A Structural Model of the World Wool Market

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ABSTRACT

This paper summarises the development, structure and data sources of the Western Australian World Wool Model. The model is a comparative static, partial equilibrium model of the world wool market. The technique used for the model is applied general equilibrium (AGE) modelling. Western Australia is separated from the rest of Australia as a production region. A key feature of the model is that raw wool is broken down into 9 different qualities, which determine the end use of the wool. The construction of a database containing these wool qualities is detailed. Potential uses for the model are outlined, and results are compared and contrasted with earlier structural models of the world wool market. Finally, advantages and disadvantages of the approach taken are outlined.

Key Words: wool, value chain modelling, processing research.

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1. Introduction

1.1 Introduction

The Western Australian World Wool Model (the model) is a comparative static partial equilibrium model of the world wool market. The model was developed by the Wool Program from Agriculture Western Australia (AgWA) and the Centre for International Economics (CIE) to measure the economic impact on Western Australian economy from research outcomes in both the “on-farm” and “off-farm” sectors.

The model consists of two major components. A database comprising of 9 different qualities of raw wool, 10 regions, and 8 stages of processing and consumption was constructed. A key feature of the regional structure of the model is that production industry from Western Australia (WA) has been separated from the rest of Australia. The database is written in input-output format.

Secondly, the economic structure model has been specified and written in software applicable to the task. GEMPACK software (Horridge, Parmenter and Pearson, 1998), which is designed for applied general equilibrium (AGE) modelling, is used to formulate and solve the model. This software package is used in the ORANI and more recently MONASH models of the Australian economy.

The purpose of this paper is not to provide full documentation of the model. It is intended to give a broad overview of the reasons behind the construction of the model, a brief history of the model development, an outline of the model database, a description of the theoretical structure of the model and document the parameters used in the model. In addition, the results will be compared with previous attempts to model research gains from processing and marketing research. Potential uses for the model are outlined. Finally, a summary of the advantages and disadvantages of the approach taken is presented.

1.2 Background

In recent years, the budget of the Wool Program (the Program) from AgWA dedicated to so called “off-farm” activities has increased significantly from almost nothing a decade ago to a significant proportion of the Program. In 1998-99, approximately $2.3m of the Program’s $6.3m budget was directed towards projects with at least some “off-farm” components. Further reallocation of the Program’s budget is likely.

Off-farm activities can be described as activities that are undertaken at points along the value chain after the wool has left the farm, for the purposes of increasing the demand for the raw product. An example of an off-farm activity may be research that is undertaken to improve the productivity of worsted spinning. Marketing and promotion (such as the Woolmark Company’s consumer advertising) can also be classified as off-farm activities, although AgWA does not undertake any direct promotion of products to consumers.

The measurement of the economic benefits from on-farm research conducted by AgWA has traditionally been undertaken using the Research Evaluation Spreadsheet (REVS), or by the use of whole farm linear programming models such as MIDAS. Unfortunately, these models are of limited use when assessing off-farm activities, as the price of commodities is given in both, that is the demand for each commodity is perfectly elastic.

In the author’s experience, the process of arbitrarily increasing the price received (or particularly the export price in the case of wool) is fraught with danger. For example, marketers can easily over-estimate the potential impact of their work (if they are willing to be tied down to a number at all!). Alternatively, wool processing researchers are very good at estimating the impact of their work on say the productivity of a spinning mill, but are usually unable to provide useful estimation on the changes in demand for wool by the firm.

The need for a consistent framework to evaluate both on-farm and off farm projects was apparent. Hence, the decision to pursue the building of a value chain model of the Western Australian wool industry was made.

The building of such a model can be broken down into two distinct parts. The first was the construction of a database in input output format. This task was undertaken within AgWA. An explanation of the database structure and a list of data sources and methods used to derive data is detailed in Chapter 3.

The second was the specification of the theoretical structure of the model, and to write and compile this structure (code) into a working model. As AgWA had little experience in this area, the Centre for International Economics (CIE) were contracted to perform this task. This was undertaken by their consultant, Derek Quirke. The code has since been rewritten at several points along the value chain to better reflect the demand and supply of wool.

2. Model Specification

2.1 General

The basis for the construction of a model of the wool value chain is that the benefits of research may accrue at points along the chain other than where the technology is adopted. For example, a cost saving technology at the spinning level will allow spinners to increase output, and thereby increase the derived demand for inputs, including wool.

The Western Australian Wool Model has a theoretical structure consisting of equations that describe;

- producers' demands for commodity inputs and primary factors;
- producers' supplies of commodities;
- export demands;
- demands for final wool products ;
- changes in stocks;
- the relationship of basic values to production costs to purchasers' prices; and
- market clearing conditions for commodities and primary factors.

Demand and supply equations for each commodity and economic agent in the value chain are derived from the solutions to the optimisation problems (e.g. cost minimisation) which are assumed to underlie the behaviour of agents in conventional microeconomic theory (modified from Horridge et al, 1998). The agents are assumed to operate in perfectly competitive markets, which does not allow them to make pure profits or economic rent.

The model merely accounts for shifts that occur, while making no comment on the likelihood of those changes. That is, the adoption level within a country or industry, plus the probability of success of achieving the expected outcome, must be exogenously imposed outside the model. The research cost of achieving any changes is not considered.

2.2 Treatment of Time

The model is comparative static in nature, meaning that there is no time frame in the model. When say a technology shock is introduced during a stage of processing, prices and quantities up and down the wool value chain will re-adjust to a new equilibrium. The model will not specify the adjustment path, or the timeframe taken to move to the new equilibrium. Only the initial and final static equilibrium positions are calculated.

The comparative static nature of the model means that it is most useful for calculating the gains to research or marketing in the long run, rather than short run forecasting. To be consistent with this approach, the quantities of capital in each stage of the process is allowed to vary in the model, with the rate of return constant at the long run level (see Horridge et al, 1998).

Comparative static modelling relies on the notion of the "typical" year. This year is expected to be the "average" year for the economy or industry in question, so that the research outcomes will be applicable to the majority of years in the future.

In recent years, it is questionable whether there is a "typical" year for the wool industry. The collapse of the minimum reserve price scheme, the numerous changes in Government policy regarding the disposal of the resulting stockpile, and mixed economic fortunes in key markets (e.g. the current Japanese recession), have contributed to a very volatile period for the Australian wool industry.

In this model, the 1995 year was chosen, largely because at the time of data collection, it was the latest year for which all countries' trade data was available. A calendar year was used rather than a financial year because this is the common practice in countries outside Australia. In terms of price, 1995 was relatively high compared with the years immediately before and after. However, it is considered that after the wool stockpile is disposed of, the prices of 1995 are not an unreasonable expectation of future prices.

The changes to the system and in particular changes to the benefits to Western Australian and other Australian woolgrowers can be considered the peak year benefits in a standard cost benefit analysis. The time to peak adoption and research costs can then be considered.

2.3 Linearization of the Model

Equations in the model are in linearized form for the purposes of making the task of solving the model less onerous. Non-linear equations are represented as linear equations relating percentage change in model variables. For a full description of model linearization see Horridge et al (1998), but consider the following function:

$F(Y,X) = 0.$

where Y is a vector of endogenous variables, X is a vector of exogenous variables, and F is a system of non-linear functions. To linearize the model, we must have an initial solution. This is given by the historical model database and can be represented as:

$F(Y^0,X^0).$

With conventional assumptions about the form of F, then for small changes in Y and X:

$F^Y(Y,X)dY + F^X(Y,X)dX = 0;$

where F^Y and F^X are matrices of the derivatives of Y and X, evaluated at the initial solution (Y^0,X^0). To express the equation in percentage form, consider the percentage changes in Y and X, given by y and x:

$y = 100*dY/Y;$ and

$x = 100* dX/X.$

Then the non-linear equations can be written in percentage change form as:

$G^Y(Y,X)y + G^X(Y,X)x = 0;$

where: $G^Y(Y,X) = F^Y(Y,X)\hat{Y}$;

$G\ (Y,X) = F^X(Y,X)\,\hat{X}$; and

$\hat{Y}, \hat{X}$ are diagonal matrices.

The resulting percentage change equations are now able to be solved by the standard techniques of linear algebra. An example of the linearization process can be found in Horridge et al (1998), which calculates the linearization of a constant elasticity of substitution (CES) input demand function. The initial function, for a producer who makes an output Z from N inputs X_k, k=1,...,n. The non-linear CES input demand function for an input X_k is given by:

$$X_k = Z_k^{1(\rho+1)} \frac{[P_k]}{[P_{AVE}]}^{-1/(\rho+1)}$$

where: $P_{AVE} = \left(\sum_{i=1}^{N} \delta_i^{1/(\rho+1)} P_i^{\rho/(\rho+1)} \right)^{-1/(\rho+1)}$; and

δ and ρ are behavioural parameters.

The linearized CES input demand function is:

$$x_k = z - \sigma(p_k - p_{ave});$$

where: $p_{ave} = \sum_{i=1}^{N} S_i p_i$; and

S_i is the cost share of input i into the production process, calculated at the initial solution.

In the linearized equations, the elasticity of input demand for the CES demand system is easily calculated by differentiating the input demand function with respect to the relevant price. The own and cross price elasticities are given by;

$$e_{kk} = -\sigma * (1 - S_k)$$

$$e_{kj} = \sigma * S_j$$

Note that the resulting matrix of elasticities is homogeneous degree zero. Also, note that the higher the value share of a commodity in total inputs, the more inelastic it will be in own price terms.

The accuracy of the linearized equations is reliable only for small changes in Y and X above. Large changes in these variables may lead to what are known as linearization errors. Horridge et al (1998) outline the scope of this problem. To limit the scale of linearization errors, they use the Euler or multi-step solution method.

3. The Model Database

3.1 Database Structure

The production and processing of wool involves a large number of different stages. Once wool is produced, it must be washed (scoured), carded, combed and/or carbonised, spun into yarn, woven or knitted, made into garments, and then sold at retail. Processed wool and wool products may be traded at any stage along the chain.

Previous attempts at structural models of the world wool market (Mullen, Alston and Wolgenant, 1989, Johnston, Tupulé, Foster and Gilmore, 1992) have aggregated wool qualities and regions because of the lack of data availability. Mullen et al (1989) only considered the wool value chain up to the demand for wool top.

In this model, the extent of aggregation is limited compared with previous studies. While this presented problems in terms of data availability, it was decided to accept some uncertainty in the composition of the database, rather than to aggregate out the potential for the model to answer some useful questions.

The model database contains apparel wool only. Carpet wool, which was considered to be wool of greater than 30 µm, has not been included.

An example of why aggregation may not be desirable may be a situation where marketers are attempting to increase the demand in a certain market, and claim the creation of "new" demand and an increase in price. However, in reality any increase in price will impact on demand in existing markets, meaning that the "new" demand may actually be replacing old demand to some extent. Although the net result would still be expected to be positive, it is unlikely to be as great as the analysis of the single market would show.

The final use for a kilogram of wool is determined by the particular quality attributes that it possesses. For this reason, and because of the large amount of wool quality research being undertaken by AgWA at both the on and off farm areas, wool has been divided into different qualities and products. Different qualities of wool are represented as different commodities in this model. There are 54 different commodities, composed of 9 raw wool, 9 scoured, 9 top/carded, 3 noil, 5 yarn, 6 fabric and 12 garments.

The qualities of raw wool are differentiated according to fibre diameter and hauteur. These qualities are shown in Figure 3.1.

Figure 3.1: Wool Qualities Included the Model

Fibre Diameter

		<20 µm	20-23 µm	>23 µm	
Hauteur	<56 mm	D^-H^-	DH^-	D^+H^-	Woollen Processing
	56-65 mm	D^-H	DH	D^+H	Worsted Processing
	>65 mm	D^-H^+	DH^+	D^+H^+	

lightweight fabric (<200 gsm) | heavyweight fabric (>200 gsm)

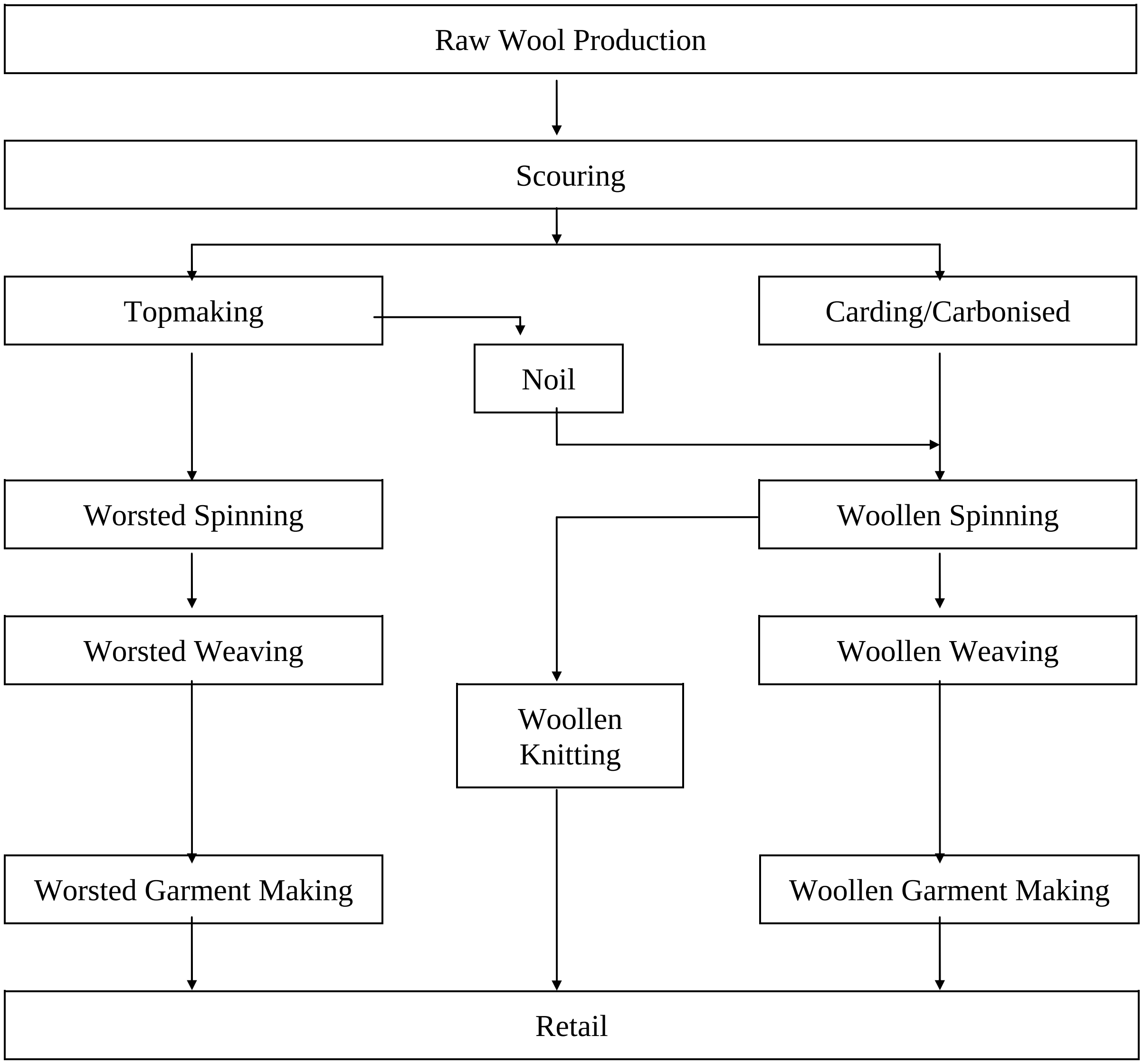
Fibre diameter is the most commonly quoted wool quality. It refers to the average diameter of wool in a lot, quoted in millionths of a metre, or microns (µm). In the model, fibre diameter is divided into 3 categories, which align with the ABS export classifications, which aided in the derivation of the data. Generally speaking, the finer the wool, the higher the value of the wool.

Hauteur is not quoted in the suite of measurements that may be applied to greasy wool, but is extremely important to the processor. The definition of hauteur is the length of fibre in a wool top or sliver, measured in millimetres (mm). In the model, hauteur is predicted using the TEAM equation (Cottle, 1990). Hauteur is a function of staple length, staple strength, fibre diameter, vegetable matter, and proportion of mid-breaks in the wool.

Shorter wool (<56 mm) will be used in the woollen system. This type of processing produces heavy woven fabrics for final products like coats or blankets, or knitted jumpers. Longer wool (56 mm and greater) is used in the worsted system, and will be used to make men's suits and trousers, women's suits, trousers and dresses, and worsted knitwear products (usually jumpers in the case of wool).

Wool is produced in greasy form, then scoured, then enters the worsted or woollen processing system. In the worsted system, wool may made into lightweight (<200 grams per square metre) or heavyweight fabrics(> 200 gsm). A stylised representation of the wool processing system is shown in Figure 3.2.

Figure 3.2: Stylised Wool Processing



There are 10 regions included in the model, 7 of which produce raw wool, and 8 which consume wool as an input into processing and wool products. Western Australia (WA) has been separated from the "Rest of Australia" (ROA) because of the focus of the funders of the model. The Australian regions are not included in the wool consuming regions because of the small scale of local consumption.

An "other" category has been created to account for the regions that are not modelled. The 7 consuming regions modelled accounted for 69 per cent of Australian Wool Exports by value in 1994-95. The regions included in the model are listed in Table 3.1.

Table 3.1: Regions Contained in the Model

Producing Regions	Consuming Regions
France	France
United Kingdom	Germany
USA	Italy
China	United Kingdom
WA	USA
ROA	Japan
Other	China
	Other

To build a model using the AGE methodology, the data (both quantity and value) must be arranged into an input-output database format (Dixon, Parmenter, Powell and Wilcoxen, 1992, pp25-37). This format allows the full value of intermediate transactions that occur on the way to final consumption of a product to be shown. A schematic representation of an input output table for a region used in the model is shown in Figure 3.3.

Figure 3.3: An Input-Output Table for a Representative Region's Wool Industry.

	Absorption Matrix			
	Industries (j)	Final Consumption	Export	Change in Stocks
Commodities (i): 1. Domestic 2. Imported				
Margins				
Taxes				
Variable Primary (Labour)				
Fixed Primary (Land, Capital)				
Other Costs				

In Figure 3.3, the output of commodity i may be consumed either by industry j, domestic consumers or the export market. An applied example of production of wool by the WA wool industry and consumed by the domestic scouring industry is shown in Figure 3.4. Here, $6.3m worth of D-H- wool is produced within WA and consumed by the local scouring industry. In turn, the WA scouring industry will add value to this wool and then sell it to the next economic agent in the chain (in this case all will go to export as there is no topmaking capacity in WA at present).

Figure 3.4: An Example of an Input Output Table: Local Raw Wool Production to WA Scouring Industry, US$'000.

		Scouring					
		D-H-	DH-	D+H-	D-H	DH	D+H
Greasy	D-H-	6,631.7					
Wool	DH-		54,699.9				
Production	D+H-			20.7			
	D-H				0.0		
	DH					91,321.7	
	D+H						4,693.0

In input-output table format, the value of production must equal the value of inputs used (including normal profit). Hence, the value of wool consumed by the scouring industry in the example will be equal to the cost of producing that wool, including the cost of primary factors (land, labour, capital), other costs (fertiliser, shearing, etc.), taxes (wholesale sales tax) and margins (brokers margin). The quality table need not be consistent for raw wool production (where inputs equal outputs) because there is no physical wool input into raw wool production.

3.2 Data Sources and Derivations

The key to being able to construct a model of this type with different regions and qualities is to be able to obtain data to the desired level across many regions and industries. Data sources do not exist for the level of detail required. This has led to previous models (Mullen et al, 1989 and Johnston et al, 1992) aggregating wool qualities and regions to a large degree.

However, with the level of data available, and certain assumptions, it is possible to construct a database to the level required. It is certainly not perfect, but it is not clear at this stage that any errors created by data inaccuracies, are any greater than errors created by the level of aggregation of the previous models. An important point to note is that when the different wool qualities are aggregated at each level, the "mass balance" is totally consistent with published data.

The year outlined in the database is the 1995 calendar year. For a discussion of the choice of the year, see Chapter 2.2. According to the database, the gross value of wool exports from Australia in this year was A$3.9 b.

Australian production data was obtained from the Wool International auction database (this database is now administered by the Australian Wool Exchange), which was provided by the Wool Service Desk of AgWA. This database was able to supply the fibre diameter categories needed for the Australian regions, and for additionally measured wool (about 80 per cent of all wool sold at auction in Australia) the characteristics required to calculate hauteur with the TEAM equation (Cottle, 1990). The distribution of additionally measured wool was assumed to hold for all Australian wool production.

Australian wool exports were obtained from the Australian Bureau of Statistics (ABS, *International Trade*, Electronic Data Service, cat. no. 5464, Canberra), and was provided by the Trade and Market Development Program of AgWA. Exports of wool are broken down in terms of stage of production, fibre diameter categories and country of destination. The fibre diameter categories in the ABS data were used as the fibre diameter categories in the model.

The fibre diameter categories for regions other than Australia were obtained from the Woolmark Company. In terms of fibre diameter, exports from these regions were assumed to be in the same proportion as production for each destination country. Most wool produced in regions other than Australia was assumed to be H^- in processing length, expect where domestic consumption and exports implied a larger worsted industry than could be supplied from Australian wool.

Information on wool and wool product trade was obtained from the TRADSTAT database, provided by the Knightridder company (a commercial supplier), and compiled by the Wool Service Desk of AgWA. This database is a compilation of trade records of the official statistical agencies of each country.

This database includes data for approximately 22 countries at the time of data purchase. Trade between countries in the dataset and those outside it is included in the database via the included countries' records, allowing for the derivation of the pattern of trade of the country outside of the dataset.

The reconciliation of one region's recorded exports to another region, against the second region's recorded imports from the first region, proved difficult. A default setting of using import data was used (unless it was needed to derive data for a country outside the data set).

The TRADSTAT database contained only averaged prices and quantities for raw and scoured wool. However, at the top, yarn and above level, useful quality information began to emerge. For example, wool top requires H and longer scoured wool, while carbonised or carded wool needs H^- scoured wool and noil. Worsted lightweight yarn was assumed to use 19 μm and less wool (of hauteur of H or longer). Additionally, data from Woolmark Company (Various Issues) provided woollen and worsted yarn production in each region.

Despite the information that could be obtained from the trade data, information was still lacking to derive the complete database. Therefore, assumptions were made about the quality distribution of the input to the topmaking and carbonising/carding industries in each region. These assumptions were made in consultation with AgWA researchers who have had substantial overseas experience in the processing sectors. Alterations were made to the estimated quality output if the outputs were not consistent with domestic scouring and scoured imports, or yarn output and exports from other parts of the database. The final distribution of the quality of wool into topmaking for each processing region is shown in Attachment 1.

Pure wool products in the database are those which were classified as 85 per cent wool or greater by weight, and are assumed to contain only wool in the model. Wool rich blend products are assumed to be 60 per cent wool and 40 per cent synthetic fibre. Wool poor products (about 15 per cent wool by weight) are not included in the model.

Processing sector cost structures were obtained from various sources, including Australian Wool Corporation (1993), Textiles Intelligence Publications, and unpublished cost structure data provided by processors.

Local prices at each stage of production were are assumed to be the import price (CIF in all cases) of the equivalent product, plus import duty. Import duties for each region were obtained from the Woolmark Company.

A common theme throughout the database derivation was that the amount and quality of information on quality, cost structures and margins was very good at the production level, but tended to deteriorate along the processing chain. Consequently, information on the retail sector that was able to be obtained is very poor.

Quantity information on production and consumption of wool and non-wool garments was available from Woolmark Company (Various Issues), but prices were not available. Therefore, an assumed retail mark-up (50 per cent) was added to the CIF import price plus duty.

4. The Economic Structure of the Model

4.1 Input-Output Separability

At each stage of production, inputs are demand from commodity producers (wool), primary factors (labour, fixed), taxes and other costs (all other inputs, including commodities not produced in the wool value chain). The output of each stage is wool or wool products of various qualities, either destined for local consumption or export.

A simplifying assumption that is made in the model is that of input output separability. This assumption is well accepted in AGE modelling, and is used in the ORANI model of the Australian economy (Horridge et al, 1998). The reason for using input-output separability is to reduce the number of parameters requiring specific evaluation (Dixon, et al, 1992). Consider a production function for an industry:

F(inputs,outputs) = 0.

Under input-output separability, this may be written as:

G(inputs) = z = H(outputs)

where z is an index of industry activity. This method allows production to be nested according to the decisions faced by the economic agent. Input-output separability will be demonstrated in practice for raw wool and yarn production. The structure of wool production is shown in Figure 4.1.

4.2 Input Demand

At the top level of input demand, the activity level of the industry will determine the demand for the first level of inputs in primary factors, taxes and other costs. The demand for these factors in all production processes in the model is based on Leontief technology.

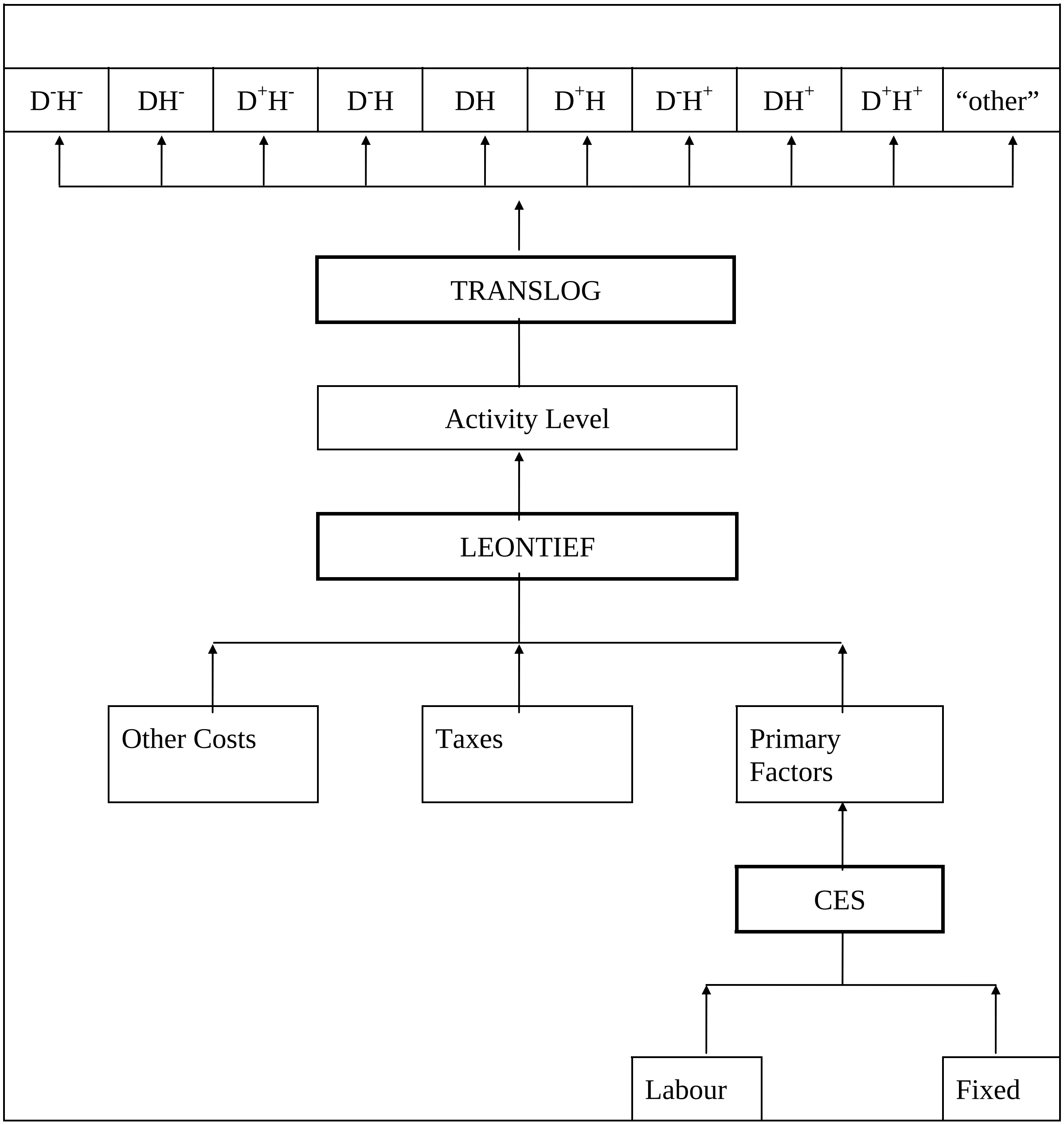
Under Leontief technology, inputs are used in fixed proportions to the level of output. No substitution between inputs is possible. This is equivalent to the assumption used by Freebairn, Davis and Edwards (1982), who assumed that the elasticity of substitution between farm and non-farm inputs is zero. The Leontief cost function is given by (Varian, 1984, p33):

$$c(w_1,w_2,y) = w_1 y/a + w_2 y/b$$

where y is the level of output, w_1 and w_2 are input prices, and a and b are constants. The advantage of using Leontief technology at the first level of the production nest is that it ensures that the physical amount of output of wool product from an industry cannot exceed the physical amount of wool input that is used as an input to production.

At the second level of the production nest, the woolgrower must decide on the combination of primary factors needed. This is done using CES substitution (see Chapter 2.3). Demands for each will depend on the price of each factor, although in this case, the supply of the fixed factors is constant, and the price will vary. It would be expected that, in wool production, the elasticity of substitution would not be great. A substitution parameter of 0.5 is used across all regions, and the elasticity of substitution is dependent upon on the share of fixed and labour in primary factor values.

Figure 4.1: Stylised Greasy Wool Production



4.3 Output Supply

As with input demand, the aggregate supply from the system is based on the activity level. Within this constraint, a change in the mix of supply is possible, depending on relative prices. A constant elasticity representation was not considered flexible enough for wool production. For example, a constant elasticity approach would assume (if all output shares were equal) that it is as easy for the woolgrowing sector to move from D^+ wool to D^- wool, as it is from D to D^-.

For this reason, a more flexible transformation technology is used. In this case, transformation is based on a translog function. The percentage change representation is given as:

$$X_k = z + (p_k - \sum_j S_{kj} p_j)$$

where: $S_{kj} = S_j = C_{kj} / S_i$;

$C_{kj} = C_{jk}$;

$\sum_j C_{kj} = 0, \forall k$; and

$\sum_j S_{kj} = 1, \forall k$.

The restrictions placed upon the translog adjustment parameter, C_{ij}, ensure that the usual symmetry (Varian, 1984 p46) and homogeneity (Varian, 1984 p33) restrictions hold;

$S_k e_{kj} = S_j e_{jk}$; and

$\sum_{k=1}^{N} e_{kj} = 0, \forall k$.

For most stages of production along the pipeline that use a constant elasticity, the transformation parameter is first estimated, and the elasticities are determined by cost or value shares. However, because of the complex nature of the translog function, wool supply elasticities were first calculated for each product in each region, and are consistent with the usual restrictions on elasticities. Then the values of C_{ij} were calculated from the initial output value shares.

Because there are 7 producing regions, and 10 products, 700 parameters are required for wool production in the model (although obviously less actually need to be specified because of the restrictions). Further work needs to be done on the value of the elasticities in the model. It is unlikely that the data will be available in satisfactory form for econometric analysis, so the method used may well be interviews with producers. An example of the elasticities used for WA is shown in Attachment 2.

If the price of all wool quality increase at the same time, the elasticity of supply of wool may be calculated. This will differ from the individual elasticities for each individual wool quality. The elasticity of supply for all wool and for DH (with the price of all other wool qualities held constant) wool for the Australian regions are presented in Table 4.1.

Table 4.1: Supply Elasticities for Australian Wool

Region	Own Price Elasticity of Supply of All Wool	Own Price Elasticity of Supply of DH Wool
WA	0.21	0.49
ROA	0.17	0.50

The overall wool own price supply elasticities are on the lower end of the range of the estimates presented by Chisholm, Haszler, Edwards and Hone (1993), and Mullen et al (1989), who used an own price supply elasticity of 1.0. An own price wool supply elasticity of Australian wool of 0.5 was used in the TEXTABARE model (Johnston et al, 1992).

The fact that the elasticity of supply of all wool from WA is greater than the equivalent elasticity for the ROA, but vice versa for the DH supply elasticities, can be explained by the relative share of outputs of each commodity. While all wool makes up a larger value share of output in the ROA, DH wool occupies a larger share of WA production.

4.4 International Trade

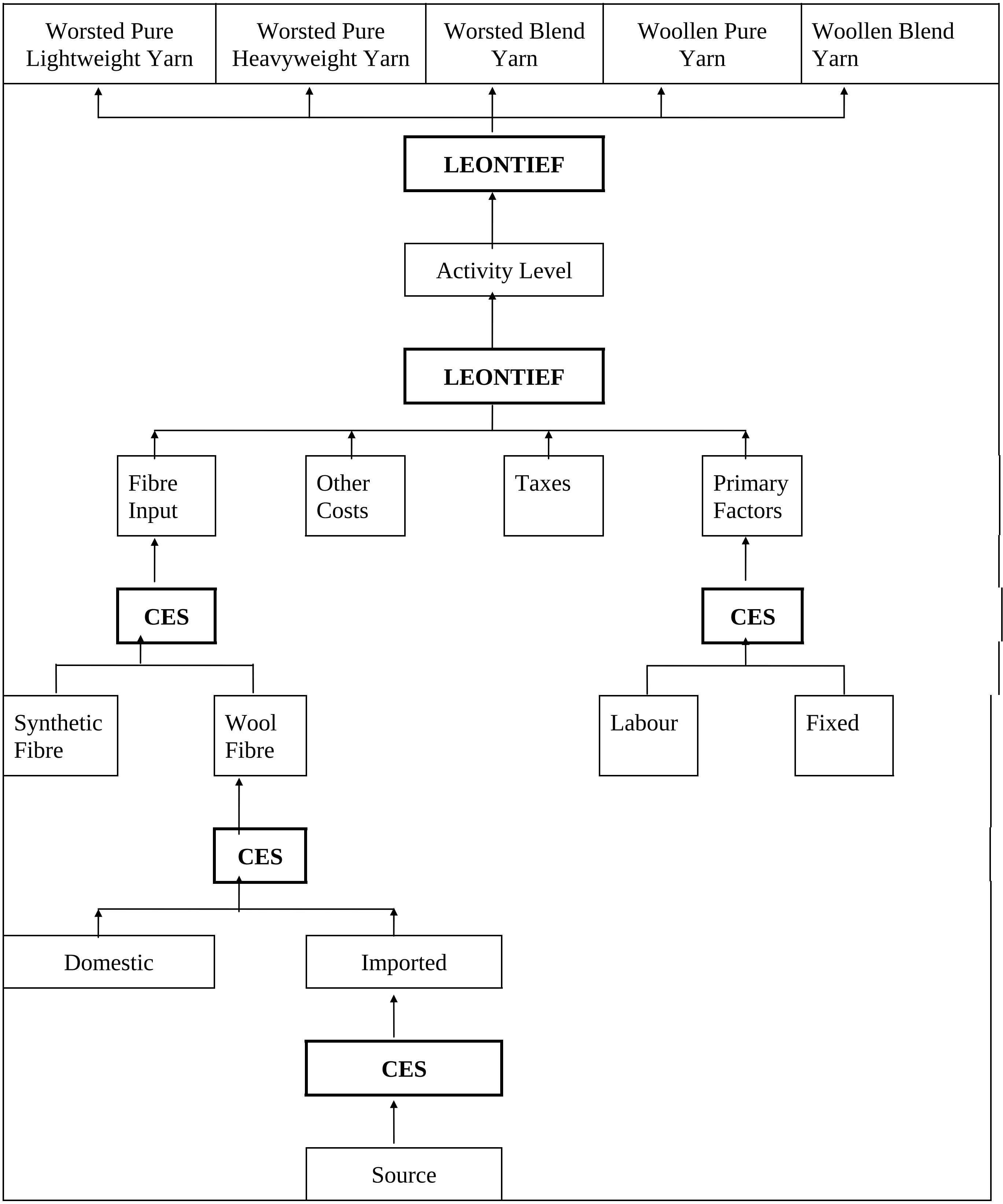
Producers have the option of choosing domestically produced or imported commodities as inputs to the production process. In this model the Armington assumption (Dixon et al, 1992, p224) is used. Under this assumption, imports and domestically produced goods are not perfect substitutes.

The structure of substitution between imports and domestically produced commodities (of the same quality) is shown for the spinning sector in Figure 4.2. The CES function is used for the transformation process. Once a decision to import wool has been made, the source region must be chosen, and again a CES function is used.

Mullen et al (1989) present evidence of estimated substitution elasticities between wool from different sources. They found that the estimated elasticities were surprisingly low, but used an elasticity of 5.0. Johnston et al (1992) use a cross price elasticity of 5.0.

It would not be surpassing if the low cross price elasticities found by Mullen et al (1989) were due to differences in the quality between the wools produced in each region. For example, if one country produces mainly short wool that will enter the woollen processing system, and another long wool that will be used in the worsted system, then the substitution prospects will be limited.

Figure 4.2: Stylised Spinning Processing Sector



In this model, the decision is based on wools of similar qualities, and so the prospects for substitution will be good. A CES substitution parameter for domestic-import substitution of 2.0 is used for all products and regions, with the elasticity depending on the cost share of domestic and imported wool in total wool use. The greater the cost share, the less will be the substitution possibilities.

It is expected that once the producer makes the decision to import product, the decision between source regions will be extremely elastic. Hence a CES transformation parameter of 5.0 is used for all products and regions.

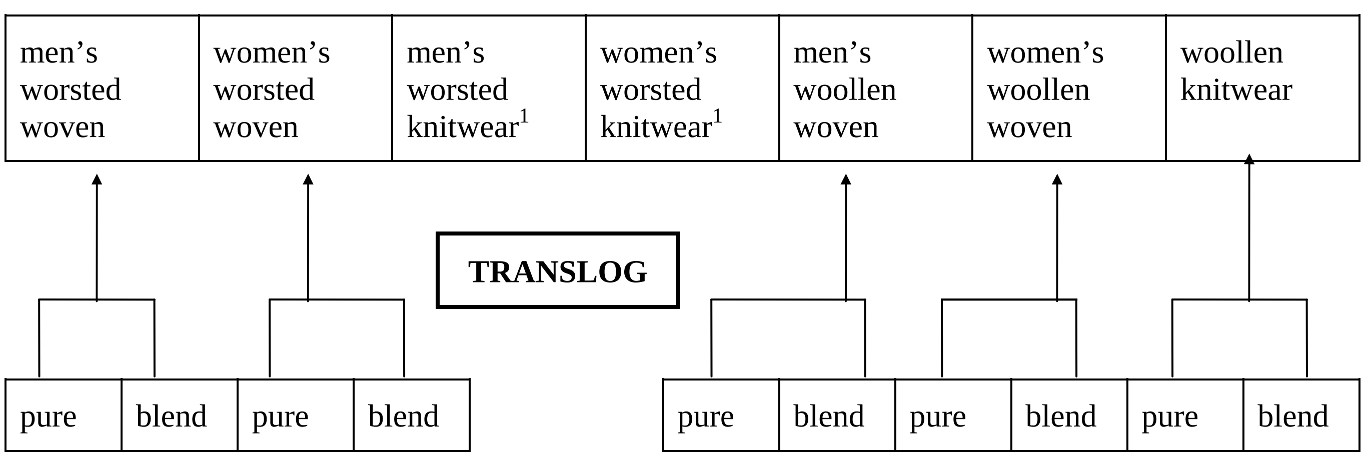
4.5 Substitution between Fibres

Wool and synthetic fibres are able to be substituted in the blended products (60 per cent wool at the initial solution). Using a CES function, the relative prices will determine the quantities of wool and synthetic fibre used. The transformation parameter used is 0.3 for the blending industries, meaning that the substitution is relatively limited. Synthetic fibres are assumed to be perfectly elastic in their supply. The elasticity of substitution is zero in the pure wool industries, as synthetics have no cost share in production of these commodities.

4.6 Consumer demand

The modelling of the retail sector has been restricted by the data availability problems outlined in Chapter 3.2. At the retail level, garment types do not compete with each other, but garments within types do. For example, pure and blended men's worst wool garments compete with each other, but men's worsted blends and women's woollen woven blend do not. A stylised representation of retail demand is shown in Figure 4.3.

Figure 4.3: Stylised Retail Demand



1. The worsted knitwear category contains only blends.

The transformation occurs using a translog function, although further research is required to determine the best functional form to use. As noted in Chapter 3.2, the database does not yet include quantities or values of garments made from other fibres. However, the parameters are set to allow some expansion of retail demand for wool garments by allowing a violation of the homogeneity assumption for the retail elasticities of demand. That is:

$$\sum_{k=1}^{N} e_{kj} < 0 .$$

This means that if the price of a particular wool garment falls, then the total market for that garment type will expand. If the homogeneity assumption held, then zero restrictions would be placed upon the cross price elasticities between wool garments and other fibre garments. Additionally, zero restrictions would be placed on the cross price elasticities between wool garments and all other consumer products, which means that a fall in the price of a wool garment cannot increase the consumer budget share of garments. Rather than impose unrealistic zero restrictions due to lack of data availability, it was decided to violate the homogeneity restriction.

4.7 Price Transmission, Zero Pure Profits and Market Clearing

A series of price transmission equations are included in the model. These are to ensure that producers and consumers are optimising their behaviour at the correct price level. For example, the price of a domestically produced commodity purchased by an industry is assumed to be equal to the output price for the producing commodity (transport margins are not well modelled at this point). Alternatively, the same industry in region r purchasing an imported product i from region s will face a price (P_{ir}) given by:

$P_{ir} = (e*P_{is}) + D_{irs}$

where: P_{is} is the output price in the source country;

e is the exchange rate between the two countries currencies; and

D_{irs} is the duty imposed on the imported product.

At this point, all values are in US dollars, but an exchange rate transmission exists if a question of the impact of a change in real exchange rates arises.

A zero pure profits condition is imposed upon each level of production in each region. This is a consequence of the assumption of perfect competition, in that it ensures only normal profit is obtained by all producers. Zero pure profits are imposed by the equality:

$$r_i = c_i$$

where: r_i is the percentage change in revenue obtained by and industry; and

c_i is the percentage change in industry costs.

Hence the zero pure profits condition is simply the optimisation rule for a producer or marginal cost equals marginal revenue.

For every commodity, the market is assumed to clear. That is, demand will equal supply at all points along the value chain. This is imposed by:

$$q_{it} = q_{ii} + q_{ie} + q_{ic} + q_{is}$$

where: q_{it} is the percentage change in commodity i that is produced in the region;

q_{ii} is the percentage change in domestic intermediate usage of commodity i;

q_{ic} is the percentage change in final domestic consumption of commodity i;

q_{ie} is the percentage change in exports of commodity i; and

q_{ii} is the percentage change in change in stocks of commodity i.

If the change in stocks is negative, then the level of production is less than consumption, and stocks are being run down. The only stocks in the model are raw wool in Australia. This is the wool stockpile accumulated under the minimum reserve price scheme. The change in stocks in the base case are negative, meaning net stockpile sales. The amount of wool sold from the stockpile is the same as for the 1995 year, which was under the fixed disposal regime (at 33 mkg per quarter).

5. Potential Uses and Results

5.1 Potential Uses

The detailed nature of the model obtained from the lack of aggregation of data enables a wide range of questions to be asked of the model. This means that the need for complex calculations outside of the model are reduced. Examples of questions that may be asked of the model include to calculate the value to WA and ROA farmers of:

- on-farm technologies to change the quality of wool production. Examples of this may be an increase in fine wool production, or strategies to increase the amount of long hauteur wool in the WA clip (via staple strength research). The model will calculate the impact on quality premiums from the increased production of wool in the higher quality categories;

- productivity improvements at any stage along the production chain. Changes in output prices and quantities, input prices and quantities, and profit for all stages of the production chain will be reported, including the flow back to woolgrowers;

- a shift towards certain quality wool in processing or consumption. An example may be a shift towards lightweight fabrics for garment production; or

- the long run impact of exogenous economic events, such as a long run fall in income in a key consumer country.

The list is certainly not exhaustive. A major strength of the model is its versatility and flexibility to many situations.

5.2 Results

The following section will examine the results of the model for a one per cent cost saving in non-fixed costs (labour and other costs) for greasy wool production, topmaking and carding/carbonising, worsted and woollen spinning and worsted and woollen weaving. The earlier stages of processing are examined because of the fact that this is where most of AgWA's efforts are focused.

The change at the processing levels is assumed to occur across both the woollen and worsted systems and across all countries. If the saving is gained by only some regions, then the substitution effects appear to be quite severe, with the regions with the saving out-competing the regions without, leading to a much reduced benefit to Australian woolgrowers.

The production technology is divided into three levels. Firstly, the cost saving is restricted to WA only. Then, research leakage allows the cost saving technology is to be used by the raw wool production industries in ROA and then the rest of the world.

Finally, a shift in retail demand of 1 per cent is allowed, although this is considered to be almost as dangerous as an exogenous increase in export price using on farm models. While cost shifts in processing can usually be derived with reasonable accuracy due to researchers' experience in the industry, and knowledge of industry cost structures, shifts in demand are less certain. The probability of success in shifting a demand curve is difficult to estimate.

A change in profitability is measured in the model as a change in returns to the fixed factor of the production stage in question. This is a similar, although more direct, method to measuring economic surplus, because the change in profit (for economic surplus is a proxy) will accrue to the fixed factors. Mostly, changes in the returns to fixed factors in Australian woolgrowers will be considered, but an examination of the flow of benefits up and down the value chain will be examined for the cost reduction in spinning case.

Finally, the results will be compared with the results of previously published models of the wool and other farm commodity value chains. Reasons for differences between the studies will be examined.

The change in Australian woolgrower profitability from a one per cent cost saving at wool production, various stages of processing and a one per cent increase in retail demand are shown in Table 5.1.

Table 5.1: Benefits to Australian Woolgrowers from a One Per Cent Saving in Non-Wool Variable Costs along the Value Chain

1 per cent cost saving to:	Change in Profitability[1] to Australian Woolgrowers (per cent)	
	WA	ROA
WA Woolgrowers	0.76	-0.05
Australian Woolgrowers	0.60	0.41
All Regions Woolgrowers	0.52	0.35
Topmaking and Carding/Carbonising	0.00[2]	0.00[2]
Spinning	0.07	0.05
Weaving	0.08	0.08
1 per cent change in retail demand for all wool apparel products	6.29	5.51

1. A one percent change in profits to WA worth approximately US$4.7 m.

2. Slightly negative.

The results in Table 5.1 are difficult to compare with the previous studies, as changes in the model are calculated in percentage change terms. As the processing industry in each country has a different cost structure, calculating a similar dollar change in each region is difficult.

An important point to note is that the substitution possibilities may lead to different distributions of benefits along the production chain than previous studies. Freebairn et al (1982) found that a $1 cost saving at any part of the chain would be passed back to the primary producer (given perfect competition). They assumed zero substitution between farm and non-farm inputs into processing.

This result was questioned by Alston and Scobie (1983), who noted that if the elasticity of substitution between farm and non-farm inputs to processing was not zero, the full benefit would not be passed on to producers. In fact, if the elasticity of substitution between farm and non-farm inputs to processing was greater than the elasticity of demand for the processed product, then the benefit to growers would be negative.

In the model, the assumption of Leontief technology when considering the input of farm (wool) and non-farm inputs leads to a substitution elasticity of zero. However, there are other substitutions at work that will lead to similar effects as those discussed by Alston and Scobie (1983). Firstly, there is the ability of processors to substitute between domestic and imported product, then between import sources. Secondly, at the spinning level, there is substitution between wool and synthetic fibres. Hence, it would not be expected that the full benefit of the cost saving would be passed back to the woolgrower.

It can be seen that, of the cost saving technologies, a one per cent change in variable costs to the raw wool production process is the most profitable for growers. This result is consistent with Mullen et al (1989). The difference between the results is that Alston and Mullen (1989) found that on-farm gains were more profitable than an increase in the demand for wool products.

If the on farm cost saving is restricted to WA woolgrowers, then the increase in profitability for them is 0.76 per cent. As the cost saving is obtained by growers from other regions, then the benefit to WA woolgrowers reduces somewhat. This is a logical result when research leakage occurs.

The gain from increasing retail demand is extremely large relative to the cost saving gains. An approximate one percent gain in retailer profits is translated into around a six per cent increase for Australian woolgrowers. As wool is the only input to the entire process that is not modelled as perfectly elastic in supply (and is actually inelastic from all regions), a large increase in the price of wool in response to an increase in retail demand is to be expected. An increase in price at the retail level is also magnified in terms of the price of raw wool. For example, greasy wool accounts for only 6.4 per cent of the total cost of a wool suit (AWC, 1993).

In Table 5.1, WA almost always received a higher level of benefit than the ROA. The major difference between the two regions appear to be that wool supply from WA is more elastic. This would seem to contradict the results presented in (Johnston et al, 1992), who found that an increase in the supply elasticity of Australian wool reduced the benefits to Australian woolgrowers from the “SIROSPUN” technology (a spinning technology).

For a situation where there is only one supplier (say Australia), it is easy to show that a demand shift under a more inelastic supply curve will lead to a higher gain in economic surplus than if the curve were more elastic. However, in this model, there is more than one supplier, and so the price of the competitors product will be built into the demand curve for Australian wool. Logically, if a competitor has a more elastic supply curve, then the demand curve for Australian wool will not shift as far to the right because of the increasing supply from competitors.

This is related to the Alston and Scobie (1983) result presented above. An assumption behind their conclusion was that the non-farm inputs were perfectly elastic in their supply, which logically meant that this was more elastic than the upward sloping farm product supply curve (they used an elasticity of 0.7).

The substitution of import source is high (a CES substitution parameter of 5.0) in the model. As supply is more elastic from WA, production will expand faster than for the ROA in response to an increase in demand, and processing countries will import WA wool at a faster rate.

Although Johnston et al (1992) contend that an increase in the supply elasticity of Australian wool would reduce the benefits from processing research, it was in the context of the own price elasticity of supply of Australian wool (0.5) being greater than the elasticity of supply of wool from other countries (0.2). At no time in their sensitivity analysis did the own price elasticity from other countries take on a value greater than the Australian value.

The negligible but negative benefit to growers from the cost saving during topmaking in Table 5.1 may be another example of the above result. Any gain or loss from reducing non-wool variable costs in topmaking will be small because wool and capital make the vast majority of the cost of topmaking (for example, for DH top in France, non-wool variable costs account for only 12 per cent of total costs in the model database), making the cost saving relatively small.

A negative benefit is possible under the conditions outlined by Alston and Scobie (1983). When the topmaking cost saving was applied, Australian exports to China fell, while the Chinese wool production increased. This could result if wool supply from China was more elastic than from WA and ROA. However, in the model, the own price supply elasticity for a one per cent rise in the price of wool of all qualities for China is about the same as for the ROA, but less than that for WA. This elasticity may not be applicable because the prices for the various qualities of wool changed by different amounts in the simulation (in fact, the prices of H- wool were actually reduced for reasons outlined below), and so the answer is extremely complex. A final conclusion on this matter has not been obtained at this point.

A further complication arises given the level of detail in this model, in that there is an interaction between the worsted and woollen processing systems via the production of noil. Noil is defined as the short fibres combed out of wool top during the worsted processing system. They are used as an input into the woollen system. Any increase in worsted production will also increase supply to the woollen system, which will have a downward impact on prices for H^- wool, offsetting, or even negating the gain to this sector from the cost saving.

An examination of the distribution of benefits along the value chain is now presented. Table 5.2 shows the flow of benefits up and down the value chain from the reduction in spinning costs. The gains shown are world-wide, so they aggregate any regional substitution effects.

Table 5.2: Changes in Profit at Different Points along the chain to a one per cent reduction in Variable Spinning Costs

Sector	Change in Profit (%)
Greasy Wool Production (world)	0.08
Scouring	0.02
Topmaking	0.01
Spinning	0.03
Weaving	0.01
Garment making	0.0003
Retailing	0.002[1]

1. Returns to fixed and variable factors.

It can be seen from Table 5.2 that the biggest, although still small (wool and capital are still the largest cost share items in spinning) gain of the processing sector goes to the sector where the cost saving is applied. Wool production receives the largest benefit of all in percentage change terms, which appears to be a reflection of the magnification of costs along the processing chain, and the fact that the substitution possibilities are much reduced due to the aggregation of the regional affects.

6. Further Development

At this stage, the model is very much still a work in progress project. Work is expect to continue for some time yet before reasonable confidence can be had in the model results. Further development for the next 12 months is expected to be concentrated in 3 main areas.

- the expansion of the database to include India and South Korea. The new database will be for the 1996 calendar year. Choosing a “typical” year from recent years is difficult, particularly given events in Asia over the last 18 months. The pre-Asian crisis year of 1996 has been chosen;

- a superior specification of the retail sector than present is needed. A suitable functional form for retail consumption needs to be specified and applied. Quantities and values of garments made from other fibres need to be obtained and applied to the new functional form; and

- the verification and improvement if necessary of many of the behavioural parameters in the model. A particular focus will be on the on-farm area in Australia where some econometric estimation may be possible.

Generally, as new information becomes available, especially as AgWA researchers spend more time with processors and retailers, the database must be continually improved. It is the weakest link of the model, so any improvement must be pursued vigorously.

7. Conclusion

The WA World Wool Model attempts to model the world wool market at a substantially more detailed level than any previous attempt. The reason for building the model was a desire by the Manager of the Wool Program in AgWA to obtain a method for evaluating off-farm research, with the objective of improving the resource allocation within the Program.

Applied general equilibrium modelling has many advantages. The specification of the initial cost and output structure of each industry imposes restrictions upon changes in variables that may not be present in producer surplus analysis. That the input-output table will be consistent both before and after any technology shock is important.

The input-output separability assumption and nesting of production and consumption allows the modeller to impose any research change at a relatively close point to where it occurs in reality. This alleviates the need for complex calculations outside the model.

Changes in technologies that affect productivity and product quality at all points along the value chain may be evaluated. The reasons for any result may be tracked to a very fine level, revealing the exact nature of the change to the researcher.

The regional nature of the result enables the researcher to see the differences that technologies may have on different production and processing regions. This is especially important for Agriculture WA, which is required to consider the economic benefit of its activities on WA.

There are several major disadvantages of the approach taken. The first is that the majority of the database is derived, relies on some reasonably arbitrary assumptions, and verification is difficult. In addition to this, the scale of error produced by any data errors is almost impossible to estimate. Despite this, the results presented in Section 5. indicate that the results are consistent with previous models with a more aggregated database.

The model is very large, with 20,400 endogenous variables solved in every simulation. While this gives the advantage of a very detailed answer, it at times somewhat makes the interpretation of results, or finding the source of an error, difficult. Owing to the software used, the physical specification and running of the model is not difficult.

Due to the scale of the model, there are many behavioural parameters that will never be realistically estimated or found through interviews with the relevant economic agents. For example, there are 100 translog transformation parameters for each of the 7 wool producing regions, or 700 parameters, for the transformation between output types alone. In addition, sensitivity analysis for these parameters will be a long and slow process. The standardisation of many parameters and the use of input and output shares to determine elasticities (particularly using CES transformation) can make the task a little less onerous.

In summary, there are both advantages and disadvantages to the modelling technique used. The answers given are detailed enough to satisfy most research evaluation (or long term economic change) questions that have been asked to this point. Explanation of results is an arduous process, but sometimes very enlightening. Verification of the results has sometimes proved difficult.

In updating the database, more information is coming to light that may improve database quality. The big advantage of using the less aggregated data approach is that the data is consistent with the aggregated or “mass balance” database, so a change towards a model using aggregated data is a relatively simple process.

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Attachment 1: Assumed Quality Distribution After Scoured and Scoured Trade: Inputs to Topmaking and Carding/Carbonising (after adjustments) of Processing Regions

France

	D-	D	D+
H-	0 %	8 %	4 %
H	2 %	82 %	3 %
H+	1 %	0 %	0 %

Germany

	D-	D	D+
H-	0 %	0 %	18 %
H	2 %	50 %	9 %
H+	0 %	17 %	4 %

Italy

	D-	D	D+
H-	2 %	16 %	26 %
H	23 %	21 %	1 %
H+	1 %	9 %	0 %

United Kingdom

	D-	D	D+
H-	0 %	24 %	47 %
H	1 %	17 %	10 %
H+	0 %	0 %	0 %

Japan

	D-	D	D+
H-	1 %	20 %	1 %
H	11 %	51 %	6 %
H+	1 %	10 %	0 %

USA

	D-	D	D+
H-	2 %	47 %	12 %
H	1 %	22 %	6 %
H+	0 %	9 %	0 %

China

	D-	D	D+
H-	0 %	15 %	25 %
H	2 %	24 %	27 %
H+	0 %	4 %	4 %

Other

	D-	D	D+
H-	0 %	29 %	44 %
H	0 %	4 %	8 %
H+	0 %	4 %	9 %

Attachment 2: Raw Wool Production Own Price Elasticities of WA Wool Production

	Wool Outputs										
	D-H-	DH-	D+H-	D-H	DH	D+H	D-H+	DH+	D+H+	Other	Total
D-H-	0.35	-0.10		-0.10	-0.05					-0.10	0.00
DH-	-0.05	0.45	-0.10	-0.05	-0.10	-0.05				-0.10	0.00
D+H-		-14.80	15.05		-0.05	-0.10				-0.10	0.00
D-H	-0.08	-0.09		0.52	-0.10		-0.10	-0.05		-0.10	0.00
DH		-0.02		-0.01	0.43	-0.10	-0.05	-0.10	-0.05	-0.10	0.00
D+H		-0.16			-1.67	2.08		-0.05	-0.10	-0.10	0.00
D-H+				-6.52	-30.49		37.21	-0.10		-0.10	0.00
DH+				-0.02	-0.33	-0.01		0.56	-0.10	-0.10	0.00
D+H+					-0.39	-0.05		-0.23	0.76	-0.10	0.00
Total	-0.01	-0.02	0.00	-0.01	-0.11	-0.01	0.00	-0.03	-0.01	0.20	0.00

Note: Blank cells imply an elasticity of zero.