Economic Evaluation of New Technologies and Promotions in the Australian Sheep and Wool Industries

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Abstract

Knowledge about the size and distribution of returns from alternative broad types of R&D and promotion investments permit strategic-level decisions about resource allocation, both within and across research programs. The Australian sheep meat and wool industries are characterised by strong cross-commodity relationships due to the joint product nature of the industries. An equilibrium displacement model of the Australian sheep meat and wool industries was developed to account for these relationships and any indirect benefits and costs arising from spill-over and feedback effects between the industries as a result of research-induced innovation or promotion. The potential annual returns and their distribution among the various industry sectors were estimated from different hypothetical investment scenarios to demonstrate the model's relevance to R&D and promotion policy and decision-making.

Key words

Australian sheep and wool industries, equilibrium displacement model, cross-commodity relationships, R&D and promotion evaluation

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Introduction

Cross-commodity relationships are an important feature of the Australian sheep meat and wool industries. Examples include joint production of wool and lamb, and substitution in domestic consumption of lamb and mutton. Published industry models to date are either large and data intensive (for example, Vere *et al.* 2000), and therefore difficult to maintain, or single industry approaches that largely ignore the cross-product interactions (Mullen *et al.* 1989; Mullen and Alston 1994; Hill *et al.* 1996).

Since the collapse of the Reserve Price Scheme for wool in 1990 the Australian sheep meat and wool industries have undergone significant structural change and been faced with a number of challenging issues. Global demand for wool has declined with strong competition from substitute fibres emerging in wool's traditional apparel markets. Lower returns for wool and periods of sustained drought have contributed to sheep numbers falling from 173 million in 1990 to a little over 100 million in 2005. During this time wool production has decreased by more than the decrease in sheep numbers with an increased proportion of ewes and decreased proportion of wethers in the national flock indicative of a shift in focus towards lamb production (Martin, King and Shafron 2004). A sharp decline in Australia's wool processing industry has resulted from global overcapacity and the emergence of China and other low labour cost regions in wool processing. Welfare concerns over live sheep exports and mulesing to prevent fly strike have featured prominently in media headlines amid animal rights campaigns for boycotts on the purchase of Australian sheep and wool products. Given the increased competition and uncertain market conditions facing the Australian sheep meat and wool industries, it is imperative that funds made available for R&D and promotion are invested efficiently to maximise net returns to the industries and the community.

Significant contributions in the form of compulsory levies on gross wool and livestock sales are made by Australian producers to R&D investments and generic promotions undertaken by industry research providers and organisations such as the Australian Sheep Industry Cooperative Research Centre (Sheep CRC), Australian Wool Innovation (AWI) and Meat and Livestock Australia (MLA). Debate as to the allocation of funds directed to R&D or promotion has always been a contentious issue. As pointed out by Piggott (1998), Australian woolgrowers and red meat producers have often questioned the level of returns received on the investment of their levy dollars. Reliable information is a fundamental requirement in any decisions regarding levy changes but to date such information has been limited because comprehensive industry models have not been available.

Knowing the potential size and distribution of returns from alternative research and promotion investments across different sectors of an industry enable more informed strategic level decisions to be made about how to allocate limited resources among a number of investment options. Credible economic evaluation requires at the very least the consideration of the multiple components of the Australian sheep meat and wool industries. Disregarding indirect effects may have important policy implications for the generation and allocation of investment funds.

The economic evaluations of research or promotion expenditures are often undertaken using comparative static analyses more commonly known as equilibrium displacement models (EDM) (for example, Freebairn, Davis and Edwards 1982; Wohlgenant 1993; Zhao *et al.* 2000a; Zhao, Anderson and Wittwer 2003). The structure of an industry is represented by a system of general functional form demand and supply equations defining equilibrium in all markets. The impacts of new technologies in various industry sectors or successful promotion campaigns in various product markets are modeled as shifts in the relevant supply or demand curves. When an exogenous shift displaces the equilibrium, the resulting market price and quantity changes allow changes in producer and consumer surplus to be estimated for the various industry sectors.

This paper develops an EDM to assess the returns to the Australian sheep meat and wool industries from effective R&D or promotion campaigns. The main aims of the paper are to provide a disaggregated economic framework to allow estimation and comparison of the annual total returns from R&D and promotion investments and their distribution among the various industry sectors and markets. In addition to the evaluation and comparison of alternative broad types of research and promotion investments, the industry wide impacts of particular technologies or promotions can also be evaluated. The explicit contributions of the paper are two-fold. Firstly, the cross-commodity relationships and multi-product nature of the industries are accounted for within the model, and secondly, a high degree of industry disaggregation allows for the evaluation of individual investments specific to an agricultural zone or commodity type. This has particular relevance to evaluation of R&D investments where new technologies may not be applicable, nor adopted, Australia wide.

The Structural Model

The Australian sheep and wool industries consist of numerous market segments. Analysis of the returns from research, promotion or government policies undertaken in different industry sectors or markets require a model properly representative of the industry structure. Horizontal and vertical industry disaggregation allows for the distribution of total industry returns among the various regions and sectors to be estimated.

The structure of the Australian sheep and wool industries represented in Figure 1 consists of four connecting diagrams. The logic of the block structure of diagrams is as follows. Figure 1(a) shows the disaggregation of the national flock and associated production of wool, lamb, mutton and live sheep. Figure 1(b) traces the supplies of wool from the farm to the warehouse where it is sold at auction and either exported or purchased for use in domestic processing. Following on from Figure 1(b), the different stages of the domestic wool processing sector and exports of semi-processed wool products are depicted in Figure 1(c). Connecting directly back to Figure 1(a), the various stages of the sheep meat supply chain and markets for lamb, mutton and live sheep are presented in Figure 1(d).

In Figure 1(a) the industries are horizontally disaggregated into merino sheep and non-merino sheep. Merino sheep are further disaggregated by agricultural zone and production enterprise within each zone.[1] Breeding intention separates merino ewes in the high rainfall and wheat-sheep zones into merino lamb and non-merino lamb producing enterprises. Merino sheep not used for breeding purposes are classified as dry sheep and are grouped together. As such, merino wethers and merino hoggets within each zone are combined as a single enterprise or sector.

Australian wool production is divided into four main diameter categories corresponding to Australian Bureau of Statistics wool export categories of 19 μm and finer, 20-23 μm, 24-27 μm and 28 μm or broader. Wool of the same diameter classification within each zone is assumed homogeneous in quality. Vertical disaggregation of the wool industry includes the warehousing, export and Australian early-stage processing sectors. Around 85 per cent of wool is sold through the auction system while the rest is sold 'privately' on-farm or to local wool handling facilities. For simplification in this analysis it is assumed that 100 per cent of wool is sold through the auction system. The warehouse sector

[1] Agricultural production within Australia comprises three agricultural zones, high rainfall, wheat-sheep and pastoral.

(Figure 1b) is assumed to include wool handling, storage, testing and associated selling costs. The majority of Australian wool production is exported in its raw greasy form with the remainder undergoing some degree of early-stage processing before being exported as scoured wool, carbonised wool or wool tops. Limited quantities of wool tops are used as inputs in domestic later-stage processing such as spinning and weaving. Early-stage processing of wool in Australia is separated into scouring, carbonising and top making sectors (Figure 1c). Post-sale costs such as transport, dumping and shipment preparation for greasy wool are included in the export sector.

Vertical disaggregation of the sheep meat supply chain (Figure 1d) beyond the farm gate consists of processing and marketing sectors. The processing sector undertakes all slaughtering and processing activities necessary to produce lamb and mutton for the export market and carcasses of lamb and mutton for sale to domestic retailers. The domestic marketing or retail sector processes the carcasses and packages the products for sale to final consumers. This sector comprises supermarkets, butchers and integrated abattoir or independent boning rooms that undertake the same process.

The resulting EDM of the Australian sheep meat and wool industries is a system of 295 equations with 295 endogenous variables.[2] As is typical in EDM analysis it is assumed that all production functions exhibit constant returns to scale and profit maximisation is an implicit behavioural assumption of each industry sector within the model. The impacts of new technologies in various industry sectors or successful promotion campaigns in various product markets are represented by 42 exogenous supply and 19 exogenous demand shift variables.

Input Data

Estimates of market parameters and base equilibrium values for all sectors are required to solve the model. Average values taken over a period of years to dampen the impact of seasonal effects or other anomalies are typically used to represent the base equilibrium situation. In 2002, Australian woolgrowers began operating in a free market for the first time in almost thirty years after the last of the 4.7 million-bale wool stockpile was sold. In order for the data to reflect current market values and production systems, the base equilibrium values, and associated input cost and output revenue shares, used in the

[2] The general functional form equations specifying the model are listed in the appendix at the end of this paper.

model (Table 1) were taken as averages of prices and quantities for the three-year period 2002-03 to 2004-05.

The market elasticities (Table 2) were specified according to relevant empirical studies and subjective judgement. The values are indicative of a medium-run time frame of 3-5 years.

The possible R&D and promotion investment scenarios are numerous. Consequently, this study is limited to five alternative hypothetical investment scenarios:

Scenario 1: R&D in lamb production
Cost reduction in lamb production resulting from any farm technologies that reduce the cost of producing lambs. The technology applies to all non-merino and merino lambs produced for slaughter in all three agricultural zones.

Scenario 2: R&D in sheep meat processing
Cost reduction in the sheep meat processing sector resulting from new technologies or improvements in management that reduce the cost of slaughtering and processing lamb and mutton

Scenario 3: R&D in wool production
Cost reduction in wool production resulting from any farm technologies that reduce the cost of producing wool. The technology applies to all types of wool grown in all three agricultural zones

Scenario 4: Promotion of lamb in the domestic market
Increase in the ‘willingness to pay’ by domestic consumers of lamb due to promotion or changes in tastes in the domestic market.

Scenario 5: Promotion of greasy wool in the export market
Increase in the ‘willingness to pay’ by export consumers of greasy wool due to promotion or changes in tastes in overseas markets.

Results

The annual economic welfare changes and the distribution of benefits among various industry sectors for the five hypothetical scenarios are summarised in Table 3. For each R&D scenario a one per cent cost reduction is depicted by a one per cent downward parallel shift of the supply curve in the relevant sector. In the promotion scenarios a one per cent upward parallel shift of the relevant demand curve represents a one per cent increase in consumers' willingness to pay.

Total Welfare Gains

In terms of absolute value, wool production research (Scenario 3) and greasy wool promotion (Scenario 5) provide the largest total returns ($24.52 million and $22.11 million, respectively). For the investment scenarios specifically related to lamb research or promotion, the largest total returns are for domestic lamb promotion (Scenario 4, $14.61 million) followed by lamb production research (Scenario 1, $9.23 million). Sheep meat processing research generates the smallest total amount (Scenario 2, $6.51 million).

Distribution of Welfare Gains

The exogenous shifts in investment Scenarios 1 and 4 simulate either new technologies or promotions related specifically to lamb while Scenario 2 refers to lamb and mutton. Domestic consumers are the main beneficiaries in each scenario accruing 47.1 per cent of the total benefits from domestic lamb promotion (Scenario 4), 31.3 per cent from sheep meat processing research (Scenario 2) and 30.8 per cent from lamb production research (Scenario 1).

In general, as overseas demand for Australian lamb is more elastic than domestic demand, surplus gains for domestic consumers should be considerably larger than those received by overseas consumers. However, shares of the total benefits collected by overseas consumers are significant (14.7 per cent to 30.6 per cent). Due to the joint nature of production, wool export quantities increase as lamb production increases in all three scenarios. Depending on the scenario in question, purchasers of Australian greasy and processed wool are the recipients of 60 per cent to 67 per cent of the additional surplus gained by overseas consumers.

Lamb production research (Scenario 1, 23.7 per cent) and sheep meat processing research (Scenario 2, 22.2 per cent) provide sheep producers with the highest percentage share of total benefits from the three scenarios. Domestic lamb promotion (Scenario 4) delivers 18.6 per cent of the total benefits to sheep producers. Dry sheep enterprises experience negative surplus changes in response to lamb production research and promotion investment in the domestic market. Taking this into consideration, lamb producing enterprises actually receive 28 per cent of the benefits from lamb production research and 21 per cent of total returns from investment in domestic promotion.

Sheep meat processors obtain 13 per cent of the total benefits from sheep meat processing research and around 8 per cent of the benefits from lamb production research and domestic promotion of lamb. Domestic retailers capture a 10 per cent share of the additional benefits from lamb promotion and approximately 5 per cent of the benefits in each of the other two scenarios. The wool warehouse/brokerage, domestic wool processing, wool export and sheep meat export sectors gain small amounts, all receiving benefit shares of less than 1 per cent in each scenario. Elastic supplies of inputs and small value added to products in these sectors restrict the total benefit shares.[3]

New technology in wool production and successful promotion of greasy wool in export markets are depicted in Scenarios 3 and 5, respectively. As the majority of Australian wool is exported in either greasy or semi-processed form, overseas consumers gain significant shares of the total returns in each case (49.5 per cent and 53.8 per cent). Purchasers of greasy or semi-processed wool acquire upwards of 85 per cent of the total benefits going abroad with the remainder split among overseas consumers of lamb, mutton and live sheep. Domestic wool processors incur a loss of surplus from successful overseas promotion of Australian greasy wool.

Domestic consumers receive much smaller shares of total benefits from wool related investments (11.3 per cent and 7.6 per cent). Additional surplus gains are mostly the outcome of lower retail prices for lamb resulting from increased supply.

Sheep producers gain the greatest share of total returns (33.3 per cent) from greasy wool promotion (Scenario 5) while wool production research (Scenario 3) yields a 31.2 per cent share. Unlike lamb specific investments where some of the additional surplus gains accruing to lamb producing enterprises are transferred from the dry sheep enterprises, the wool specific investment scenarios deliver positive gains to all sheep enterprises in the model. Other industry sectors individually receive up to 4 per cent of the total benefits.

[3] With relatively elastic supply the changes in producer surplus are smaller than with inelastic supply as the changes in price are smaller.

General Comments

A number of qualifications need to be stated. The results are derived from hypothetical one per cent exogenous shifts in the relevant sector demand or supply curves. The costs involved in implementing the one per cent shifts are not taken into consideration. Therefore, comparison of the monetary returns from the different scenarios can only be made under the assumption that the investment costs required to implement the equal demand or supply curve shifts are the same in each sector. To demonstrate, if the monetary investments in lamb production research and sheep meat processing research were identical (equal $ investment induces equal % shift) sheep and wool producers as a whole would prefer lamb production research ($2.19 million) to sheep meat processing research ($1.45 million). For sheep and wool producers to be indifferent as to which sector the research funds are directed, investment in sheep meat processing would need to be approximately 51 per cent more efficient than investment in lamb production (2.19/1.45 = 1.51). In other words the size of the percentage shift necessary to generate the same returns to producers from sheep meat processing research as from a 1 per cent cost reduction in lamb production would be 1.51 per cent.

In terms of monetary gains, which investment scenario is preferred over another depends on the costs required to shift the demand or supply curves in the relevant market. Even without knowledge of the investment costs the distributions of total benefits among industry sectors from alternative scenarios are directly comparable. The same amount of money invested in different industry sectors may result in demand or supply shifts of unequal size but the distribution of total benefits among industry sectors for a particular scenario is independent of the magnitude of the initial shift (Zhao 1999, p160). For example, the producers' share of the total benefits from lamb production research (23.7 per cent in Scenario 1) is the same irrespective of the size of the percentage reduction in the cost of producing lamb. However, the results are dependent on the assumptions made, and values chosen, for the parameters and price and quantity data used in the model. Accounting for the sensitivity of the results to uncertain parameter values is discussed in the next section.

Finally, it should also be noted that the partial equilibrium framework of the model does not account for economic benefits or spillovers to other industries such, as the beef or grains industries, that result from investment undertaken in the Australian sheep and wool industries.

Sensitivity Analysis

Simple discrete sensitivity analysis can be used to demonstrate the impacts that different price and quantity data may also have on the results. To illustrate, Scenario 4 (domestic lamb promotion) was re-run with retail prices of lamb and mutton halved. As expected, total surplus was reduced by one half because the total retail value of lamb halved. Benefits to all industry sectors were smaller with the value to sheep and wool producers falling by $0.44 million from $2.72 million to $2.28 million. Conversely, the share of total benefits accruing to sheep and wool producers increased from 18.6 per cent to 31.2 per cent. Therefore, it is important to bear in mind that total benefits and the distribution of those benefits may be influenced by assumptions regarding prices and quantities highlighting the need for accurate and timely data.

The parameter values in the model were chosen from published estimates, economic theory and the authors' subjective judgement. Following Zhao *et al*. (2000b), a stochastic approach to sensitivity analysis was used to account for uncertain parameter values. Probability distributions were assigned to each of the unknown parameters. From each distribution were drawn 2000 values. The EDM was run 2000 times using a different set of parameter values for each run to generate 2000 sets of price and quantity changes, and 2000 sets of economic surplus changes. The 2000 sets of surplus changes were used to estimate probability distributions of the surplus changes from which means, standard deviations and 95 per cent subjective probability intervals (95 per cent PI) were calculated. The process was repeated for each R&D and promotion scenario.

The probability distributions assigned to the parameters were either truncated normal distributions or mixed truncated normal and exponential distributions. Sign restrictions were placed on the parameters based on theoretical constraints. For example, export and domestic own-price elasticities of demand, and product transformation elasticities are expected to have negative signs. Truncating the distribution from above at zero restricts these parameters to take negative values. Own-price elasticities of supply, input substitution elasticities and cross-price domestic demand elasticities are expected to have positive signs. Truncating the distribution from below at zero restricts these values to take positive values.

Placing sign restrictions on a parameter may cause the distribution to become asymmetric which has certain implications for the probabilities for particular ranges of values. However, for most parameters in the model, the truncation is more than three standard deviations from the mode and has little effect on the distributions. In instances where the subjective view was that truncated normal distributions were not representative of the probabilities that the parameter values may assume, mixed truncated normal and exponential distributions were used to provide the necessary skewed shape.

Summary statistics for the welfare benefits corresponding to each scenario are presented in Table 4. The figures on the left side of each column are the benefits in millions of dollars and those on the right side are the percentage shares of the total benefits for each industry sector. The base estimates and means, standard deviations and 95 per cent PIs are reported in the rows underneath each industry sector heading. Given the probability distributions specified for each of the market elasticities, the figures in Table 4 provide a measure of the variability of the welfare changes. For example, in Scenario 1 the mean benefit to sheep producers from lamb production research is \$2.24 million with an average 24.2 per cent share of the total benefits. This compares to the base estimates derived from the model of \$2.19 million and 23.7 per cent of total benefits. The standard deviation of the benefits to sheep producers is \$0.35 million or approximately 3.8 per cent. The subjective 95 per cent PI is different from a conventional sampling theory confidence interval in that it is derived from subjective prior distributions (Zhao 1999). It is obtained by discarding the lowest 2.5 per cent and highest 2.5 per cent of the 2000 simulated welfare changes. The remaining first and last values form an estimate of the interval. Thus, for Scenario 1 we have 95 per cent confidence that sheep producers will receive between \$1.67 million to \$3.05 million or 18 per cent to 33 per cent of the total benefits from this particular type of on-farm research. Comparing the subjective 95 per cent PI with approximately two standard deviations from the mean allows for any asymmetry in the distribution to be discovered. For example, two standard deviations from the mean in Scenario1 provides interval estimates of \$1.54 million to \$2.94 million to sheep producers indicating the distribution is skewed slightly to the right.

Single Commodity vs. Joint Product Analysis

How important is it to consider the multiple components of the Australian sheep meat and wool industries when undertaking economic evaluations of research or promotion expenditures? To demonstrate, Scenarios 1 (lamb production research) and 4 (domestic lamb promotion) were re-simulated using single-industry approaches whereby associated production of wool, mutton and live sheep were assumed zero. As shown in Table 5, exclusion of the cross-commodity relationships has implications for the distribution of total benefits. In isolation, a 1 per cent lower lamb production cost (Scenario 1a) delivers around 28 per cent of the total benefits to lamb producers which are consistent with the percentage share accruing to the lamb producing enterprises in Scenario 1 when all production outputs are included. However, as noted above the combined returns of all sheep and wool producers are less than this (23.7 per cent). Overseas consumers receive a much larger portion of the additional gains when all commodities are considered (30.6 per cent compared to 13.9 per cent) while the reverse applies for domestic consumers (30.8 per cent compared to 39.5 per cent). Gains to domestic processors and retailers are also higher under the single commodity analysis. Similar disparities were found in the distribution of benefit shares between Scenarios 4 and 4a.

Conclusions

The EDM specified in this paper was developed to account for the cross-commodity interactions present within the Australian sheep and wool industries. The economic framework enables analysis of total welfare changes and their distribution among industry sectors from exogenous changes impacting on the Australian sheep and wool industries. These include, but are not limited to, the evaluation of alternative broad types of research and promotion investments or the impacts of government market interventions. The model can also be used to evaluate specific R&D or promotion investments and provides a high degree of industry disaggregation not previously developed in other models.

The application of the model was demonstrated by estimating total industry returns and their distribution among various industry sectors and market participants for five hypothetical R&D and promotion scenarios. The largest potential annual returns to the Australian sheep and wool industries, and to sheep and wool producers, were from effective R&D that reduces the cost of wool production by 1 per cent ($25.5 million) and effective promotion of greasy wool in export markets that increases demand by 1 per cent ($22.1 million). While the monetary gains are only comparable under the assumption of equal investment efficiency, the benefit shares provide a meaningful comparison. Sheep and wool producers as a group always receive the greatest share of total benefits from investment in greasy wool promotion (33.3 per cent) and wool production research (31.2 per cent). Domestic promotion of lamb generates the largest share of benefits to domestic consumers (47.2 per cent) while overseas consumers receive 53.8 per cent of the additional gains from export promotion of greasy wool.

The results are conditional on the values specified for the parameters, and prices and quantities within the model. Data limitations required the authors to often rely on subjective judgement to specify values as information on elasticities, and base prices and quantities were scarce or non-existent in some instances. Consequently, stochastic sensitivity analysis was undertaken to estimate summary statistics and establish 95 per cent probability intervals for the economic surplus changes.

Failure to account for all sheep and wool industry components was shown to redistribute the benefits shares among industry sectors and markets, highlighting the importance of neglecting cross-commodity relationships within the industries.

From an industry perspective, the model specified in this paper provides the structure to enable cost-benefit analysis once information on investment costs is known. This can assist priority-setting and policy decisions within the industry by helping to identify the total returns, and the beneficiaries of those returns, from alternative R&D or promotion investments. The model is not only of relevance to levy-paying producers, other industry groups and providers of R&D and promotion but also the community in general, as public contributions to investment are funded by government and consumers share in the benefits from investment.

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Table 1: Base Equilibrium Values 2002-03 to 2004-05

Wool, Lamb, Mutton & Live Sheep Production	**<u>Wool, lamb & mutton from non-merino sheep</u>** *Total value*: TV_{Y1} = 550.57 *Cost shares*: k_{X1} = 0.08 (sheep – annual service flow cost)**; k_{X1W} = 0.92 (other inputs) *Revenue shares*: γ_{Y13W} = 0.05 (24-27 micron wool); γ_{Y14W} = 0.14 (≥28 micron wool); γ_{Y1L} = 0.76 (prime lamb); γ_{Y1M} = 0.05 (mutton)
	<u>Wool, lamb & mutton from merino ewes (high rainfall zone)</u> *Total value*: TV_{Y2} = 292.65 *Cost shares*: k_{X21} = 0.11 (sheep – annual service flow cost); k_{X21W} = 0.89 (other inputs) *Revenue shares*: γ_{Y21W} = 0.23 (≤ 19 micron wool); γ_{Y22W} = 0.15 (20-23 micron wool); γ_{Y23W} = 0.02 (24-27 micron wool); γ_{Y2L} = 0.54 (1st cross lamb); γ_{Y2M} = 0.06 (mutton)
	Total value: TV_{Y3} = 472.45 *Cost shares*: k_{X31} = 0.21 (sheep – annual service flow cost); k_{X31W} = 0.79 (other inputs) *Revenue shares*: γ_{Y31W} = 0.43 (≤ 19 micron wool); γ_{Y32W} = 0.30 (20-23 micron wool); γ_{Y33W} = 0.05 (24-27 micron wool); γ_{Y3L} = 0.09 (merino lamb); γ_{Y3M} = 0.13 (mutton)
	<u>Wool, lamb & mutton from merino ewes (wheat-sheep zone)</u> *Total value*: TV_{Y4} = 547.03 *Cost shares*: k_{X41} = 0.09 (sheep – annual service flow cost); k_{X41W} = 0.91 (other inputs) *Revenue shares*: γ_{Y41W} = 0.11 (≤ 19 micron wool); γ_{Y42W} = 0.23 (20-23 micron wool); γ_{Y43W} = 0.02 (24-27 micron wool); γ_{Y4L} = 0.61 (1st cross lamb); γ_{Y4M} = 0.03 (mutton)
	Total value: TV_{Y5} = 719.73 *Cost shares*: k_{X51} = 0.18 (sheep – annual service flow cost); k_{X51W} = 0.82 (other inputs) *Revenue shares*: γ_{Y51W} = 0.23 (≤ 19 micron wool); γ_{Y52W} = 0.48 (20-23 micron wool); γ_{Y53W} = 0.03 (24-27 micron wool); γ_{Y5L} = 0.18 (merino lamb); γ_{Y5M} = 0.08 (mutton)
	<u>Wool, lamb & mutton from merino ewes (pastoral zone)</u> *Total value*: TV_{Y6} = 229.63 *Cost shares*: k_{X61} = 0.26 (sheep – annual service flow cost); k_{X61W} = 0.74 (other inputs) *Revenue shares*: γ_{Y61W} = 0.11 (≤ 19 micron wool); γ_{Y62W} = 0.37 (20-23 micron wool); γ_{Y63W} = 0.04 (24-27 micron wool); γ_{Y6L} = 0.15 (merino lamb); γ_{Y6M} = 0.33 (mutton)
	<u>Wool, lamb & mutton from merino wethers/hoggets (high rainfall zone)</u> *Total value*: TV_{Y7} = 655.99 *Cost shares*: k_{X71} = 0.29 (sheep – annual service flow cost); k_{X71W} = 0.71 (other inputs) *Revenue shares*: γ_{Y71W} = 0.43 (≤ 19 micron wool); γ_{Y72W} = 0.32 (20-23 micron wool); γ_{Y73W} = 0.05 (24-27 micron wool); γ_{Y7E} = 0.11 (live sheep); γ_{Y7M} = 0.09 (mutton)
	<u>Wool, lamb & mutton from merino wethers/hoggets (wheat-sheep zone)</u> *Total value*: TV_{Y8} = 781.27 *Cost shares*: k_{X81} = 0.42 (sheep – annual service flow cost); k_{X81W} = 0.58 (other inputs) *Revenue shares*: γ_{Y81W} = 0.19 (≤ 19 micron wool); γ_{Y82W} = 0.43 (20-23 micron wool); γ_{Y83W} = 0.03 (24-27 micron wool); γ_{Y8E} = 0.27 (live sheep); γ_{Y8M} = 0.08 (mutton)
	<u>Wool, lamb & mutton from merino wethers/hoggets (pastoral zone)</u> *Total value*: TV_{Y9} = 144.93 *Cost shares*: k_{X91} = 0.70 (sheep – annual service flow cost); k_{X91W} = 0.30 (other inputs) *Revenue shares*: γ_{Y91W} = 0.11 (≤ 19 micron wool); γ_{Y92W} = 0.43 (20-23 micron wool); γ_{Y93W} = 0.05 (24-27 micron wool); γ_{Y9E} = 0.03 (live sheep); γ_{Y9M} = 0.38 (mutton)
Wool Warehouse Sector	**<u>≥28 micron wool</u>** *Total value*: TV_{Z1} = 82.26 *Cost shares*: k_{Y1W} = 0.95 (wool); k_{YNM} = 0.05 (other inputs) *Revenue shares*: γ_{Z1W} = 0.94 (greasy wool for export); γ_{Z1S} = 0.06 (greasy wool for domestic processing)

Table 1 (cont.): Base Equilibrium Values 2002-03 to 2004-05

Wool Warehouse Sector	**<u>< 19 micron wool</u>** *Total value*: TV_{Z2} = 1007.54 *Cost shares*: k_{Y2W} = 0.95 (wool); k_{YFM} = 0.05 (other inputs) *Revenue shares*: γ_{Z2W} = 0.82 (greasy wool for export); γ_{Z2S} = 0.18 (greasy wool for domestic processing) **<u>20-23 micron wool</u>** *Total value*: TV_{Z3} = 1419.09 *Cost shares*: k_{Y3W} = 0.95 (wool); k_{YMM} = 0.05 (other inputs) *Revenue shares*: γ_{Z3W} = 0.76 (greasy wool for export); γ_{Z3S} = 0.24 (greasy wool for domestic processing) **<u>24-27 micron wool</u>** *Total value*: TV_{Z4} = 161.65 *Cost shares*: k_{Y4W} = 0.95 (wool); k_{YBM} = 0.05 (other inputs) *Revenue shares*: γ_{Z4W} = 0.76 (greasy wool for export); γ_{Z4S} = 0.24 (greasy wool for domestic processing)
Domestic Wool Scouring Sector	**<u>Scoured wool</u>** *Total value*: TV_{CS} = 609.35 *Cost shares*: k_{Z1S} = 0.01 (≥28 micron wool); k_{Z2S} = 0.30 (≤ 19 micron wool); k_{Z3S} = 0.56 (20-23 micron wool); k_{Z4S} = 0.06 (24-27 micron wool); k_{ZCS} = 0.07 (other inputs) *Revenue shares*: γ_{ZCW} = 0.18 (scoured wool for carbonising); γ_{F1S} = 0.01 (≥28 micron wool); γ_{F2S} = 0.29 (≤ 19 micron wool); γ_{F3S} = 0.46 (20-23micron wool); γ_{F4S} = 0.06 (24-27micron wool)
Domestic Wool Carbonising Sector	**<u>Carbonised wool</u>** *Total value*: TV_{FCW} = 128.84 *Cost shares*: k_{ZCW} = 0.84 (scoured wool); k_{ZCB} = 0.16 (other inputs)
Domestic Wool Top Sector	**<u>Wool Tops</u>** *Total value*: TV_{FT} = 241.16 *Cost shares*: k_{Z2T} = 0.37 (≤ 19 micron wool); k_{Z3T} = 0.43 (20-23 micron wool); k_{Z4T} = 0.09 (24-27 micron wool); k_{ZWT} = 0.11 (other inputs) *Revenue shares*: γ_{F2T} = 0.41 (≤ 19 micron wool top); γ_{F3T} = 0.45 (20-23micron wool top); γ_{F4T} = 0.10 (24-27micron wool); γ_{FNW} = 0.04 (noils of wool)
Wool Export Sector and Wool Exports	**<u>Greasy Wool</u>** *Total value*: TV_{Q1W} = 83.50 *Cost shares*: k_{Z1W} = 0.93 (≥28 micron wool); k_{ZNM} = 0.07 (other inputs) *Total value*: TV_{Q2W} = 863.96 *Cost shares*: k_{Z2W} = 0.96 (≤ 19 micron wool); k_{ZFM} = 0.04 (other inputs) *Total value*: TV_{Q3W} = 1127.29 *Cost shares*: k_{Z3W} = 0.95 (20-23 micron wool); k_{ZMM} = 0.05 (other inputs) *Total value*: TV_{Q4W} = 131.14 *Cost shares*: k_{Z4W} = 0.94 (24-27 micron wool); k_{ZBM} = 0.06 (other inputs) **<u>Scoured Wool</u>** *Total value*: TV_{Q1S} = 4.11 *Cost shares*: k_{F1S} = 0.90 (≥28 micron wool); k_{FNS} = 0.10 (other inputs) *Total value*: TV_{Q2S} = 92.05 *Cost shares*: k_{F2S} = 0.95 (≤ 19 micron wool); k_{FFS} = 0.05 (other inputs) *Total value*: TV_{Q3S} = 188.78 *Cost shares*: k_{F3S} = 0.95 (20-23 micron wool); k_{FMS} = 0.05 (other inputs)

Table 1 (cont.): Base Equilibrium Values 2002-03 to 2004-05

Wool Export Sector and Wool Exports	*Total value*: TV_{Q4S} = 16.06 *Cost shares*: k_{F4S} = 0.95 (24-27 micron wool); k_{FBS} = 0.05 (other inputs) **<u>Carbonised Wool</u>** *Total value*: TV_{QCW} = 137.70 *Cost shares*: k_{FCW} = 0.94 (wool); k_{FCB} = 0.06 (other inputs) **<u>Wool Tops</u>** *Total value*: TV_{Q2T} = 102.25 *Cost shares*: k_{F2T} = 0.96 (≤ 19 micron wool); k_{FFT} = 0.04 (other inputs) *Total value*: TV_{Q3T} = 113.51 *Cost shares*: k_{F3T} = 0.96 (20-23 micron wool); k_{FMT} = 0.04 (other inputs) *Total value*: TV_{Q4T} = 24.54 *Cost shares*: k_{F4T} = 0.96 (24-27 micron wool); k_{FBT} = 0.04 (other inputs) *Total value*: TV_{QNW} = 12.79 *Cost shares*: k_{FNW} = 0.85 (noils); k_{FNE} = 0.15 (other inputs)
Sheep Meat Processing Sector	**<u>Lamb</u>** *Total value*: TV_{ZL} = 1626.49 *Cost shares*: k_{YL} = 0.70 (lamb); k_{YSL} = 0.30 (other inputs) *Revenue shares*: γ_{ZLE} = 0.38 (export lamb); γ_{ZLD} = 0.62 (domestic lamb) **<u>Mutton</u>** *Total value*: TV_{ZM} = 437.50 *Cost shares*: k_{YM} = 0.73 (mutton); k_{YSM} = 0.27 (other inputs) *Revenue shares*: γ_{ZME} = 0.73 (export mutton); γ_{ZMD} = 0.27 (domestic mutton)
Sheep Meat Marketing Sectors & Meat Products	**<u>Lamb</u>** *Total value*: TV_{QLE} = 630.65 *Cost shares*: k_{ZLE} = 0.98 (export lamb); k_{Z1L} = 0.02 (other inputs) *Total value*: TV_{QLD} = 1457.22 *Cost shares*: k_{ZLD} = 0.69 (domestic lamb); k_{Z2L} = 0.31 (other inputs) **<u>Mutton</u>** *Total value*: TV_{QME} = 432.92 *Cost shares*: k_{ZME} = 0.98 (export mutton); k_{Z1M} = 0.02 (other inputs) *Total value*: TV_{QMD} = 229.66 *Cost shares*: k_{ZMD} = 0.67 (domestic mutton); k_{Z2M} = 0.33 (other inputs) **<u>Live Sheep Exports</u>** *Total value*: TV_{QSE} = 293.49

**In the model sheep are classed as a semi-durable input. The annual service flow cost from a durable input can be derived as the sum of three component costs, depreciation, maintenance and opportunity costs (Lawrence and McKay 1980; O'Donnell and Woodland 1995).

Table 2: Medium-term Market Elasticity Values

<u>Sheep Supply</u>
Non-merino sheep = 1.2
Merino sheep (high rainfall zone) = 1.0
Merino sheep (wheat-sheep zone) = 1.2
Merino sheep (pastoral zone) = 0.8

<u>Other Inputs Supply</u>
Farm inputs = 3
Wool warehouse inputs = 2.5
Wool export inputs = 2.5
Domestic wool processing inputs = 1.0
Sheep meat processing = 2.0
Sheep meat marketing = 2.0

<u>Input Substitution</u>
Farm:
Between sheep and other farm inputs = 0.1
Wool Warehouse:
Between wool and other warehouse inputs
Between same fibre diameter categories of wool produced from the same agricultural zone = 5.0
Between same fibre diameter categories of wool produced different agricultural zones = 2.0
Wool Processing:
Between wool and other processing inputs = 0.1
Between different fibre diameter categories of wool = 0.1
Wool Export:
Between wool and other export inputs = 0.1
Sheep Meat Processing:
Between lamb and other processing inputs = 0.1
Between non-merino lambs produced from different agricultural zones = 5.0
Between merino lambs produced from different agricultural zones = 5.0
Between non-merino and merino lambs = 2.0
Between mutton (sheep) and other processing inputs = 0.1
Between mutton produced from different agricultural zones and/or enterprises = 5.0
Sheep Meat Marketing:
Between lamb and other marketing inputs = 0.1
Between mutton and other marketing inputs = 0.1

<u>Product Transformation</u>
Farm:
Between $\leq$ 19 micron wool and 20-23 micron wool = -0.5
Between 20-23 micron wool and 24-27 micron wool = -0.25
Between wool and lamb = -0.2
Between mutton and live sheep exports = -1.8
Wool Warehouse:
Between greasy wool for export and greasy wool for processing = -2.0
Wool Processing:
Between semi-processed wool of different fibre diameter categories = -0.1
Sheep Meat Processing:
Between lamb carcass for export and lamb carcass for the domestic market = -0.5
Between mutton carcass for export and mutton carcass for the domestic market = -1.0

Table 2 (cont.): Medium-term Market Elasticity Values

<u>**Demand**</u>
Export:
≥28 micron greasy wool = -2.0
24-27 micron greasy wool = -1.9
20-23 micron greasy wool = -1.2
≤ 19 micron greasy wool = -1.0
≥28 micron scoured wool = -2.0
24-27 micron scoured wool = -1.9
20-23 micron scoured wool = -1.2
≤ 19 micron scoured wool = -1.0
Wool top and noil = -1.5
Lamb = -2.5
Mutton = -5.0
Live sheep = -2.0
Domestic:
Lamb = -1.5
Mutton = -1.4
Lamb with respect to the price of mutton = 0.13
Mutton with respect to the price of lamb = 0.82

Table 3: Economic Surplus Changes ($ million) and Distribution of Total Surplus Changes (%) to Various Industry Sectors: Scenarios 1-5

	Scenario 1		Scenario 2		Scenario 3		Scenario 4		Scenario 5	
	$m	%	$m	%	$m	%	$m	%	$m	%
Producers										
ΔPS_{X1}	0.91	9.85	0.43	6.64	0.36	1.47	1.18	8.05	0.22	1.00
ΔPS_{X21}	0.30	3.28	0.15	2.38	0.36	1.48	0.41	2.81	0.27	1.23
ΔPS_{X31}	0.14	1.48	0.11	1.72	1.04	4.23	0.12	0.82	1.05	4.76
ΔPS_{X41}	0.66	7.16	0.30	4.68	0.57	2.31	0.90	6.15	0.40	1.82
ΔPS_{X51}	0.46	4.98	0.18	2.72	1.31	5.34	0.40	2.73	1.45	6.55
ΔPS_{X61}	0.12	1.25	0.14	2.20	0.48	1.97	0.08	0.53	0.35	1.56
ΔPS_{X71}	-0.15	-1.63	0.01	0.21	1.72	7.02	-0.13	-0.91	1.69	7.64
ΔPS_{X81}	-0.20	-2.17	0.02	0.27	1.71	6.96	-0.17	-1.19	1.60	7.26
ΔPS_{X91}	-0.05	-0.49	0.09	1.39	0.10	0.40	-0.06	-0.39	0.31	1.44
Subtotal: ΔPS_X	2.19	23.72	1.45	22.20	7.64	31.18	2.72	18.61	7.36	33.28
Wool Warehouse/Brokers										
ΔPS_{YW}	0.04	0.41	0.02	0.30	0.17	0.69	0.03	0.21	0.21	0.94
Wool Processors										
ΔPS_{ZW}	0.05	0.55	0.03	0.44	0.29	1.17	0.04	0.26	-0.09	-0.43
Wool Exporters										
ΔPS_{ZWF}	0.05	0.51	0.02	0.38	0.21	0.87	0.04	0.26	0.25	1.11
Sheepmeat Processors										
ΔPS_{YS}	0.71	7.64	0.84	12.91	0.79	3.24	1.27	8.71	0.52	2.36
Sheepmeat Exporters										
ΔPS_{Z1}	0.02	0.21	0.02	0.15	0.03	0.14	0.01	0.07	0.03	0.12
Domestic Sheepmeat Retailers										
ΔPS_{Z2}	0.51	5.51	0.36	5.35	0.47	1.91	1.50	10.28	0.27	1.22
Overseas Consumers										
ΔCS_{QGW} (greasy wool)	1.54	16.70	0.84	12.94	8.29	33.82	1.18	8.10	11.23	50.77
ΔCS_{QPW} (processed wool)	0.36	3.92	0.20	3.11	2.04	8.34	0.27	1.85	-0.67	-3.05
ΔCS_{QLE} (lamb)	0.90	9.70	0.61	9.34	0.74	3.03	0.63	4.28	0.39	1.76
ΔCS_{QME} (mutton)	0.08	0.91	0.13	2.02	0.37	1.53	0.11	0.73	0.35	1.57
ΔCS_{QSE} (live sheep)	-0.06	-0.60	-0.04	-0.65	0.68	2.76	-0.04	-0.26	0.61	2.79
Subtotal: ΔCS_{QE}	2.83	30.63	1.74	26.76	12.13	49.47	2.15	14.69	11.91	53.84
Domestic Consumers										
ΔCS_{QD}	2.85	30.82	2.04	31.27	2.78	11.34	6.89	47.16	1.67	7.56
Total Surplus	**9.23**	**100**	**6.51**	**100**	**24.52**	**100**	**14.61**	**100**	**22.11**	**100**

Table 4: Summary Statistics for Welfare Changes ($million) and Benefit Shares (%) for Various Industry Groups

	Scenario 1		Scenario 2		Scenario 3		Scenario 4		Scenario 5	
	$m	%	$m	%	$m	%	$m	%	$m	%
Sheep Producers: ΔPS_X										
Base	2.19	23.72	1.45	22.20	7.64	31.18	2.72	18.61	7.36	33.28
Mean	2.24	24.24	1.32	20.28	7.53	30.72	2.67	18.34	7.28	32.93
Standard deviation	0.35	3.79	0.28	4.30	0.83	3.38	0.43	2.93	0.87	3.93
95 per cent PI	1.67	18.07	0.67	10.29	6.02	24.55	1.96	13.46	5.59	25.28
	3.05	33.00	1.84	28.26	9.30	37.93	3.61	24.79	9.02	40.80
Warehouse/Brokers Wool: ΔPS_{YW}										
Base	0.04	0.41	0.02	0.30	0.17	0.69	0.03	0.21	0.21	0.94
Mean	0.04	0.39	0.02	0.26	0.16	0.64	0.03	0.19	0.22	1.00
Standard deviation	0.01	0.10	0.01	0.10	0.05	0.20	0.01	0.07	0.05	0.22
95 per cent PI	0.02	0.20	0.003	0.05	0.05	0.20	0.01	0.06	0.14	0.63
	0.06	0.65	0.03	0.46	0.26	1.06	0.04	0.27	0.35	1.58
Wool Processors: ΔPS_{ZW}										
Base	0.05	0.55	0.03	0.44	0.29	1.17	0.04	0.26	-0.09	- 0.43
Mean	0.04	0.48	0.02	0.36	0.25	1.02	0.03	0.22	-0.08	-0.36
Standard deviation	0.01	0.10	0.01	0.15	0.09	0.37	0.01	0.10	0.04	0.18
95 per cent PI	0.01	0.10	0.003	0.05	0.07	0.29	0.008	0.05	-0.18	- 0.81
	0.08	0.86	0.04	0.61	0.46	1.88	0.06	0.41	0.006	0.03
Wool Exporters: ΔPS_{ZWF}										
Base	0.05	0.51	0.02	0.38	0.21	0.87	0.04	0.26	0.25	1.11
Mean	0.04	0.48	0.02	0.32	0.19	0.79	0.03	0.24	0.26	1.18
Standard deviation	0.01	0.10	0.01	0.12	0.06	0.24	0.01	0.08	0.06	0.27
95 per cent PI	0.02	0.21	0.004	0.06	0.06	0.24	0.01	0.07	0.16	0.75
	0.07	0.76	0.04	0.61	0.32	1.31	0.06	0.41	0.42	1.90
Sheepmeat Processors: ΔPS_{YS}										
Base	0.71	7.64	0.84	12.91	0.79	3.24	1.27	8.71	0.52	2.36
Mean	0.67	7.25	1.04	15.98	0.76	3.09	1.31	9.00	0.49	2.22
Standard deviation	0.23	2.49	0.44	6.73	0.25	1.02	0.36	2.46	0.17	0.80
95 per cent PI	0.32	3.46	0.50	7.63	0.37	1.51	0.82	5.63	0.22	1.01
	1.22	13.20	2.15	33.00	1.35	5.50	2.16	14.84	0.91	4.12

Table 4 (cont): Summary Statistics for Welfare Changes ($million) and Benefit Shares (%) for Various Industry Groups

	Scenario 1		Scenario 2		Scenario 3		Scenario 4		Scenario 5	
	$m	%	$m	%	$m	%	$m	%	$m	%
Sheepmeat Exporters: ΔPS_{Z1}										
Base	0.02	0.21	0.02	0.15	0.03	0.14	0.01	0.07	0.03	0.12
Mean	0.02	0.21	0.02	0.27	7.53	30.72	0.02	0.11	0.03	0.13
Standard deviation	0.006	0.06	0.005	0.07	0.83	3.38	0.006	0.04	0.01	0.04
95 per cent PI	0.01	0.11	0.01	0.15	6.02	24.55	0.006	0.04	0.02	0.08
	0.03	0.32	0.03	0.46	9.30	37.93	0.03	0.21	0.05	0.20
Domestic Sheepmeat Retailers: ΔPS_{Z2}										
Base	0.51	5.51	0.36	5.35	0.47	1.91	1.50	10.28	0.27	1.22
Mean	0.47	5.09	0.34	5.14	0.43	1.76	1.53	10.50	0.22	1.00
Standard deviation	0.17	1.84	0.12	1.83	0.16	0.65	0.40	2.75	0.05	0.22
95 per cent PI	0.16	1.73	0.12	1.79	0.14	0.20	0.92	6.32	0.14	0.57
	0.85	9.20	0.59	9.03	0.78	1.06	2.43	16.69	0.35	3.18
Overseas Consumers: ΔCS_{QE}										
Base	2.83	30.63	1.74	26.76	12.13	49.47	2.15	14.69	11.91	53.84
Mean	2.89	31.28	1.68	25.81	12.43	50.71	2.11	14.50	12.05	54.50
Standard deviation	0.26	2.81	0.18	2.76	0.92	3.75	0.38	2.58	1.01	4.57
95 per cent PI	2.43	26.30	1.31	20.12	10.77	43.92	1.44	9.88	10.14	45.86
	3.44	37.23	2.02	31.03	14.4	58.77	2.90	19.95	14.13	63.91
Domestic Consumers: ΔCS_{QD}										
Base	2.85	30.82	2.04	31.27	2.78	11.34	6.89	47.16	1.67	7.56
Mean	2.81	30.41	2.04	31.42	2.73	11.14	6.87	47.02	1.62	7.33
Standard deviation	0.35	3.79	0.25	3.84	0.32	1.31	0.81	5.56	0.24	1.08
95 per cent PI	2.19	23.70	1.59	24.38	2.14	8.73	5.38	36.95	1.16	5.25
	3.56	38.53	2.58	39.63	3.43	13.99	8.65	59.41	2.15	9.72
Total Benefits: ΔTS										
Base	9.23	100	6.51	100	24.52	100	14.61	100	22.11	100
Mean	9.23		6.51		24.52		14.61		22.11	
Standard deviation	0.006		0.006		0.007		0.007		0.009	
95 per cent PI	9.221		6.502		24.503		14.597		22.095	
	9.247		6.524		24.553		14.622		22.124	

Table 5: Economic Surplus Changes ($ million) and Distribution of Total Surplus Changes (%) to Various Industry Sectors: Scenarios 1, 1a, 4 and 4a.

	Scenario 1		Scenario 1a		Scenario 4		Scenario 4a	
	$m	%	$m	%	$m	%	$m	%
Producers								
ΔPS_{X1}	0.91	9.85			1.18	8.05		
ΔPS_{X21}	0.30	3.28			0.41	2.81		
ΔPS_{X31}	0.14	1.48			0.12	0.82		
ΔPS_{X41}	0.66	7.16			0.90	6.15		
ΔPS_{X51}	0.46	4.98			0.40	2.73		
ΔPS_{X61}	0.12	1.25			0.08	0.53		
ΔPS_{X71}	-0.15	-1.63			-0.13	-0.91		
ΔPS_{X81}	-0.20	-2.17			-0.17	-1.19		
ΔPS_{X91}	-0.05	-0.49			-0.06	-0.39		
Subtotal: ΔPS_X	2.19	23.72	2.57	27.9	2.72	18.61	3.39	23.2
Wool Warehouse/Brokers								
ΔPS_{YW}	0.04	0.41			0.03	0.21		
Wool Processors								
ΔPS_{ZW}	0.05	0.55			0.04	0.26		
Wool Exporters								
ΔPS_{ZWF}	0.05	0.51			0.04	0.26		
Sheepmeat Processors								
ΔPS_{YS}	0.71	7.64	0.95	10.3	1.27	8.71	1.46	10.0
Sheepmeat Exporters								
ΔPS_{Z1}	0.02	0.21	0.02	0.2	0.01	0.07	0.01	0.1
Domestic Sheepmeat Retailers								
ΔPS_{Z2}	0.51	5.51	0.75	8.2	1.50	10.28	1.69	11.6
Overseas Consumers								
ΔCS_{QGW}	1.54	16.70			1.18	8.10		
ΔCS_{QPW}	0.36	3.92			0.27	1.85		
ΔCS_{QLE}	0.90	9.70			0.63	4.28		
ΔCS_{QME}	0.08	0.91			0.11	0.73		
ΔCS_{QSE}	-0.06	-0.60			-0.04	-0.26		
Subtotal: ΔCS_{QE}	2.83	30.63	1.28	13.9	2.15	14.69	0.92	6.3
Domestic Consumers								
ΔCS_{QD}	2.85	30.82	3.65	39.5	6.89	47.16	7.14	48.8
Total Surplus	**9.23**	**100**	**9.23**	**100**	**14.61**	**100**	**14.61**	**100**

Figure 1(a): Model Structure

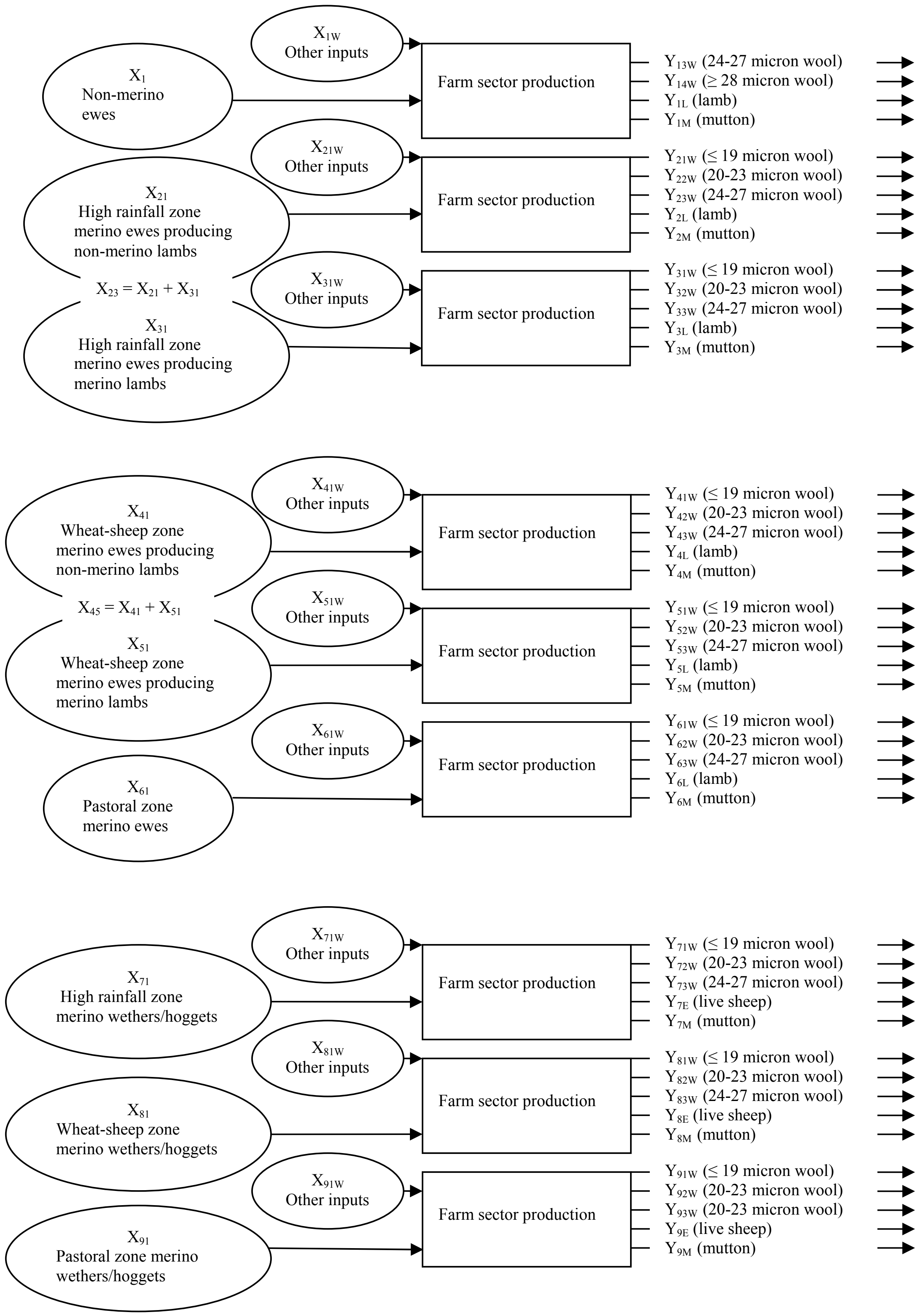


Figure 1(b): Model Structure

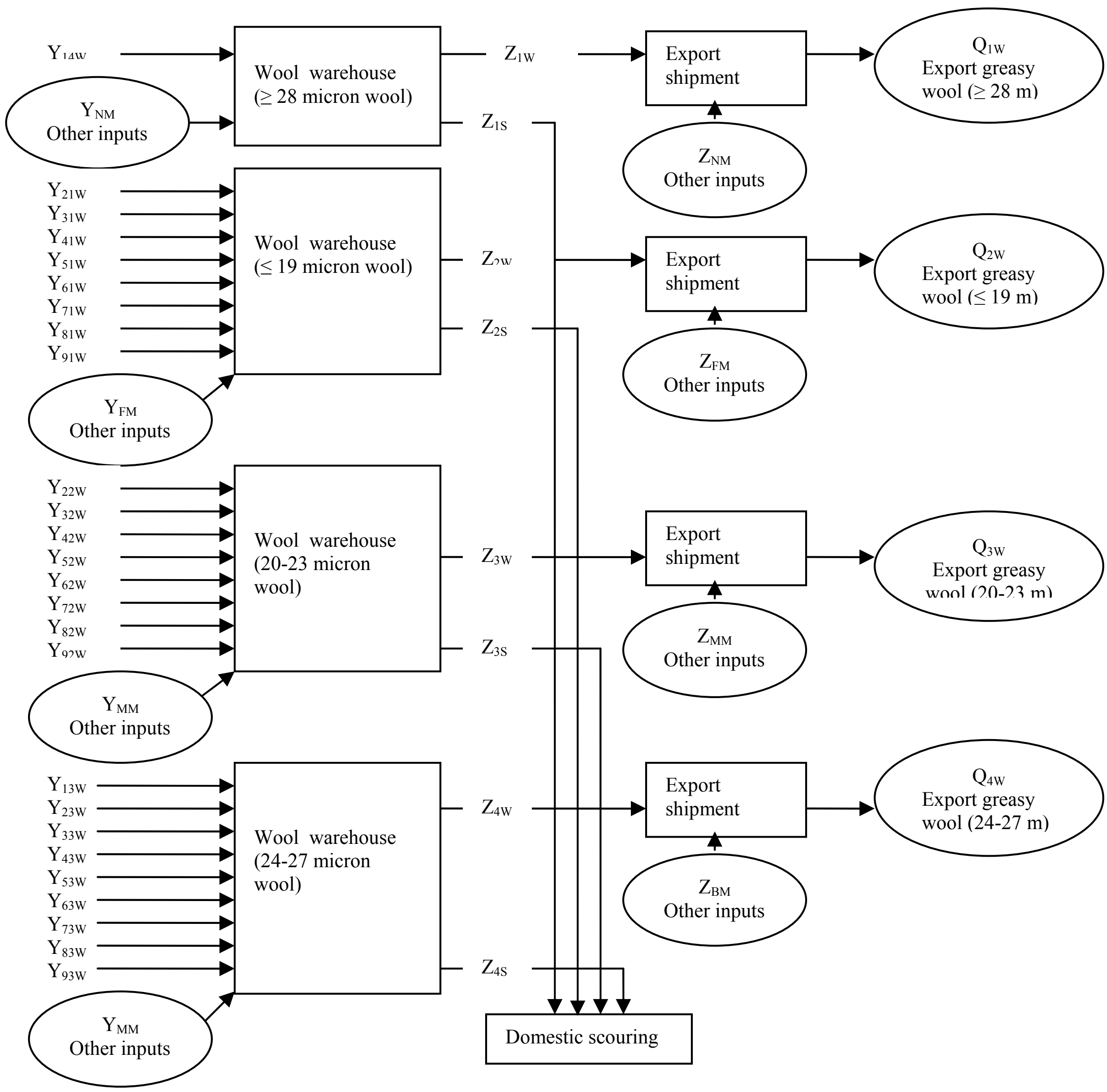


Figure 1(c): Model Structure

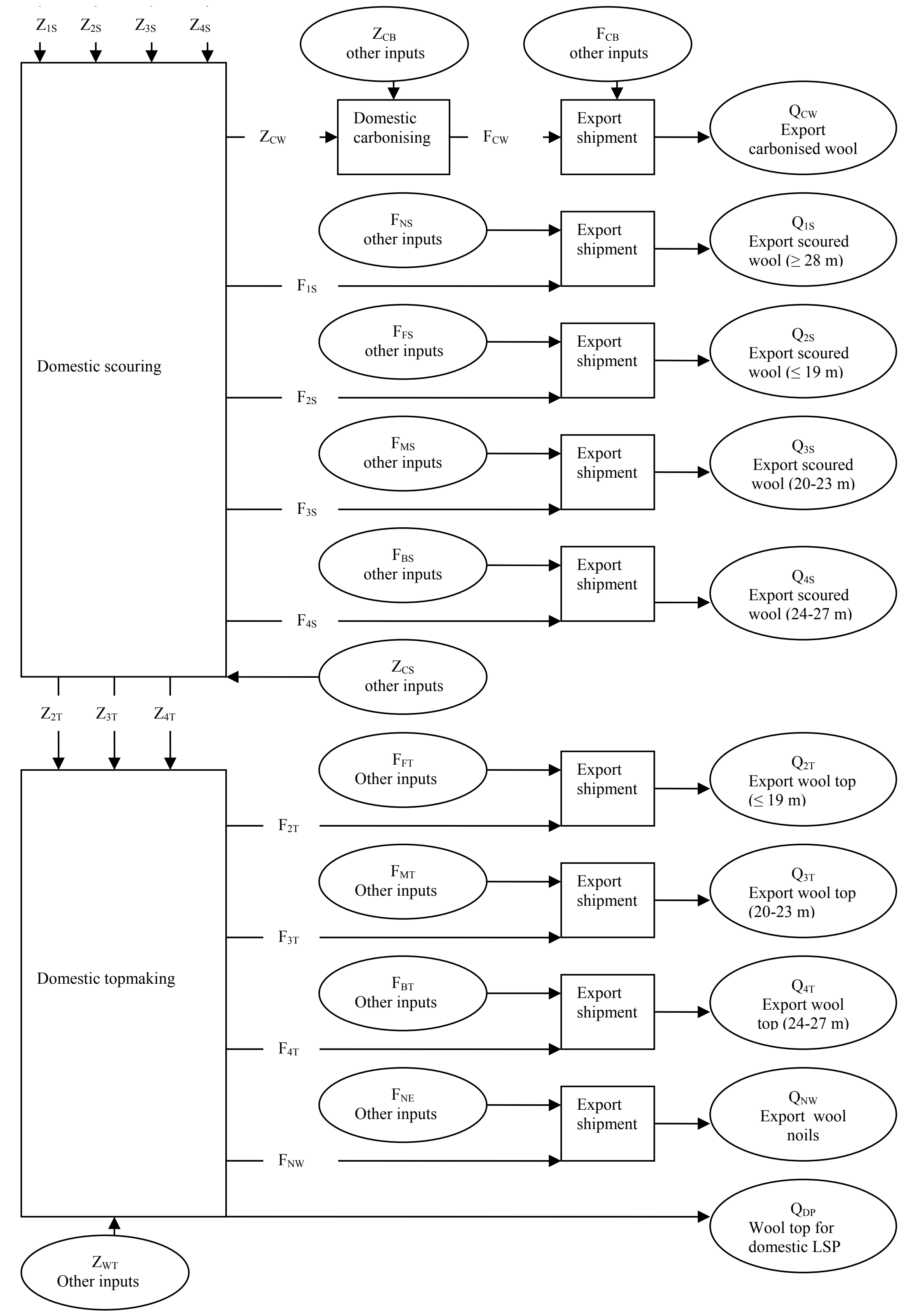
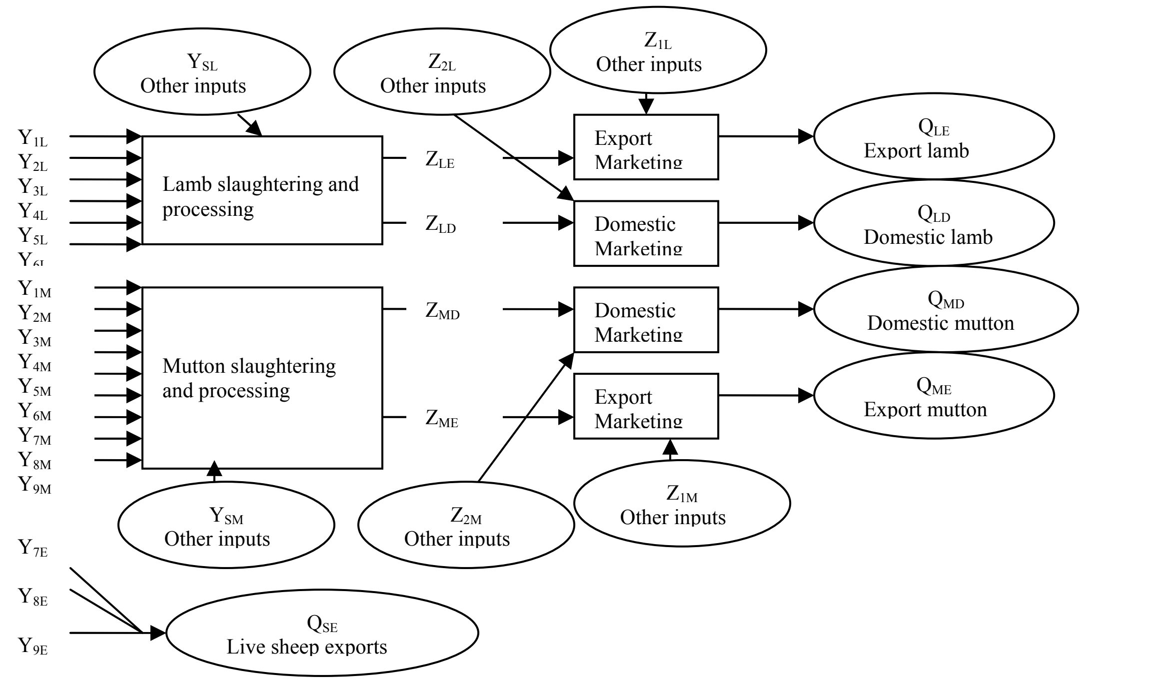


Figure 1(d): Model Structure



Appendix: The EDM General Functional Form Equations

The general functional form system of equations describing the equilibrium of the Australian sheep and wool industries are specified in equations (1-295). In all relevant equations the exogenous supply shifters T_{Xi} represent technologies that reduce the costs of production and the N_{Qi} terms are exogenous demand shifters representing changes in demand due to promotion or changes in taste.

The supplies of each type of sheep and the supplies of other inputs to the farm enterprises within the model are represented by Equations (1)-(18). The two types of merino ewe enterprises in the high rainfall zone (X_{21} and X_{31}) are homogeneous with a single price and share the same supply schedule given by Equations (3) and (6). Similarly, Equations (7) and (10) specify the supply of merino ewes in the wheat-sheep zone (X_{41} and X_{51}). Other input supplies to the various industry sectors relate to their own prices and are represented by Equations (99-104), (176), (192), (196), (208-220) and (260-263).

Equations (19-36), (105-151), (177-181), (193-194), (197-200), (221-246) and (264-271) are the output-constrained input demands for the relevant industry sectors derived from their respective cost functions using Shephard's Lemma.

The input-constrained output supplies for each sector in Equations (55-98), (164-175), (184-191) and (203-207) are derived from their respective revenue functions using the Samuelson-McFadden Lemma.

Equations (37-54), (152-163), (182-183) and (201-202) are the equilibrium conditions for the multiple output producing sectors. Equilibrium conditions are imposed through two equations for each sector. For example, Equation (37) is the multi-output product transformation function for the non-merino farm sector ensuring that aggregated input quantities are equal to aggregated output quantities. Equation (38) sets the unit costs (c_{Y1}) incurred per unit of aggregated output (Y_1) equal to the unit revenue (r_{XN}) earned per unit of aggregated input (X_N). Equations (195), (247-259) and (272-275) are the market clearing value equilibrium conditions for the single output producing sectors specifying that unit prices of output equal the unit costs of production at the margin.

Live sheep exports are homogeneous with a single price. Equation (276) ensures the total quantity of live sheep exports equals the sum of live sheep exports originating from the three agricultural zones.

Equations (277-295) are the demand functions for Australian wool, lamb, mutton and live sheep exports. Lamb and mutton are assumed substitutes in the domestic market as indicated in equations (294) and (295).

Input supply to farm enterprises

(1) $X_1 = X_1(w_1, T_{X1})$

(2) $X_{1W} = X_{1W}(w_{1W}, T_{X1W})$

(3) $X_{23} = X_{23}(w_{23}, T_{X23})$

(4) $X_{21W} = X_{21W}(w_{21W}, T_{X21W})$

(5) $X_{31W} = X_{31W}(w_{31W}, T_{X31W})$

(6) $X_{23} = X_{21} + X_{31}$

(7) $X_{45} = X_{45}(w_{45}, T_{X45})$

(8) $X_{41W} = X_{41W}(w_{41W}, T_{X41W})$

(9) $X_{51W} = X_{51W}(w_{51W}, T_{X51W})$

(10) $X_{45} = X_{41} + X_{51}$

(11) $X_{61} = X_{61}(w_{61}, T_{X61})$

(12) $X_{61W} = X_{61W}(w_{61W}, T_{X61W})$

(13) $X_{71} = X_{71}(w_{71}, T_{X71})$

(14) $X_{71W} = X_{71W}(w_{71W}, T_{X71W})$

(15) $X_{81} = X_{81}(w_{81}, T_{X81})$

(16) $X_{81W} = X_{81W}(w_{81W}, T_{X81W})$

(17) $X_{91} = X_{91}(w_{91}, T_{X91})$

(18) $X_{91W} = X_{91W}(w_{91W}, T_{X91W})$

Output constrained input demands of farm enterprises

(19) $X_1 = Y_1 c'_{Y1,1}(w_1, w_{1W})$

(20) $X_{1W} = Y_1 c'_{Y1,1W}(w_1, w_{1W})$

(21) $X_{21} = Y_2 c'_{Y2,23}(w_{23}, w_{21W})$

(22) $X_{21W} = Y_2 c'_{Y2,21W}(w_{23}, w_{21W})$

(23) $X_{31} = Y_3c'_{Y3,23}(w_{23}, w_{31W})$ (24) $X_{31W} = Y_3c'_{Y3,31W}(w_{23}, w_{31W})$

(25) $X_{41} = Y_4c'_{Y4,45}(w_{45}, w_{41W})$ (26) $X_{41W} = Y_4c'_{Y4,41W}(w_{45}, w_{41W})$

(27) $X_{51} = Y_5c'_{Y5,45}(w_{45}, w_{51W})$ (28) $X_{51W} = Y_5c'_{Y5,51W}(w_{45}, w_{51W})$

(29) $X_{61} = Y_6c'_{Y6,61}(w_{61}, w_{61W})$ (30) $X_{61W} = Y_6c'_{Y6,61W}(w_{61}, w_{61W})$

(31) $X_{71} = Y_7c'_{Y7,71}(w_{71}, w_{71W})$ (32) $X_{71W} = Y_7c'_{Y7,71W}(w_{71}, w_{71W})$

(33) $X_{81} = Y_8c'_{Y8,81}(w_{81}, w_{81W})$ (34) $X_{81W} = Y_8c'_{Y8,81W}(w_{81}, w_{81W})$

(35) $X_{91} = Y_9c'_{Y9,91}(w_{91}, w_{91W})$ (36) $X_{91W} = Y_9c'_{Y9,91W}(w_{91}, w_{91W})$

Farm enterprise equilibriums

(37) $X_N(X_1, X_{1W}) = Y_1(Y_{13W}, Y_{14W}, Y_{1L}, Y_{1M})$

(38) $c_{Y1}(w_1, w_{1W}) = r_{XN}(v_{13W}, v_{14W}, v_{1L}, v_{1M})$

(39) $X_2(X_{21}, X_{21W}) = Y_2(Y_{21W}, Y_{22W}, Y_{23W}, Y_{2L}, Y_{2M})$

(40) $c_{Y2}(w_{23}, w_{21W}) = r_{X2}(v_{21W}, v_{22W}, v_{23W}, v_{2L}, v_{2M})$

(41) $X_3(X_{31}, X_{31W}) = Y_3(Y_{31W}, Y_{32W}, Y_{33W}, Y_{3L}, Y_{3M})$

(42) $c_{Y3}(w_{23}, w_{31W}) = r_{X3}(v_{31W}, v_{32W}, v_{33W}, v_{3L}, v_{3M})$

(43) $X_4(X_{41}, X_{41W}) = Y_4(Y_{41W}, Y_{42W}, Y_{43W}, Y_{4L}, Y_{4M})$

(44) $c_{Y4}(w_{45}, w_{41W}) = r_{X4}(v_{41W}, v_{42W}, v_{43W}, v_{4L}, v_{4M})$

(45) $X_5(X_{51}, X_{51W}) = Y_5(Y_{51W}, Y_{52W}, Y_{53W}, Y_{5L}, Y_{5M})$

(46) $c_{Y5}(w_{45}, w_{51W}) = r_{X5}(v_{51W}, v_{52W}, v_{53W}, v_{5L}, v_{5M})$

(47) $X_6(X_{61}, X_{61W}) = Y_6(Y_{61W}, Y_{62W}, Y_{63W}, Y_{6L}, Y_{6M})$

(48) $c_{Y6}(w_{61}, w_{61W}) = r_{X6}(v_{61W}, v_{62W}, v_{63W}, v_{6L}, v_{6M})$

(49) $X_7(X_{71}, X_{71W}) = Y_7(Y_{71W}, Y_{72W}, Y_{73W}, Y_{7E}, Y_{7M})$

(50) $c_{Y7}(w_{71}, w_{71W}) = r_{X7}(v_{71W}, v_{72W}, v_{73W}, p_{SE}, v_{7M})$

(51) $X_8(X_{81}, X_{81W}) = Y_8(Y_{81W}, Y_{82W}, Y_{83W}, Y_{8E}, Y_{8M})$

(52) $c_{Y8}(w_{81}, w_{81W}) = r_{X8}(v_{81W}, v_{82W}, v_{83W}, p_{SE}, v_{8M})$

(53) $X_9(X_{91}, X_{91W}) = Y_9(Y_{91W}, Y_{92W}, Y_{93W}, Y_{9E}, Y_{9M})$

(54) $c_{Y9}(w_{91}, w_{91W}) = r_{X9}(v_{91W}, v_{92W}, v_{93W}, p_{SE}, v_{9M})$

Input constrained output supply of farm enterprises

(55) $Y_{13W} = X_Nr'_{XN,13W}(v_{13W}, v_{14W}, v_{1L}, v_{1M})$

(56) $Y_{14W} = X_Nr'_{XN,14W}(v_{13W}, v_{14W}, v_{1L}, v_{1M})$

(57) $Y_{1L} = X_Nr'_{XN,1L}(v_{13W}, v_{14W}, v_{1L}, v_{1M})$

(58) $Y_{1M} = X_Nr'_{XN,1M}(v_{13W}, v_{14W}, v_{1L}, v_{1M})$

(59) $Y_{21W} = X_2r'_{X2,21W}(v_{21W}, v_{22W}, v_{23W}, v_{2L}, v_{2M})$

(60) $Y_{22W} = X_2r'_{X2,22W}(v_{21W}, v_{22W}, v_{23W}, v_{2L}, v_{2M})$

(61) $Y_{23W} = X_2 r'_{X2,23W}(v_{21W}, v_{22W}, v_{23W}, v_{2L}, v_{2M})$

(62) $Y_{2L} = X_2 r'_{X2,2L}(v_{21W}, v_{22W}, v_{23W}, v_{2L}, v_{2M})$

(63) $Y_{2M} = X_2 r'_{X2,2M}(v_{21W}, v_{22W}, v_{23W}, v_{2L}, v_{2M})$

(64) $Y_{31W} = X_3 r'_{X3,31W}(v_{31W}, v_{32W}, v_{33W}, v_{3L}, v_{3M})$

(65) $Y_{32W} = X_3 r'_{X3,32W}(v_{31W}, v_{32W}, v_{33W}, v_{3L}, v_{3M})$

(66) $Y_{33W} = X_3 r'_{X3,33W}(v_{31W}, v_{32W}, v_{33W}, v_{3L}, v_{3M})$

(67) $Y_{3L} = X_3 r'_{X3,3L}(v_{31W}, v_{32W}, v_{33W}, v_{3L}, v_{3M})$

(68) $Y_{3M} = X_3 r'_{X3,3M}(v_{31W}, v_{32W}, v_{33W}, v_{3L}, v_{3M})$

(69) $Y_{41W} = X_4 r'_{X4,41W}(v_{41W}, v_{42W}, v_{43W}, v_{4L}, v_{4M})$

(70) $Y_{42W} = X_4 r'_{X4,42W}(v_{41W}, v_{42W}, v_{43W}, v_{4L}, v_{4M})$

(71) $Y_{43W} = X_4 r'_{X4,43W}(v_{41W}, v_{42W}, v_{43W}, v_{4L}, v_{4M})$

(72) $Y_{4L} = X_4 r'_{X4,4L}(v_{41W}, v_{42W}, v_{43W}, v_{4L}, v_{4M})$

(73) $Y_{4M} = X_4 r'_{X4,4M}(v_{41W}, v_{42W}, v_{43W}, v_{4L}, v_{4M})$

(74) $Y_{51W} = X_5 r'_{X5,51W}(v_{51W}, v_{52W}, v_{53W}, v_{5L}, v_{5M})$

(75) $Y_{52W} = X_5 r'_{X5,52W}(v_{51W}, v_{52W}, v_{53W}, v_{5L}, v_{5M})$

(76) $Y_{53W} = X_5 r'_{X5,53W}(v_{51W}, v_{52W}, v_{53W}, v_{5L}, v_{5M})$

(77) $Y_{5L} = X_5 r'_{X5,5L}(v_{51W}, v_{52W}, v_{53W}, v_{5L}, v_{5M})$

(78) $Y_{5M} = X_5 r'_{X5,5M}(v_{51W}, v_{52W}, v_{53W}, v_{5L}, v_{5M})$

(79) $Y_{61W} = X_6 r'_{X6,61W}(v_{61W}, v_{62W}, v_{63W}, v_{6L}, v_{6M})$

(80) $Y_{62W} = X_6 r'_{X6,62W}(v_{61W}, v_{62W}, v_{63W}, v_{6L}, v_{6M})$

(81) $Y_{63W} = X_6 r'_{X6,63W}(v_{61W}, v_{62W}, v_{63W}, v_{6L}, v_{6M})$

(82) $Y_{6L} = X_6 r'_{X6,6L}(v_{61W}, v_{62W}, v_{63W}, v_{6L}, v_{6M})$

(83) $Y_{6M} = X_6 r'_{X6,6M}(v_{61W}, v_{62W}, v_{63W}, v_{6L}, v_{6M})$

(84) $Y_{71W} = X_7 r'_{X7,71W}(v_{71W}, v_{72W}, v_{73W}, p_{SE}, v_{7M})$

(85) $Y_{72W} = X_7 r'_{X7,72W}(v_{71W}, v_{72W}, v_{73W}, p_{SE}, v_{7M})$

(86) $Y_{73W} = X_7 r'_{X7,73W}(v_{71W}, v_{72W}, v_{73W}, p_{SE}, v_{7M})$

(87) $Y_{7E} = X_7 r'_{X7,7E}(v_{71W}, v_{72W}, v_{73W}, p_{SE}, v_{7M})$

(88) $Y_{7M} = X_7 r'_{X7,7M}(v_{71W}, v_{72W}, v_{73W}, p_{SE}, v_{7M})$

(89) $Y_{81W} = X_8 r'_{X8,81W}(v_{81W}, v_{82W}, v_{83W}, p_{SE}, v_{8M})$

(90) $Y_{82W} = X_8 r'_{X8,82W}(v_{81W}, v_{82W}, v_{83W}, p_{SE}, v_{8M})$

(91) $Y_{83W} = X_8 r'_{X8,83W}(v_{81W}, v_{82W}, v_{83W}, p_{SE}, v_{8M})$

(92) $Y_{8E} = X_8 r'_{X8,8E}(v_{81W}, v_{82W}, v_{83W}, p_{SE}, v_{8M})$

(93) $Y_{8M} = X_8 r'_{X8,8M}(v_{81W}, v_{82W}, v_{83W}, p_{SE}, v_{8M})$

(94) $Y_{91W} = X_9 r'_{X9,91W}(v_{91W}, v_{92W}, v_{93W}, p_{SE}, v_{9M})$

(95) $Y_{92W} = X_9 r'_{X9,92W}(v_{91W}, v_{92W}, v_{93W}, p_{SE}, v_{9M})$

(96) $Y_{93W} = X_9 r'_{X9,93W}(v_{91W}, v_{92W}, v_{93W}, p_{SE}, v_{9M})$

(97) $Y_{9E} = X_9 r'_{X9,9E}(v_{91W}, v_{92W}, v_{93W}, p_{SE}, v_{9M})$

(98) $Y_{9M} = X_9 r'_{X9,9M}(v_{91W}, v_{92W}, v_{93W}, p_{SE}, v_{9M})$

Other input supply to wool warehouse sectors

(99) $Y_{NM} = Y_{NM}(v_{NM}, T_{YNM})$ (100) $Y_{BM} = Y_{BM}(v_{BM}, T_{YBM})$

(101) $Y_{MM} = Y_{MM}(v_{MM}, T_{YMM})$ (102) $Y_{FM} = Y_{FM}(v_{FM}, T_{YFM})$

Other input supply to lamb and mutton slaughtering/processing sectors

(103) $Y_{SL} = Y_{SL}(v_{SL}, T_{YSL})$ (104) $Y_{SM} = Y_{SM}(v_{SM}, T_{YSM})$

Output constrained input demand of wool warehouse sectors

(105) $Y_{14W} = Z_1 c'_{Z1,14W}(v_{14W}, v_{NM})$

(106) $Y_{NM} = Z_1 c'_{Z1,NM}(v_{1W}, v_{WN})$

(107) $Y_{21W} = Z_2 c'_{Z2,21W}(v_{21W}, v_{31W}, v_{41W}, v_{51W}, v_{61W}, v_{71W}, v_{81W}, v_{91W}, v_{FM})$

(108) $Y_{31W} = Z_2 c'_{Z2,31W}(v_{21W}, v_{31W}, v_{41W}, v_{51W}, v_{61W}, v_{71W}, v_{81W}, v_{91W}, v_{FM})$

(109) $Y_{41W} = Z_2 c'_{Z2,41W}(v_{21W}, v_{31W}, v_{41W}, v_{51W}, v_{61W}, v_{71W}, v_{81W}, v_{91W}, v_{FM})$

(110) $Y_{51W} = Z_2 c'_{Z2,51W}(v_{21W}, v_{31W}, v_{41W}, v_{51W}, v_{61W}, v_{71W}, v_{81W}, v_{91W}, v_{FM})$

(111) $Y_{61W} = Z_2 c'_{Z2,61W}(v_{21W}, v_{31W}, v_{41W}, v_{51W}, v_{61W}, v_{71W}, v_{81W}, v_{91W}, v_{FM})$

(112) $Y_{71W} = Z_2 c'_{Z2,71W}(v_{21W}, v_{31W}, v_{41W}, v_{51W}, v_{61W}, v_{71W}, v_{81W}, v_{91W}, v_{FM})$

(113) $Y_{81W} = Z_2 c'_{Z2,81W}(v_{21W}, v_{31W}, v_{41W}, v_{51W}, v_{61W}, v_{71W}, v_{81W}, v_{91W}, v_{FM})$

(114) $Y_{91W} = Z_2 c'_{Z2,91W}(v_{21W}, v_{31W}, v_{41W}, v_{51W}, v_{61W}, v_{71W}, v_{81W}, v_{91W}, v_{FM})$

(115) $Y_{FM} = Z_2 c'_{Z2,FM}(v_{21W}, v_{31W}, v_{41W}, v_{51W}, v_{61W}, v_{71W}, v_{81W}, v_{91W}, v_{FM})$

(116) $Y_{22W} = Z_3 c'_{Z3,22W}(v_{22W}, v_{32W}, v_{42W}, v_{52W}, v_{62W}, v_{72W}, v_{82W}, v_{92W}, v_{MM})$

(117) $Y_{32W} = Z_3 c'_{Z3,32W}(v_{22W}, v_{32W}, v_{42W}, v_{52W}, v_{62W}, v_{72W}, v_{82W}, v_{92W}, v_{MM})$

(118) $Y_{42W} = Z_3 c'_{Z3,42W}(v_{22W}, v_{32W}, v_{42W}, v_{52W}, v_{62W}, v_{72W}, v_{82W}, v_{92W}, v_{MM})$

(119) $Y_{52W} = Z_3 c'_{Z3,52W}(v_{22W}, v_{32W}, v_{42W}, v_{52W}, v_{62W}, v_{72W}, v_{82W}, v_{92W}, v_{MM})$

(120) $Y_{62W} = Z_3 c'_{Z3,62W}(v_{22W}, v_{32W}, v_{42W}, v_{52W}, v_{62W}, v_{72W}, v_{82W}, v_{92W}, v_{MM})$

(121) $Y_{72W} = Z_3 c'_{Z3,72W}(v_{22W}, v_{32W}, v_{42W}, v_{52W}, v_{62W}, v_{72W}, v_{82W}, v_{92W}, v_{MM})$

(122) $Y_{82W} = Z_3 c'_{Z3,82W}(v_{22W}, v_{32W}, v_{42W}, v_{52W}, v_{62W}, v_{72W}, v_{82W}, v_{92W}, v_{MM})$

(123) $Y_{92W} = Z_3 c'_{Z3,92W}(v_{22W}, v_{32W}, v_{42W}, v_{52W}, v_{62W}, v_{72W}, v_{82W}, v_{92W}, v_{MM})$

(124) $Y_{MM} = Z_3 c'_{Z3,MM}(v_{22W}, v_{32W}, v_{42W}, v_{52W}, v_{62W}, v_{72W}, v_{82W}, v_{92W}, v_{MM})$

(125) $Y_{13W} = Z_4 c'_{Z4,13W}(v_{13W}, v_{23W}, v_{33W}, v_{43W}, v_{53W}, v_{63W}, v_{73W}, v_{83W}, v_{93W}, v_{BM})$

(126) $Y_{23W} = Z_4 c'_{Z4,23W}(v_{13W}, v_{23W}, v_{33W}, v_{43W}, v_{53W}, v_{63W}, v_{73W}, v_{83W}, v_{93W}, v_{BM})$

(127) $Y_{33W} = Z_4c'_{Z4,33W}(v_{13W}, v_{23W}, v_{33W}, v_{43W}, v_{53W}, v_{63W}, v_{73W}, v_{83W}, v_{93W}, v_{BM})$

(128) $Y_{43W} = Z_4c'_{Z4,43W}(v_{13W}, v_{23W}, v_{33W}, v_{43W}, v_{53W}, v_{63W}, v_{73W}, v_{83W}, v_{93W}, v_{BM})$

(129) $Y_{53W} = Z_4c'_{Z4,53W}(v_{13W}, v_{23W}, v_{33W}, v_{43W}, v_{53W}, v_{63W}, v_{73W}, v_{83W}, v_{93W}, v_{BM})$

(130) $Y_{63W} = Z_4c'_{Z4,63W}(v_{13W}, v_{23W}, v_{33W}, v_{43W}, v_{53W}, v_{63W}, v_{73W}, v_{83W}, v_{93W}, v_{BM})$

(131) $Y_{73W} = Z_4c'_{Z4,73W}(v_{13W}, v_{23W}, v_{33W}, v_{43W}, v_{53W}, v_{63W}, v_{73W}, v_{83W}, v_{93W}, v_{BM})$

(132) $Y_{83W} = Z_4c'_{Z4,83W}(v_{13W}, v_{23W}, v_{33W}, v_{43W}, v_{53W}, v_{63W}, v_{73W}, v_{83W}, v_{93W}, v_{BM})$

(133) $Y_{93W} = Z_4c'_{Z4,93W}(v_{13W}, v_{23W}, v_{33W}, v_{43W}, v_{53W}, v_{63W}, v_{73W}, v_{83W}, v_{93W}, v_{BM})$

(134) $Y_{BM} = Z_4c'_{Z4,1BM}(v_{13W}, v_{23W}, v_{33W}, v_{43W}, v_{53W}, v_{63W}, v_{73W}, v_{83W}, v_{93W}, v_{BM})$

Output constrained input demand of lamb and mutton slaughtering/processing sectors

(135) $Y_{1L} = Z_Lc'_{ZL,1L}(v_{1L}, v_{2L}, v_{3L}, v_{4L}, v_{5L}, v_{6L}, v_{SL})$

(136) $Y_{2L} = Z_Lc'_{ZL,2L}(v_{1L}, v_{2L}, v_{3L}, v_{4L}, v_{5L}, v_{6L}, v_{SL})$

(137) $Y_{3L} = Z_Lc'_{ZL,3L}(v_{1L}, v_{2L}, v_{3L}, v_{4L}, v_{5L}, v_{6L}, v_{SL})$

(138) $Y_{4L} = Z_Lc'_{ZL,4L}(v_{1L}, v_{2L}, v_{3L}, v_{4L}, v_{5L}, v_{6L}, v_{SL})$

(139) $Y_{5L} = Z_Lc'_{ZL,5L}(v_{1L}, v_{2L}, v_{3L}, v_{4L}, v_{5L}, v_{6L}, v_{SL})$

(140) $Y_{6L} = Z_Lc'_{ZL,6L}(v_{1L}, v_{2L}, v_{3L}, v_{4L}, v_{5L}, v_{6L}, v_{SL})$

(141) $Y_{SL} = Z_Lc'_{ZL,SL}(v_{1L}, v_{2L}, v_{3L}, v_{4L}, v_{5L}, v_{6L}, v_{SL})$

(142) $Y_{1M} = Z_Mc'_{ZM,1M}(v_{1M}, v_{2M}, v_{3M}, v_{4M}, v_{5M}, v_{6M}, v_{7M}, v_{8M}, v_{9M}, v_{SM})$

(143) $Y_{2M} = Z_Mc'_{ZM,2M}(v_{1M}, v_{2M}, v_{3M}, v_{4M}, v_{5M}, v_{6M}, v_{7M}, v_{8M}, v_{9M}, v_{SM})$

(144) $Y_{3M} = Z_Mc'_{ZM,3M}(v_{1M}, v_{2M}, v_{3M}, v_{4M}, v_{5M}, v_{6M}, v_{7M}, v_{8M}, v_{9M}, v_{SM})$

(145) $Y_{4M} = Z_Mc'_{ZM,4M}(v_{1M}, v_{2M}, v_{3M}, v_{4M}, v_{5M}, v_{6M}, v_{7M}, v_{8M}, v_{9M}, v_{SM})$

(146) $Y_{5M} = Z_Mc'_{ZM,5M}(v_{1M}, v_{2M}, v_{3M}, v_{4M}, v_{5M}, v_{6M}, v_{7M}, v_{8M}, v_{9M}, v_{SM})$

(147) $Y_{6M} = Z_Mc'_{ZM,6M}(v_{1M}, v_{2M}, v_{3M}, v_{4M}, v_{5M}, v_{6M}, v_{7M}, v_{8M}, v_{9M}, v_{SM})$

(148) $Y_{7M} = Z_Mc'_{ZM,7M}(v_{1M}, v_{2M}, v_{3M}, v_{4M}, v_{5M}, v_{6M}, v_{7M}, v_{8M}, v_{9M}, v_{SM})$

(149) $Y_{8M} = Z_Mc'_{ZM,8M}(v_{1M}, v_{2M}, v_{3M}, v_{4M}, v_{5M}, v_{6M}, v_{7M}, v_{8M}, v_{9M}, v_{SM})$

(150) $Y_{9M} = Z_Mc'_{ZM,9M}(v_{1M}, v_{2M}, v_{3M}, v_{4M}, v_{5M}, v_{6M}, v_{7M}, v_{8M}, v_{9M}, v_{SM})$

(151) $Y_{SM} = Z_Mc'_{ZM,SM}(v_{1M}, v_{2M}, v_{3M}, v_{4M}, v_{5M}, v_{6M}, v_{7M}, v_{8M}, v_{9M}, v_{SM})$

Wool warehouse sectors equilibrium

(152) $Y_N(Y_{14W}, Y_{NM}) = Z_1(Z_{1W}, Z_{1S})$

(153) $c_{Z1}(v_{14W}, v_{NM}) = r_{YN}(u_{1W}, u_{1S})$

(154) $Y_F(Y_{21W}, Y_{31W}, Y_{41W}, Y_{51W}, Y_{61W}, Y_{71W}, Y_{81W}, Y_{91W}, Y_{FM}) = Z_2(Z_{2W}, Z_{2S})$

(155) $c_{Z2}(v_{21W}, v_{31W}, v_{41W}, v_{51W}, v_{61W}, v_{71W}, v_{81W}, v_{91W}, v_{FM}) = r_{YF}(u_{2W}, u_{2S})$

(156) $Y_C(Y_{22W}, Y_{32W}, Y_{42W}, Y_{52W}, Y_{62W}, Y_{72W}, Y_{82W}, Y_{92W}, Y_{MM}) = Z_3(Z_{3W}, Z_{3S})$

(157) $c_{Z3}(v_{22W}, v_{32W}, v_{42W}, v_{52W}, v_{62W}, v_{72W}, v_{82W}, v_{92W}, v_{MM}) = r_{YC}(u_{2W}, u_{2S})$

(158) $Y_B(Y_{13W}, Y_{23W}, Y_{33W}, Y_{43W}, Y_{53W}, Y_{63W}, Y_{73W}, Y_{83W}, Y_{93W}, Y_{BM}) = Z_4(Z_{4W}, Z_{4S})$

(159) $c_{Z4}(v_{13W}, v_{23W}, v_{33W}, v_{43W}, v_{53W}, v_{63W}, v_{73W}, v_{83W}, v_{93W}, v_{BM}) = r_{YB}(u_{3W}, u_{3S})$

Lamb and mutton slaughtering/processing sectors equilibrium

(160) $Y_L(Y_{1L}, Y_{2L}, Y_{3L}, Y_{4L}, Y_{5L}, Y_{6L}, Y_{SL},) = Z_L(Z_{LE}, Z_{LD})$

(161) $c_{ZL}(v_{1L}, v_{2L}, v_{3L}, v_{4L}, v_{5L}, v_{6L}, v_{SL},) = r_{YL}(u_{LE}, u_{LD})$

(162) $Y_M(Y_{1M}, Y_{2M}, Y_{3M}, Y_{4M}, Y_{5M}, Y_{6M}, Y_{7M}, Y_{8M}, Y_{9M}, Y_{SM},) = Z_M(Z_{ME}, Z_{MD})$

(163) $c_{ZM}(v_{1M}, v_{2M}, v_{3M}, v_{4M}, v_{5M}, v_{6M}, v_{7M}, v_{8M}, v_{9M}, v_{SM},) = r_{YM}(u_{ME}, u_{MD})$

Input constrained output supply of wool warehouse sectors

(164) $Z_{1W} = Y_N r'_{YN,1W}(u_{1W}, u_{1S})$ (165) $Z_{1S} = Y_N r'_{YN,1S}(u_{1W}, u_{1S})$

(166) $Z_{2W} = Y_F r'_{YF,2W}(u_{2W}, u_{2S})$ (167) $Z_{2S} = Y_F r'_{YF,2S}(u_{2W}, u_{2S})$

(168) $Z_{3W} = Y_C r'_{YC,3W}(u_{3W}, u_{3S})$ (169) $Z_{3S} = Y_C r'_{YC,3S}(u_{3W}, u_{3S})$

(170) $Z_{4W} = Y_B r'_{YB,4W}(u_{4W}, u_{4S})$ (171) $Z_{4S} = Y_B r'_{YB,4S}(u_{4W}, u_{4S})$

Input constrained output supply of lamb and mutton slaughtering/processing sectors

(172) $Z_{LE} = Y_L r'_{YL,LE}(u_{LE}, u_{LD})$ (173) $Z_{LD} = Y_L r'_{YL,LD}(u_{LE}, u_{LD})$

(174) $Z_{ME} = Y_M r'_{YM,ME}(u_{ME}, u_{MD})$ (175) $Z_{MD} = Y_M r'_{YM,MD}(u_{ME}, u_{MD})$

Other input supply to wool scouring sector

(176) $Z_{CS} = Z_{CS}(u_{CS}, T_{ZCS})$

Output constrained input demand of wool scouring sector

(177) $Z_{1S} = Z_S c'_{ZS,1S}(u_{1S}, u_{2S}, u_{3S}, u_{4S}, u_{CS})$

(178) $Z_{2S} = Z_S c'_{ZS,2S}(u_{1S}, u_{2S}, u_{3S}, u_{4S}, u_{CS})$

(179) $Z_{3S} = Z_S c'_{ZS,3S}(u_{1S}, u_{2S}, u_{3S}, u_{4S}, u_{CS})$

(180) $Z_{4S} = Z_S c'_{ZS,4S}(u_{1S}, u_{2S}, u_{3S}, u_{4S}, u_{CS})$

(181) $Z_{CS} = Z_S c'_{ZS,CS}(u_{1S}, u_{2S}, u_{3S}, u_{4S}, u_{CS})$

Wool scouring sector equilibrium

(182) $Z_C(Z_{1S}, Z_{2S}, Z_{3S}, Z_{4S}, Z_{CS}) = Z_S(Z_{CW}, F_{1S}, F_{2S}, F_{3S}, F_{4S}, Z_{2T}, Z_{3T}, Z_{4T})$

(183) $c_{ZS}(u_{1S}, u_{2S}, u_{3S}, u_{4S}, u_{CS}) = r_{ZC}(u_{CW}, s_{1S}, s_{2S}, s_{3S}, s_{4S}, u_{2T}, u_{3T}, u_{4T})$

Input constrained output supply of wool scouring sector

(184) $F_{1S} = Z_C r'_{ZC,1S}(u_{CW}, s_{1S}, s_{2S}, s_{3S}, s_{4S}, u_{2T}, u_{3T}, u_{4T})$

(185) $F_{2S} = Z_C r'_{ZC,2S}(u_{CW}, s_{1S}, s_{2S}, s_{3S}, s_{4S}, u_{2T}, u_{3T}, u_{4T})$

(186) $F_{3S} = Z_C r'_{ZC,3S}(u_{CW}, s_{1S}, s_{2S}, s_{3S}, s_{4S}, u_{2T}, u_{3T}, u_{4T})$

(187) $F_{4S} = Z_C r'_{ZC,4S}(u_{CW}, s_{1S}, s_{2S}, s_{3S}, s_{4S}, u_{2T}, u_{3T}, u_{4T})$

(188) $Z_{2T} = Z_C r'_{ZC,2T}(u_{CW}, s_{1S}, s_{2S}, s_{3S}, s_{4S}, u_{2T}, u_{3T}, u_{4T})$

(189) $Z_{3T} = Z_C r'_{ZC,3T}(u_{CW}, s_{1S}, s_{2S}, s_{3S}, s_{4S}, u_{2T}, u_{3T}, u_{4T})$

(190) $Z_{4T} = Z_C r'_{ZC,4T}(u_{CW}, s_{1S}, s_{2S}, s_{3S}, s_{4S}, u_{2T}, u_{3T}, u_{4T})$

(191) $Z_{CW} = Z_C r'_{ZC,CW}(u_{CW}, s_{1S}, s_{2S}, s_{3S}, s_{4S}, u_{2T}, u_{3T}, u_{4T})$

Other input supply to wool carbonising sector

(192) $Z_{CB} = Z_{CB}(u_{CB}, T_{ZCB})$

Output constrained input demand of wool carbonising sector

(193) $Z_{CW} = F_{CW} c'_{FCW,CW}(u_{CW}, u_{CB})$

(194) $Z_{CB} = F_{CW} c'_{FCW,CB}(u_{CW}, u_{CB})$

Wool carbonising sector equilibrium

(195) $s_{CW} = c_{FCW}(u_{CW}, u_{CB})$

Other input supply to wool topmaking sector

(196) $Z_{WT} = Z_{WT}(u_{WT}, T_{ZWT})$

Output constrained input demand of wool topmaking sector

(197) $Z_{2T} = F_T c'_{FT,2T}(u_{2T}, u_{3T}, u_{4T}, u_{WT})$

(198) $Z_{3T} = F_T c'_{FT,3T}(u_{2T}, u_{3T}, u_{4T}, u_{WT})$

(199) $Z_{4T} = F_T c'_{FT,4T}(u_{2T}, u_{3T}, u_{4T}, u_{WT})$

(200) $Z_{WT} = F_T c'_{FT,WT}(u_{2T}, u_{3T}, u_{4T}, u_{WT})$

Wool topmaking sector equilibrium

(201) $Z_T(Z_{2T}, Z_{3T}, Z_{4T}, Z_{WT}) = F_T(F_{2T}, F_{3T}, F_{4T}, F_{NW}, Q_{DP})$

(202) $c_{FT}(u_{2T}, u_{3T}, u_{4T}, u_{WT}) = r_{ZT}(s_{2T}, s_{3T}, s_{4T}, s_{NW}, p_{DP})$

Input constrained output supply of wool topmaking sector

(203) $F_{2T} = Z_T r'_{ZT,2T}(s_{2T}, s_{3T}, s_{4T}, s_{NW}, p_{DP})$

(204) $F_{3T} = Z_T r'_{ZT,3T}(s_{2T}, s_{3T}, s_{4T}, s_{NW}, p_{DP})$

(205) $F_{4T} = Z_T r'_{ZT,4T}(s_{2T}, s_{3T}, s_{4T}, s_{NW}, p_{DP})$

(206) $F_{NW} = Z_T r'_{ZT,NW}(s_{2T}, s_{3T}, s_{4T}, s_{NW}, p_{DP})$

(207) $Q_{DP} = Z_T r'_{ZT,DP}(s_{2T}, s_{3T}, s_{4T}, s_{NW}, p_{DP})$

Other input supply to export greasy wool shipment sectors

(208) $Z_{NM} = Z_{NM}(u_{NM}, T_{ZNM})$ (209) $Z_{FM} = Z_{FM}(u_{FM}, T_{ZFM})$

(210) $Z_{MM} = Z_{MM}(u_{MM}, T_{ZMM})$ (211) $Z_{BM} = Z_{BM}(u_{BM}, T_{ZBM})$

Other input supply to export carbonised wool shipment sector

(212) $F_{CB} = F_{CB}(s_{CB}, T_{FCB})$

Other input supply to export scoured wool shipment sectors

(213) $F_{NS} = F_{NS}(s_{NS}, T_{FNS})$ (214) $F_{FS} = F_{FS}(s_{FS}, T_{FFS})$

(215) $F_{MS} = F_{MS}(s_{MS}, T_{FMS})$ (216) $F_{BS} = F_{BS}(s_{BS}, T_{FBS})$

Other input supply to export wool tops shipment sectors

(217) $F_{FT} = F_{FT}(s_{FT}, T_{FFT})$ (218) $F_{MT} = F_{MT}(s_{MT}, T_{FMT})$

(219) $F_{BT} = F_{BT}(s_{BT}, T_{FBT})$ (220) $F_{NE} = F_{NE}(s_{NE}, T_{FNE})$

Output constrained input demand of export greasy wool shipment sectors

(221) $Z_{1W} = Q_{1W}c'_{Q1W,1W}(u_{1W}, u_{NM})$ (222) $Z_{NM} = Q_{1W}c'_{Q1W,NM}(u_{1W}, u_{NM})$

(223) $Z_{2W} = Q_{2W}c'_{Q2W,2W}(u_{2W}, u_{FM})$ (224) $Z_{FM} = Q_{2W}c'_{Q2W,FM}(u_{2W}, u_{FM})$

(225) $Z_{3W} = Q_{3W}c'_{Q3W,3W}(u_{3W}, u_{MM})$ (226) $Z_{MM} = Q_{3W}c'_{Q3W,FM}(u_{3W}, u_{FM})$

(227) $Z_{4W} = Q_{4W}c'_{Q4W,4W}(u_{4W}, u_{BM})$ (228) $Z_{BM} = Q_{4W}c'_{Q4W,BM}(u_{4W}, u_{BM})$

Output constrained input demand of export carbonised wool shipment sector

(229) $F_{CW} = Q_{CW}c'_{QCW,CW}(s_{CW}, s_{CB})$ (230) $F_{CB} = Q_{CW}c'_{QCW,CB}(s_{CW}, s_{CB})$

Output constrained input demand of export scoured wool shipment sectors

(231) $F_{1S} = Q_{1S}c'_{Q1S,1S}(s_{1S}, s_{NS})$ (232) $F_{NS} = Q_{1S}c'_{Q1S,NS}(s_{1S}, s_{NS})$

(233) $F_{2S} = Q_{2S}c'_{Q2S,2S}(s_{2S}, s_{FS})$ (234) $F_{FS} = Q_{2S}c'_{Q2S,FS}(s_{1S}, s_{FS})$

(235) $F_{3S} = Q_{3S}c'_{Q3S,3S}(s_{3S}, s_{MS})$ (236) $F_{MS} = Q_{3S}c'_{Q3S,MS}(s_{3S}, s_{MS})$

(237) $F_{4S} = Q_{4S}c'_{Q4S,4S}(s_{4S}, s_{BS})$ (238) $F_{BS} = Q_{4S}c'_{Q4S,BS}(s_{4S}, s_{BS})$

Output constrained input demand of export wool tops shipment sectors

(239) $F_{2T} = Q_{2T}c'_{Q2T,2T}(s_{2T}, s_{FT})$ (240) $F_{FT} = Q_{2T}c'_{Q2T,FT}(s_{2T}, s_{FT})$

(241) $F_{3T} = Q_{3T}c'_{Q3T,3T}(s_{3T}, s_{FMT})$ (242) $F_{MT} = Q_{3T}c'_{Q3T,MT}(s_{3T}, s_{MT})$

(243) $F_{4T} = Q_{4T}c'_{Q4T,4T}(s_{4T}, s_{BT})$ (244) $F_{BT} = Q_{4T}c'_{Q4T,BT}(s_{4T}, s_{BT})$

(245) $F_{NW} = Q_{NW}c'_{QNW,NW}(s_{NW}, s_{NE})$ (246) $F_{NE} = Q_{NW}c'_{QNW,NE}(s_{NW}, s_{NE})$

Export greasy wool shipment sector equilibrium

(247) $p_{1W} = c_{Q1W}(u_{1W}, u_{NM})$ (248) $p_{2W} = c_{Q2W}(u_{2W}, u_{FM})$

(249) $p_{3W} = c_{Q3W}(u_{3W}, u_{MM})$ (250) $p_{4W} = c_{Q4W}(u_{4W}, u_{BM})$

Export carbonised wool shipment sector equilibrium

(251) $p_{CW} = c_{QCW}(s_{CW}, s_{CB})$

Export scoured wool shipment sector equilibrium

(252) $p_{1S} = c_{Q1S}(s_{1S}, s_{NS})$ (253) $p_{2S} = c_{Q2S}(s_{2S}, s_{FS})$

(254) $p_{3S} = c_{Q3S}(s_{3S}, s_{MS})$ (255) $p_{4S} = c_{Q4S}(s_{4S}, s_{BS})$

Export wool tops shipment sector equilibrium

(256) $p_{2T} = c_{Q2T}(s_{2T}, s_{FT})$ (257) $p_{3T} = c_{Q2T}(s_{3T}, s_{MT})$

(258) $p_{4T} = c_{Q4T}(s_{4T}, s_{BT})$ (259) $p_{NW} = c_{QNW}(s_{NW}, s_{NW})$

Other input supply to lamb and mutton marketing sectors

(260) $Z_{1L} = Z_{1L}(u_{1L}, T_{Z1L})$ (261) $Z_{2L} = Z_{2L}(u_{2L}, T_{Z2L})$

(262) $Z_{1M} = Z_{1M}(u_{1M}, T_{Z1M})$ (263) $Z_{2M} = Z_{2M}(u_{2M}, T_{Z2M})$

Output constrained input demand of lamb and mutton marketing sectors

(264) $Z_{LE} = Q_{LE}c'_{QLE,LE}(u_{LE}, u_{1L})$ (265) $Z_{1L} = Q_{LE}c'_{QLE,1L}(u_{LE}, u_{1L})$

(266) $Z_{LD} = Q_{LD}c'_{QLD,LD}(u_{LD}, u_{2L})$ (267) $Z_{2L} = Q_{LD}c'_{QLD,2L}(u_{LD}, u_{2L})$

(268) $Z_{MD} = Q_{MD}c'_{QMD,MD}(u_{MD}, u_{2M})$ (269) $Z_{2M} = Q_{MD}c'_{QMD,2M}(u_{MD}, u_{2M})$

(270) $Z_{ME} = Q_{ME}c'_{QME,ME}(u_{ME}, u_{1M})$ (271) $Z_{1M} = Q_{ME}c'_{QME,1M}(u_{ME}, u_{1M})$

Lamb and mutton marketing sectors equilibrium

(272) $p_{LE} = c_{QLE}(u_{LE}, u_{1L})$ (273) $p_{LD} = c_{QLD}(u_{LD}, u_{2L})$

(274) $p_{MD} = c_{QMD}(u_{MD}, u_{2M})$ (275) $p_{ME} = c_{QME}(u_{ME}, u_{1M})$

Origin of live sheep exports

(276) $Q_{SE} = Y_{7E} + Y_{8E} + Y_{9E}$

Export demand for Australian greasy wool

(277) $Q_{1W} = Q_{1W}(p_{1W}, N_{Q1W})$ (278) $Q_{2W} = Q_{2W}(p_{2W}, N_{Q2W})$

(279) $Q_{3W} = Q_{3W}(p_{3W}, N_{Q3W})$ (280) $Q_{4W} = Q_{4W}(p_{4W}, N_{Q4W})$

Export demand for Australian carbonised wool

(281) $Q_{CW} = Q_{CW}(p_{CW}, N_{QCW})$

Export demand for Australian scoured wool

(282) $Q_{1S} = Q_{1S}(p_{1S}, N_{Q1S})$ (283) $Q_{2S} = Q_{2S}(p_{2S}, N_{Q2S})$

(284) $Q_{3S} = Q_{3S}(p_{3S}, N_{Q3S})$ (285) $Q_{4S} = Q_{4S}(p_{4S}, N_{Q4S})$

Export demand for Australian wool tops

(286) $Q_{2T} = Q_{2T}(p_{2T}, N_{Q2T})$ (287) $Q_{3T} = Q_{3T}(p_{3T}, N_{Q3T})$

(288) $Q_{4T} = Q_{4T}(p_{4T}, N_{Q4T})$

Export demand for Australian noils/other wool

(289) $Q_{NW} = Q_{NW}(p_{NW}, N_{QNW})$

Domestic demand for LSP wool

(290) $Q_{DP} = Q_{DP}(p_{DP}, N_{QDP})$

Export demand for Australian lamb and mutton

(291) $Q_{LE} = Q_{LE}(p_{LE}, N_{QLE})$

(292) $Q_{ME} = Q_{ME}(p_{ME}, N_{QME})$

Export demand for Australian live sheep

(293) $Q_{SE} = Q_{SE}(p_{SE}, N_{QSE})$

Domestic retail demand for Australian lamb and mutton

(294) $Q_{LD} = Q_{LD}(p_{LD}, p_{MD}\ N_{QLD}, N_{QMD})$

(295) $Q_{MD} = Q_{MD}(p_{LD}, p_{MD}\ N_{QLD}, N_{QMD})$

The structural model of the Australian sheep and wool industries represented in general functional form by Equations (1)-(295) defines equilibrium in all markets. The model in displacement form is found by totally differentiating the system of equations at the initial equilibrium points. Implicit in this approach is the use of local linear approximation when estimating the finite changes in the endogenous variables. Zhao, Mullen and Griffith (1997) demonstrated that when small parallel exogenous shifts are implemented in EDM, the price, quantity and economic surplus change estimates are exact if the percentage change in variable (.) is defined as $E(.) = \Delta(.)/(.)$. [4]

[4] To conserve space the equilibrium displacement form equations are not presented here but are available from the author on request.