay (WTP) Retail Pricing ($/kg)			
Retail Group	Retail product	Ungrade (UG)	Good Everyday (3 Star)	Better than everyday (4 Star)	Premium (5 Star)
RETAIL	Pricing Relationship	0.5	1.0	1.5	2.0
GRILL	Steak	13.75	27.50	41.25	54.95
	RODZ	11.95	23.95	35.95	47.90
	Glued Log	11.95	23.95	35.95	47.90
	Kebabs	8.65	17.25	25.95	34.50
	Schnitzel	4.99	9.99	14.99	19.99
ROAST	Roast	9.50	18.95	28.50	37.90
STIR-FRY	Stir-fry	6.95	13.95	20.95	27.90
THIN-SLICE	Thin Slice	8.50	16.95	25.95	34.95
SLOW COOK	Diced Beef	6.50	12.95	19.45	25.95
	Pet Beef	2.40	4.75	7.15	9.50
	Osso Bucco	3.25	6.45	9.65	12.90
CORN	Corned meat	5.65	11.30	16.95	22.60
VALUE-ADD	Beef Bacon	6.25	12.45	18.65	24.95
	Pastrami	6.25	12.45	18.65	24.95
TRIMS	Modified Atmosphere Pack (MAP) premium mince	15.40	15.40	15.40	15.40
	Retail Mince	6.15	6.15	6.15	6.15
	Kitchen Mince	10.00	10.00	10.00	10.00
	Sausage Mince	5.40	5.40	5.40	5.40
	Wholesale Mince	6.15	6.15	6.15	6.15
WASTE	Fat	0.10	0.10	0.10	0.10
	Bone	0.20	0.20	0.20	0.20

Appendix 1: Retail Pricing matrix for cooking method by predicted eating quality outcome

Cut Description	Cut Code	Cooking Method[a]	Flat Price ($/kg)	MSA Pricing ($/kg)			
				Ungrade	3 Star	4 Star	5 Star
Tenderloin Fillet	TDR062	GRL	17.03	8.41	17.03	25.23	33.60
Butt Tenderloin	AM2170	GRL	14.04	7.19	14.04	20.89	27.72
Tenderloin Meat	ZZZ011	GRL	14.09	7.12	14.09	21.06	28.00
Bare Striploin	STR045	GRL	15.86	8.04	15.86	23.68	31.46
Rump Cap	RMP005	GRL	13.64	5.74	13.64	16.40	21.69
Rump D Muscle	RMP131	GRL	14.70	7.54	14.70	21.87	29.01
Rump Eye Muscle	RMP231	GRL	14.64	7.58	14.64	21.69	28.72
Rump Tail (Tri Tip)	RMP087	SFR	7.26	4.00	7.26	10.52	13.76
Outside Flat	OUT005	RST	9.17	5.09	9.17	13.30	17.36
Eye Round	EYE075	RST	9.91	5.29	9.91	14.58	19.18
Heel	OUT029	SFR	2.94	1.51	2.94	4.40	5.84
Osso Bucco	ZZZ004	SCT	3.30	1.67	3.30	4.94	6.59
Eye of Knuckle	KNU066	RST	10.56	5.50	10.56	15.68	20.72
Knuckle Undercut	KNU098	SFR	6.93	3.97	6.93	9.89	12.83
Knuckle Cover	KNU099	RST	9.54	5.18	9.54	13.94	18.28
Knuckle Side	KNU100	SFR	7.18	4.02	7.18	10.34	13.48
Topside (Cap Off)	AM2001	RST	9.66	5.18	9.66	14.19	16.65
Topside Cap	TOP033	SCT	6.77	3.84	6.77	9.71	12.66
Thin Flank	AM2200	SFR	6.60	3.85	6.60	9.34	12.07
Denuded Cube	CUB045	GRL	14.50	7.54	14.50	21.46	28.39
Spinalis	SPN081	GRL	12.85	6.73	12.85	18.97	25.06
Bolar Blade	BLD096	GRL	10.27	5.75	10.27	14.79	19.31
Oyster Blade	OYS036	GRL	11.48	4.93	11.48	14.79	19.68
Chuck Tender	CTR085	SFR	6.51	3.80	6.51	9.25	11.99
Brisket	AM2320	SCT	4.92	3.51	4.92	6.33	7.76
Fore Shin	FQshin	SCT	7.11	3.88	7.11	10.36	13.61
Polk Chuck	ZZZ002	SCT	6.52	3.77	6.52	9.30	12.07
Rodz Pieces	ZZZ001	GRL	14.49	5.77	14.49	16.20	21.37
Trim 75VL	BfTr75	N/A	4.14	4.14	4.14	4.14	4.14
Trim 80VL	BfTr85	N/A	6.45	6.45	6.45	6.45	6.45
Trim 85VL	BfTr80	N/A	8.76	8.76	8.76	8.76	8.76
Bones	BonesO	N/A	0.13	0.13	0.13	0.13	0.13
Waste & Fat	WstFat	N/A	0.06	0.06	0.06	0.06	0.06

Appendix 2: Primal cooking method designation, flat price ($/kg) and MSA price ($/kg) used to calculate wholesale primal value

Where cooking method[a]: CRN = Corned (pickled); GRL = Grilling; RST = Roast; SCT = Slow Cook; SFR = Stir-fry; TSL = Thin-slice;