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FIBRE SUBSTITUTION IN THE UNITED KINGDOM WORSTED SPINNING SECTOR

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EXECUTIVE SUMMARY

With the demise of the Reserve Price Scheme and the consequent collapse of wool prices to market levels well below the previous floor price levels and with over 4 million bales of wool in stock, everyone in the wool industry is asking whether wool prices matter. The present study provides an up-to-date answer to this question by estimating fibre demand equations for the United Kingdom worsted spinning sector. The answer is that prices do matter but their effects on fibre demand are not large. If extrapolated to the entire processing industry, our results suggest that the recent substantial drops in wool prices will do little to clear Australia's large stocks of wool, particularly in the short run.

These conclusions are derived from an analysis of the demand for 6 fibres in the United Kingdom worsted spinning sector. The fibres included in the study are crossbred wool, merino wool, fine hair, acrylic, polyester and nylon. The analysis covers the period 1971 to 1990 during which time wool's volume share of a declining market fell by 12 percentage points to be 56 per cent in 1990 (Figure 1). Over the same period, fibre prices moved strongly in favour of synthetics suggesting that the decline in wool's market share was price related (Figure 2).

The main picture to emerge from the results is that the major fibre substitution possibilities exist between crossbred and merino wools and between the three synthetic fibre types. All other

Figure 1: Fibre Consumed in the UK Worsteds Spinning Sector

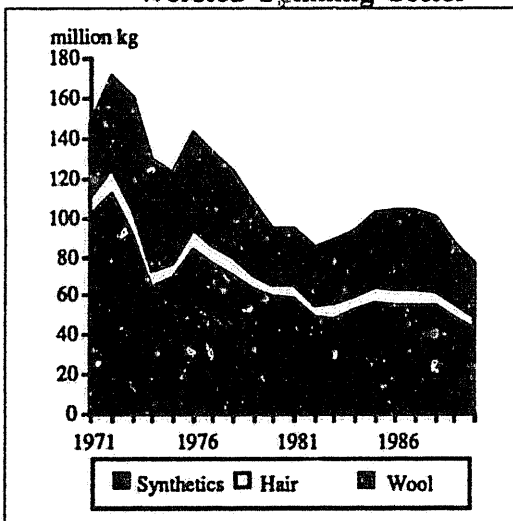
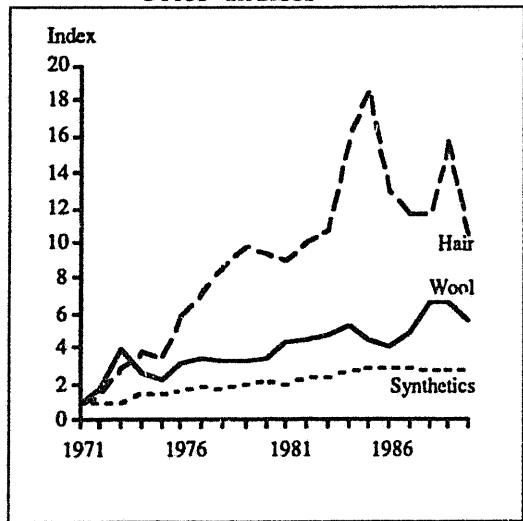


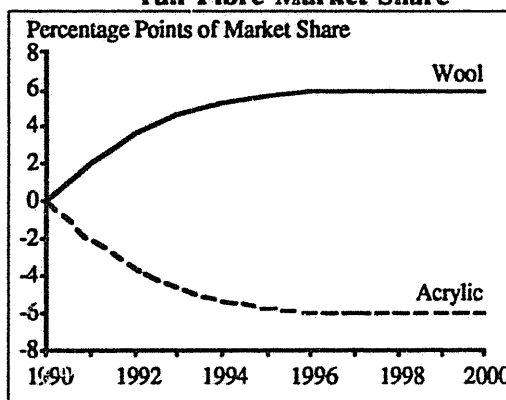
Figure 2: United Kingdom Fibre Price Indices



inter-fibre group effects are quite small with the exception of the effects of wool price changes on the consumption of the minor synthetics, polyester and nylon. The demand for both wool types remains relatively unaffected by a change in the relative price of hair or any of the three synthetics.

As a result of these limited substitution possibilities, the demand for wool in aggregate is relatively unresponsive to price movements. For example, in the short-term the recent large declines in wool prices are calculated to lead to a 5.8 per cent increase in the market share held by merino wool in the United Kingdom worsted spinning sector. However, this gain is achieved largely at the expense of crossbred wool which is simulated to suffer a 7 per cent decline in market share. However, our results suggest that full adjustment to fibre price movements can take in excess of 5 years (Figure 3). In spite of the recent substantial falls in wool prices, it will take several years for wool to gain an increased market share in the worsted sector. Given the long adjustment

Figure 3: Forecast Change in Long-run Fibre Market Share



times involved, the very high wool price rises of the later 1980s would still be depressing fibre demand in the United Kingdom worsted sector and it will take several years for lower prices in recent times to be fully translated into increased demand by processors on the auction floor.

It would be tempting to use the results of this study to argue for Australia to operate some form of price discrimination in international wool markets. The low price elasticity of demand for wool suggests that such a policy would raise wool prices by more than it would reduce demand. However, for the policy to be successfully implemented wool production in Australia would need to be restricted as would supplies from other countries. Recent experience with the operation of the Reserve Price Scheme suggests there would be severe political and administrative difficulties involved in implementing such a scheme.

We conclude that prospects for Australia's wool industry will depend critically on an improved outlook for the world economy. Increased demand from improved international macroeconomic conditions provides the best hope for Australia to unload its stockpile of wool without further substantial declines in wool prices.

FIBRE SUBSTITUTION IN THE UNITED KINGDOM

WORSTED SPINNING SECTOR

1. Introduction

Australian woolgrowers are financially vulnerable to the large amount of capital they have invested in the huge stockpile of wool accumulated by the Australian Wool Corporation during its operation of the Reserve Price Scheme. The efficient management and disposal of this stockpile will greatly influence woolgrowers' incomes for many years to come. Knowledge of future market demand and the factors that influence it are essential to optimal disposal of the stockpile. They are also essential to fully understand what will be the long-term impact of the large falls in wool prices following abandonment of the Reserve Price Scheme.

This study provides an up-to-date analysis of the microeconomic factors, particularly fibre substitution, affecting wool demand in a large and important wool-using sector of the United Kingdom. Mill level data are used for the UK worsted spinning sector, the output of which is used principally to produce apparel. The results for the UK are taken to be representative of demand response at the spinning stage.

Fibre substitution in response to relative price changes can occur at several stages during processing or at the final demand stage of the textile 'pipeline'. Fibre demand during the processing stages is derived from final demand in the sense that processors will only make production decisions which are consistent with consumer's tastes and preferences for end use characteristics or qualities in apparel. The spinning stage of processing where raw fibres are spun into yarns is the principal stage at which fibre choice decisions are made. Substitution of fibres will occur in response to relative price changes depending on the extent to which different fibres can be spun into yarns with similar end-use characteristics. Consumers will then substitute apparel qualities in response to relative price changes resulting from the cost of producing yarn with the relevant end-use characteristics or qualities.

Use of mill level data at the spinning stage thus enables us to focus on the critical point of the process where fibre choice decisions are made. It avoids the introduction of errors that can occur when constant conversion factors are used to convert final demand data to mill level, as was done by Ball, et al. (1989). Use of mill level data also enables the substitution elasticities

between wool and other fibres to be obtained directly from the model results. The study of Short and Beare (1990) only obtained the United States retail demand elasticities directly and not the derived demand elasticity for wool fibre which could only be obtained through further manipulation of their results.

Fibre substitution at the spinning stage is examined in this study using the Generalised McFadden cost function methodology. This functional form was developed by Diewert and Wales (1987) to overcome some of the practical shortcomings of earlier flexible functional forms such as the translog. It allows for imposition of the correct curvature conditions during estimation without loss of flexibility properties. Use of this methodology and data source has permitted the inclusion of a larger number of fibre types than has previously been possible. Two wool types (crossbred and merino), three synthetic types (acrylic, polyester and nylon) and hair fibres are included in the analysis.

Slow response times to changes in relative fibre prices are an important characteristic of apparel production. Earlier studies of fibre substitution have lacked a comprehensive theoretical framework to take account of this important feature. In this study a planning price model of imperfect adjustment is estimated (Woodland 1977, Lawrence 1987). In this model, processors respond fully each period to a notional set of planning prices which in turn adjust gradually to actual prices. The rate at which the planning prices adjust to actual prices is estimated as part of the overall estimating system. Wool demand can thus respond at a faster or slower rate than synthetic fibre demand. Using this method, the response pattern of demand following a relative price change can be plotted over time. This information is vital to a thorough understanding of fibre demand.

In the following section the process of fibre and fabric production is reviewed and the characteristics of the UK worsted spinning sector examined. Previous studies are then briefly reviewed. The Generalised McFadden cost function model is presented in the fourth and fifth sections followed by the planning price model in the sixth section. The influence of final demand level factors on fibre demand is then examined in the seventh section and the important policy implications emanating from the study are summarised.

2. Fibres and Fabric Production

Textiles are an indispensable part of modern life. They are used not only for all types of wearing apparel but also for household linen, furnishings, accessories and a wide range of industrial use such as filters and padding.

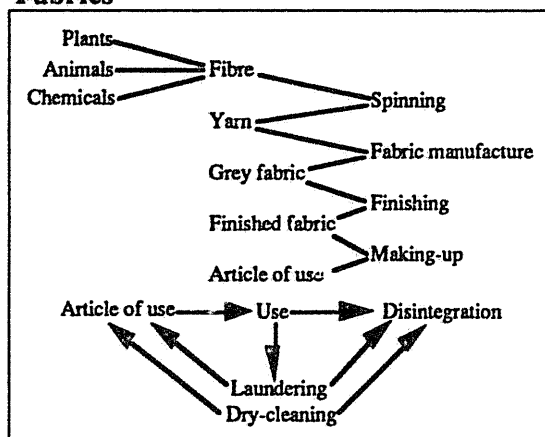
Starting from natural or artificial fibrous material a series of consecutive production processes leads to the final article of fabric ready for use. Continuing use of the fabric leads to changes in its properties and its eventual deterioration and disintegration which necessitates its replacement. This process is illustrated in Box 1.

This study focus on a specific type of fabric — worsted — in whose production wool is relatively important. Wool is used principally in the production of worsted and woollen fabrics. Worsteds are mainly used in the production of

expensive apparel and quality garments. Woollens, on the other hand, are used in less expensive casual clothing and blankets. The differences between the two fabric types are set out in Box 2.1.

To produce worsted yarn the wool is first sorted and blended and then scoured to remove grease and vegetable matter. Oil is then added to the wool to lubricate it for the spinning operation. The scoured or clean wool is then put through the carding process where it is passed between large rollers covered with thousands of teeth. The fibres are disentangled and made to lie as parallel as possible. This process is continued through the gilling and combing operations which also remove the shorter fibres (called 'noils'), place the longer fibres (called 'tops') as parallel as possible and further clean the fibres by removing any remaining loose impurities. The noils are used as filler for other types of wool fabric and are a major source of raw material for 'woollen' yarns.

Figure 2.1: Production and Use of Fabrics



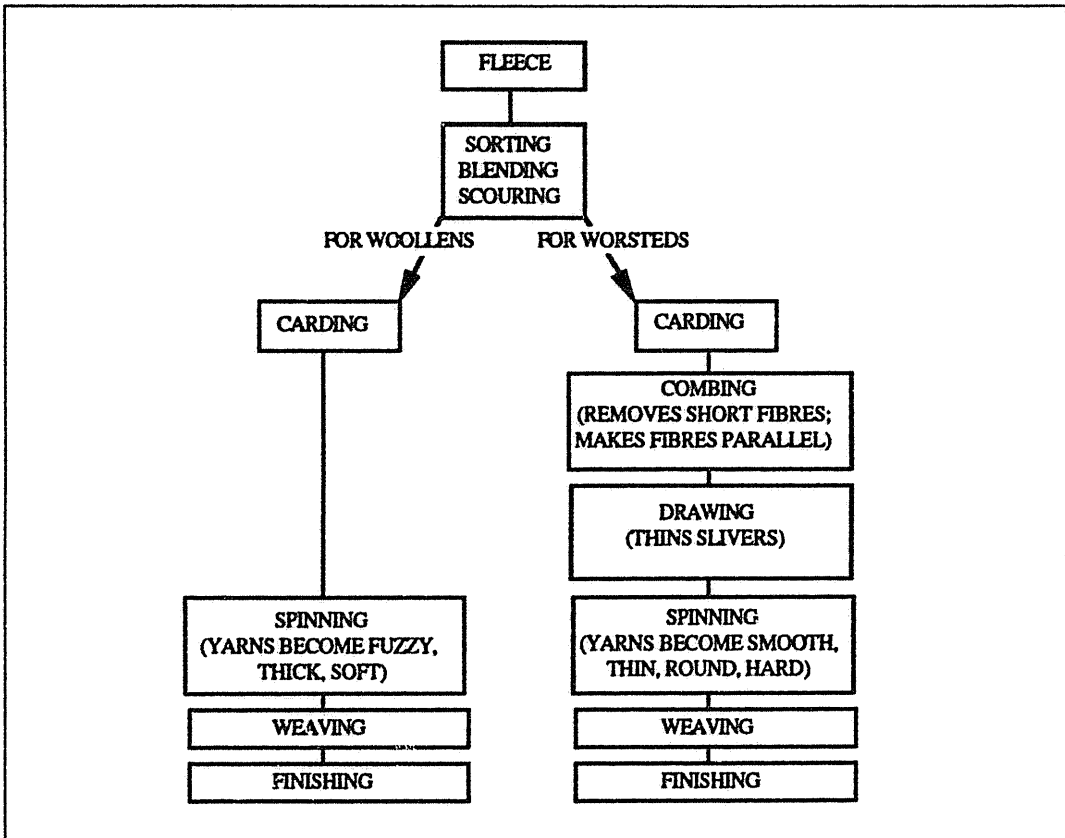
Source: Komreich (1966, p. 12)

Box 2.1: Differences Between Woollen and Worsted Fabrics

	WOOLLEN FABRICS	WORSTED FABRICS
Fibre	Short, curly fibres	Long, straight fibres
Yarn	Carded only; slack twist; weaker yarns	Carded and combed; tight twist; greater tensile strength than woollens; generally yarn-dyed
Weave	Indistinct pattern; usually plain weave, sometimes twill; thread count generally less than worsteds	Distinct pattern; chiefly twill weave, frequently plain weave; more closely woven than woollens
Finish	Soft finish; fulling, flocking, napping, steaming; since napping can conceal quality of construction, woollens are easily adulterated	Hard finish; singed, steamed; unfinished worsteds are napped; adulteration more difficult as fillers would be easily discernible
Appearance and touch	Soft, fuzzy, thick	Flat, rough, harsh
Characteristics	Warmer than worsteds, not so durable; naps acts as a protective agent against shine; soft surface catches and holds dirt; stains easily removed	Wrinkle less than woollens, more durable; hold creases and shape; become shiny with use; more resistant to dust
Uses	Generally less expensive than worsteds if poorer yarns are used; desirable for sportswear, jackets, sweaters, skirts, blankets, winter use	Costlier yarns; appropriate for tailored and dressy wear; spring and summer coats and suits, tropical suits; good for business wear
Typical fabrics	Tweed, homespun, flannel, broadcloth, shetland, cassimere	Gabardine, whipcord, serge, worsted cheviot, tropical worsted, Bedford cord.

Source: Griffith, Potter and Corbman (1970, p. 221)

Box 2.2: Processing Wool for Worsted and Woollens

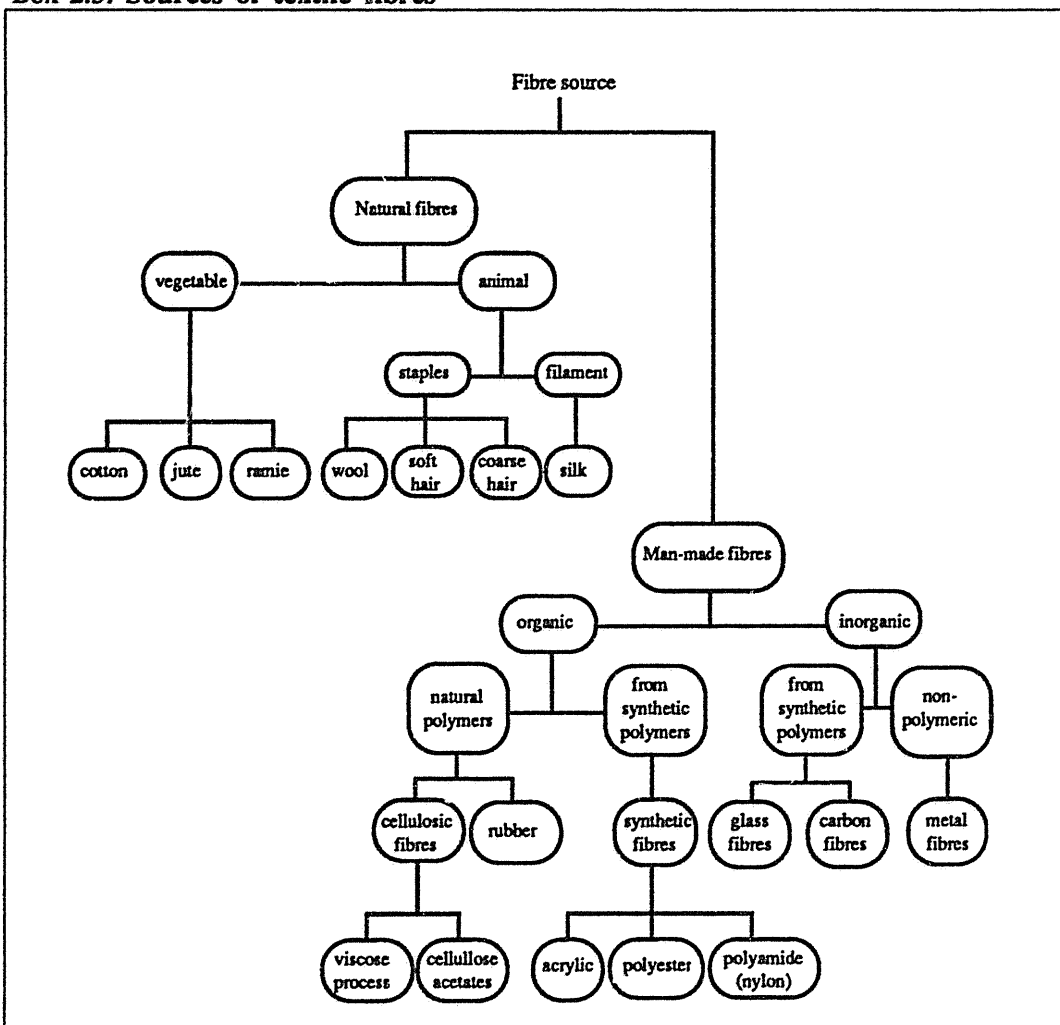


Source: Griffith, Potter and Corbman (1970, p. 218)

The tops then go through the 'drawing' operation which draws, drafts, twists and winds the stock, making the webs more compact and thinning them into 'slubbings'. The slubbings then go through the 'roving' phase which is a light twisting operation to hold the slubbings intact. Finally, in the spinning operation the wool roving is drawn out and twisted into yarn. Most worsted yarn then goes to the weaving and subsequent phases where it is made into high quality garments. Some worsted yarn is also used for handknitting.

Wool used in the production of woollen yarn goes through less processing and carding of a different kind. The process for the two types of yarns are outlined in Box 2.2. Non-wool fibres used in the production of worsted yarns generally go through similar processing to that outlined above.

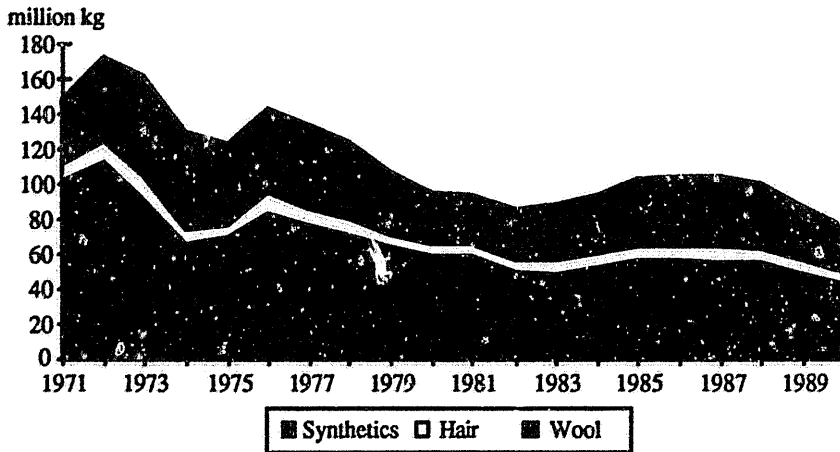
Box 2.3: Sources of textile fibres



Source: Egan (1991)

In producing yarns for fabric production spinners have the ability to choose from a range of fibre types. The basic choice is between natural and man-made fibres. Within natural fibres there are those sourced from vegetables (eg. cotton and jute) and those from animals (eg. wool, hair and silk). Within man-made fibres there are again two broad categories — those from organic and inorganic sources. Organic man-made fibres are in turn made up of those from natural polymers (rubber and cellulosic fibres) and those from synthetic polymers (acrylic, polyester and nylon). The full extent of fibre choice is illustrated in Box 2.3. The principle fibres used in the UK worsted spinning sector are wool, hair and synthetic fibres.

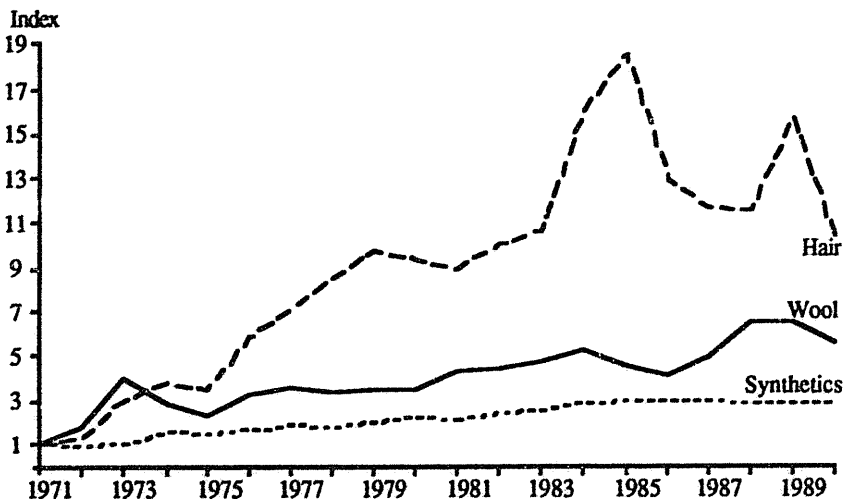
Figure 2.2: Fibre Consumed in the UK Worsted Spinning Sector



Source: Swan Consultants (Canberra) database

The quantity of fibre consumed in drawing tops in the UK worsted spinning sector has steadily declined over the last 20 years (Figure 2.2). From a peak of around 170 million kilograms in 1972, fibre consumed had declined to around 70 million kilograms by 1990. Wool fibre has borne a disproportionate share of the decline going from around 110 million kilograms in 1972 or 65 per cent of total fibre consumption to around 40 million kilograms in 1990 or just over 50 per cent of the total. Furthermore, most of the variation in total fibre consumption has arisen from fluctuations in the quantity of wool used in drawing tops.

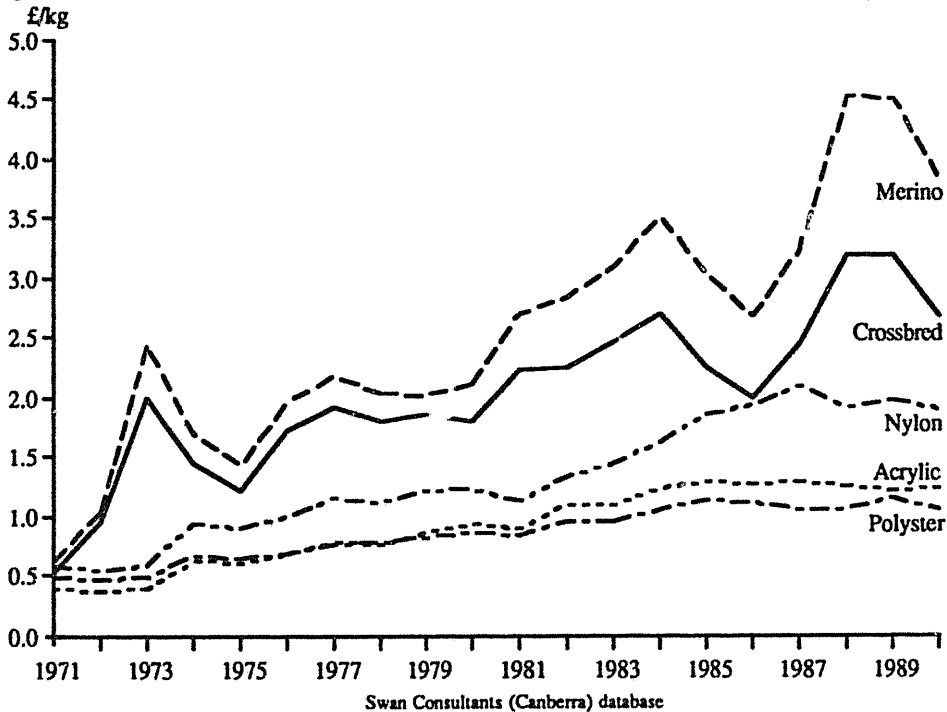
Figure 2.3: United Kingdom Fibre Price Indices



Source: Swan Consultants (Canberra) database

Price indices for the three major fibre types used — wool, hair and synthetics — are presented in Figure 2.3 for the 20 year period 1971 to 1990. Price increases for hair have far outstripped those for the other two fibre categories, increasing 10 fold over the period. Wool prices have increased around 6 fold over the period while synthetics prices have less than tripled. Given the divergences in the rate of increase in fibre prices and the corresponding change in relative fibre prices over the last 20 years, one would expect to see at least some evidence of fibre substitution having occurred.

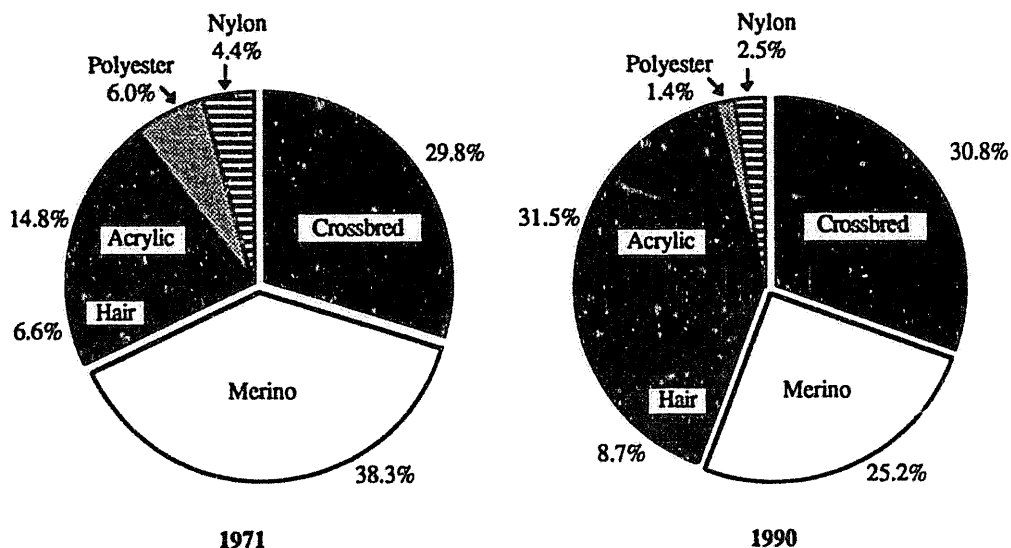
Figure 2.4: UK Wool and Synthetic Fibre Prices (pounds sterling/kg)



Concentrating on the major fibres (wool and synthetics) the divergence in prices is even more striking when considered in terms of pounds sterling per kilogram (Figure 2.4). In 1971 prices for the two wool types and three synthetics were all very close together. By 1973 there had been a dramatic divergence with the two wool prices peaking at levels around four times higher than the three synthetics, before falling back. Since 1975 wool prices have again diverged from the prices of synthetics with the exception of 1986 and 1990 when wool prices fell. Within the

wool category, the price of merino wool has steadily diverged from that of crossbred. The operation of the Reserve Price Scheme has contributed to this in recent years. Within the synthetics category, the prices of acrylic and polyester fibres have moved in unison and shown the least increase over the period while nylon fibre prices have increased relative to them.

Figure 2.5: UK Worsted Spinning Sector — Fibre Volume Shares for 1971 and 1990



Source: Swan Consultants (Canberra) database

Fibre volume shares for 1971 and 1990 are presented in Figure 2.5. There have been major changes not only in the split between wool and synthetics but also within each of these categories. Acrylic has been the major gainer over this period while merino wool has been the major loser. The volume share of hair has remained relatively small but increased marginally while polyester and nylon have become relatively unimportant. Acrylic's share, on the other hand, has more than doubled to now be over 30 per cent while merino wool's share has fallen considerably to now account for only a quarter of fibre volume. Crossbred wool's share has remained relatively constant at around 30 per cent. What is likely to have happened over this period, based on observation of relative price changes, is that both merino and crossbred wool have lost volume share to acrylic but crossbred wool has been able to regain some share at the expense of merino wool. In the following sections of the paper the process of fibre substitution is examined using econometric models.

3. Previous Studies

A number of studies have examined fibre substitution at various stages of the garment-making process over the last decade. Zeitsch (1979) estimated a model of wool/synthetic fibre substitution in the United Kingdom worsted spinning sector. The model specified was consistent with a multi-stage decision-making process in which the producer first minimised the cost of combining fibres with other inputs. Then, given the level of aggregate fibre demand determined at the first level, the cost of combining wool and synthetic fibres is minimised. The model was estimated using half-yearly data covering the period 1960 to 1970. The results indicated that wool and synthetic fibres were good substitutes over the data period with an estimated elasticity of substitution of around 4. The results also indicated that spinners took approximately one year to fully adjust to a change in fibre prices. The International Wool Secretariat's main marketing program, 'Woolmark', was found to have significantly shifted the demand for wool. The 'Woolmark' program was estimated to have a benefit/cost ratio in excess of 5 for Australian woolgrowers. There were few earlier studies of the competition between wool and synthetics due to the perceived 'non-price' nature of much of this competition, data problems due to changing quality of synthetic fibres over time and the absence of continuous data series.

Veldhuizen and Richardson (1984) also used total mill consumption data to analyse price competition between wool and synthetics at the yarn production stage. They estimated various lag structures using reduced form single equation estimation to derive factor demands for Japan, Italy and West Germany. They found that the price of wool relative to the price of synthetics was a significant determinant of wool demand but elasticities were generally inelastic, even in the long-run.

A systems approach to estimating the derived demand for different fibres was first applied by Dewbre, Vlastuin, and Ridley (1986). A two-stage estimation process was used where aggregate demand for apparel fibre was determined in the first stage as a function of the demand for final apparel products. Aggregate apparel fibre demand was allocated between the fibres wool, cotton and synthetics in the second stage of estimation. The model was estimated using data for the 8 major OECD wool-consuming countries and was based on cost-minimising behaviour. Wool, cotton and synthetic fibres were each found to have own-price elasticities of around -0.2 in the medium term. Cross elasticities between fibre types were even smaller in the medium term indicating relatively little scope for substitution.

Harris (1988) applied duality theory using a translog cost function to analyse the US demand for raw materials used in the domestic production of apparel goods. Using the assumption of weak separability, demand for apparel fibres was divided into two sub-models. Fibre demand was first allocated between natural fibres and cellulosic and non-cellulosic fibres. Demand for natural fibres was then allocated between wool and cotton. This model was extended by Ball, Beare and Harris (1989) who introduced dynamics by use of a 'partial adjustment translog' model. This model imposed the same rate of adjustment across the demand for all fibres. Adjustment of fibre demand was found to be relatively slow with only around half the adjustment having taken place after five years. In the long-run own-price elasticities of demand for cotton, wool, polyester and rayon were found to lie in the range of -0.6 to -0.9 . Greater scope for substitution between fibre types was found to exist in the long-run than had been found in most earlier studies. The demand for wool was found to be significantly influenced by the prices of cotton and polyester.

Short and Beare (1990) applied the Almost Ideal Demand System to household survey data collected in the United States to consider substitution between fibres across several different end uses. Substitution between wool, cotton and synthetic fibres was examined at the retail level. For men's apparel, fibre demand was estimated for jackets, coats, suits and knitwear. For women's apparel, fibre demand was estimated for skirts, jackets, pants-suits and knitwear. The own-price elasticity estimates obtained for wool were generally price elastic, and the magnitude of the cross-price elasticities indicated there was significant competition between fibres. The retail elasticities obtained from this study were considerably higher than the corresponding raw fibre elasticities obtained in previous studies. This result suggested that changes in fibre blends could be a significant source of fibre competition. The study also concluded that distortions in the relative prices of apparel made from different fibres would have substantial impacts on fibre consumption patterns. Results presented by Short and Beare, however, were only for retail demand elasticities and not the derived demand elasticities for wool fibre which could only be obtained through further manipulation of their results.

4. The Generalised McFadden Cost Function Model

Duality theory and the cost function provide a convenient and flexible framework for examining the responsiveness of the UK Worsted Spinning Sector to changes in fibre prices. While there are functional forms of the production function which are sufficiently flexible to allow elasticities of substitution to vary, there are several advantages in using a dual cost function

approach to derive estimates of production parameters. Cost functions are linear homogeneous in prices, regardless of the homogeneity properties of the production function, and the estimation equations have prices as independent variables instead of factor quantities, which more closely approximates the situation faced by individual firms.

Denoting the N input quantities by the vector x , input prices by the vector $p \gg 0$, output by y , and the firm's production function by $y = f(x)$, then the producer's cost function can be represented as the solution to the following constrained minimisation problem;

$$(4.1) \quad C(p; y) = \min_x (p^T x : f(x) \geq y, x \geq 0_N)$$

With numerous producers each having no control over the prices they pay for inputs, spinning sector input demand is well modelled by the cost function framework where producers vary their input usage each period to minimise the cost of producing a given amount of output.

The cost function (1) will be linearly homogeneous, increasing and concave in input prices p . If the cost function is also differentiable with respect to p then the input demand functions can be derived by applying Shephard's (1953) Lemma:

$$(4.2) \quad x_i(p; y) = \partial C(p; y) / \partial p_i$$

The main focus of this study is on fibre substitution within the UK Worsted Spinning Sector. A system of demand equations is estimated for 6 fibres (crossbred wool, merino wool, hair, acrylic, polyester and nylon) using annual data for the 20 year period 1971 to 1990. Aggregate fibre usage is assumed to be 'Leontief' with other inputs such as labour, capital and materials. This means that fibre usage moves in fixed proportions to the output of the worsted spinning sector. To conserve degrees of freedom, constant returns to scale with respect to aggregate fibre usage are imposed. This facilitates estimation of a unit cost function where costs are minimised per unit of aggregate fibre consumed.

Desirable characteristics of a functional form for the cost function are that it be flexible (able to provide a second-order approximation to an arbitrary twice continuously differentiable profit function), parsimonious (have the minimal number of free parameters required for flexibility), and consistent with the required theoretical properties of a cost function. While the translog and Generalised Leontief forms have become popular because of their flexibility and relative ease of implementation, they often suffer in empirical applications from failure to satisfy the required curvature properties at all (or any) of the observation points. In response to this problem, recent developments in functional forms have led to the development of functions which are flexible

and easily verified as satisfying curvature conditions globally. If the curvature conditions are not satisfied they can be imposed with minimal cost to flexibility properties although non-linear regression techniques then have to be used.

The functional form used for the cost function is the Generalised McFadden (GM) developed by Diewert and Wales (1987). The GM function is superior to earlier flexible forms such as the translog in that curvature conditions can be imposed on the model without loss of flexibility. Empirical implementations of the GM form and the derivative Symmetric GM form in the international trade context can be found in Diewert and Morrison (1986) and Lawrence (1987, 1989, 1990a, 1990c). The GM function has been applied to Australian agriculture by Lawrence and Zeitsch (1989, 1990) and Lawrence (1990b).

The 6 input GM unit cost function is given by:

$$(4.3) \quad C(p; y) / y = \frac{1}{2} \sum_{i=1}^5 \sum_{j=1}^5 b_{ij} p_i p_j / p_6 + \sum_{i=1}^6 b_i p_i + \sum_{i=1}^6 b_{it} p_i t + b_u (\sum_{i=1}^6 \gamma_i p_i) t^2$$

where the b_{ij} parameters are estimated subject to the following symmetry restrictions;

$$(4.4) \quad b_{ij} = b_{ji} \quad \text{for all } i, j = 1, \dots, 5;$$

t is an index of technology and the γ_i are exogenous constants set equal to the respective mean unit input quantities to conserve degrees of freedom.

By applying Shephard's Lemma the following set of unit input demand equations is obtained:

$$(4.5) \quad x_i / y = b_i + \sum_{j=1}^5 b_{ij} p_j / p_6 + p_{it} + b_u \gamma_i t^2; i = 1, \dots, 5;$$

$$(4.6) \quad x_6 / y = b_6 - \frac{1}{2} \sum_{i=1}^5 \sum_{j=1}^5 b_{ij} p_i p_j / p_6^2 + b_{6t} t + b_u \gamma_6 t^2$$

The estimating system consists of equations (4.5) and (4.6) with vectors of error terms attached and assumed to be independently distributed with a multivariate normal distribution with zero means and covariance matrix Ω . The cost function (4.3) is excluded from estimation as it adds no additional information.

A limitation of applied duality theory models in the past has been the failure of many models to satisfy the necessary curvature conditions. Jorgenson and Fraumeni (1981) attempted to overcome this problem by imposing semi-definiteness conditions on the matrix of second-order coefficients from translog functions. However, this procedure can introduce large biases in the estimated elasticities and hence destroys the constrained translog's flexibility (Diewert and Wales 1987). In the GM case, if the matrix of estimated quadratic terms $B = [b_{ij}]$ is negative semi-definite then the cost function is globally concave in prices. If B is not negative semi-

definite then it can be reparameterised using the Wiley, Schmidt and Bramble (1973) technique of replacing B by minus the product of a lower triangular matrix and its transpose:

$$(4.7) \quad B = -AA^T \quad \text{where } A = [a_{ij}]; \quad i, j = 1, \dots, 6; \quad \text{and } a_{ij} = 0 \text{ for } i < j.$$

The GM function will then be globally concave in prices without having lost its flexibility properties (Diewert and Wales 1987). The cost of this procedure is that computer-intensive non-linear regression techniques have to be used.

The Allen-Uzawa elasticities of substitution between inputs i and j (σ_{ij}) can be derived from the first and second partial derivatives of the cost function with respect to the i 'th and j 'th input prices as follows:

$$(4.8) \quad \sigma_{ij} = C_{ij} / C_i \cdot C_j$$

where subscripts on C refer to partial derivatives. Diewert (1974, p. 114) aptly describes the elasticity of substitution σ_{ij} as "a normalization of the response of input i to a change in the price on input j , $\partial X_i / \partial W_j$, where the normalization is chosen so that $\sigma_{ij} = \sigma_{ji}$ and so that σ_{ij} is invariant to changes in the scale of measurement of the inputs".

Conventional fibre demand elasticities are also derived. For the cost function these elasticities represent the change in the demand for fibre i with respect to a change in the price of fibre j subject to the aggregate quantity of fibre consumed remaining constant. They are given by:

$$(4.9) \quad \eta_{ij} = d \ln x_i / d \ln p_j = C_{ij} \cdot p_j / x_i; \quad i, j = 1, \dots, 6;$$

where C_{ij} is the second-order price derivative of the cost function and x_i is the estimated unit fibre quantity obtained from equations (4.5) and (4.6).

The relationship between the Allen-Uzawa substitution elasticities and the conventional demand elasticities is as follows:

$$(4.10) \quad \eta_{ij} = s_j \sigma_{ij} \quad \text{for all } i, j$$

where s_j is the share of fibre j in total fibre cost.

In the GM case, the second-order price derivatives are given by:

$$(4.11) \quad C_{ij} = b_{ij} / p_6 \quad \text{for } i, j = 1, \dots, 5;$$

$$(4.12) \quad C_{i6} = - \sum_{j=1}^5 b_{ij} p_j / p_6^2 = C_{6i} \quad \text{for } i = 1, \dots, 5; \text{ and}$$

$$(4.13) \quad C_{66} = \sum_{j=1}^5 \sum_{i=1}^5 b_{ij} p_i p_j / p_6^3$$

5. Results

Initial estimation of the system of input demand equations ((4.5) and (4.6) subject to (4.4)) produced estimates which failed to satisfy the concavity in prices property with one of the eigenvalues of the matrix $B = [b_{ij}]$ being positive. One of the estimated own-price elasticities from this system was also positive. Subsequent estimation of the system was undertaken imposing negative semi-definiteness on the B matrix using equation (4.7). The Davidson-Fletcher-Powell non-linear regression algorithm of the SHAZAM package (White, et al. 1990) was used with starting values set equal to the mean of the dependent variable for the constant terms and zero for all other coefficients. The constrained system estimates are presented in Table 5.1. The elasticities obtained from the constrained estimates were only marginally different from those obtained from the unconstrained system, with the exception of the own-price elasticity for hair which becomes negative with the imposition of the curvature conditions.

Table 5.1: Estimated Unit Fibre Demand Equations¹

Equation i	Coefficient								
	Constant		Second order price terms (non-linear)					Technology terms	
	b_i	a_{i1}	a_{i2}	a_{i3}	a_{i4}	a_{i5}	b_{it}	b_{iu}	
Crossbred	0.304 (13.26)	0.356 (5.04)	-0.275 (-3.87)	-0.014 (-1.42)	-0.009 (-0.16)	-0.024 (-0.68)	0.004 (2.75)	-0.004 (-10.24)	
Merino	0.414 (15.61)		-0.124 (-5.51)	0.026 (3.45)	0.141 (3.68)	0.120 (4.79)	-0.002 (-1.19)	-0.004 (-10.24)	
Hair	0.073 (21.58)			0.015 (1.79)	-0.173 (-2.53)	-0.026 (-0.36)	0.003 (9.17)	-0.004 (-10.24)	
Acrylic	0.186 (7.56)		Symmetric		0.056 (0.35)	-0.070 (-0.46)	0.009 (6.52)	-0.004 (-10.24)	
Polyester	0.100 (5.67)					-0.000 (-0.00)	-0.003 (-3.72)	-0.004 (-10.24)	
Nylon	0.032 (2.48)						-0.000 (-0.01)	-0.004 (-10.24)	
System log likelihood			400.49						

¹ t-statistics in parentheses

The mean Allen-Uzawa elasticities of fibre substitution are presented in Table 5.2. The greatest scope for substitution is shown to exist between the three synthetic fibre categories. Nylon is found to be highly substitutable with both polyester and acrylic while polyester is found to be complementary with acrylic. Nylon is found to be relatively substitutable with crossbred wool but complementary with merino. Polyester, on the other hand, is relatively substitutable with both wool types. The major synthetic, acrylic, is only moderately substitutable with the two wool categories.

Crossbred and merino wool are found to be relatively substitutable with each other. Policy-induced relative price distortions between the two wool types are, therefore, likely to have had a significant impact on the composition of the spinning sector's wool demand. Hair fibre demand is found to be virtually unrelated to merino, acrylic and nylon demand but is moderately substitutable with crossbred and relatively complementary with polyester.

Table 5.2: Mean Elasticities of Fibre Substitution for the UK Worsted Spinning Sector — 1971 to 1990

	Merino	Hair	Acrylic	Polyester	Nylon
Crossbred	1.622	0.344	0.102	1.373	2.482
Merino		-0.029	0.350	1.208	-2.457
Hair			-0.126	-1.671	-0.077
Acrylic				-3.913	7.000
Polyester					17.687

The mean conventional input demand elasticities are presented in Table 5.3. The relative magnitudes of the conventional elasticities differ significantly from the Allen-Uzawa elasticities discussed above. This is due to the fact that three of the fibres (hair, polyester and nylon) have very small shares in total fibre consumption whereas the two wool types and acrylic are each relatively large. The conventional elasticities thus give an indication of actual substitution effects arising from relative price changes whereas the Allen-Uzawa elasticities have been normalised to be scale-invariant and thus give an indication of the in-principle substitution possibilities.

The own-price elasticities for crossbred and merino wools are around -0.8 and -0.4 , respectively. This implies that a 10 per cent fall in the relative price of crossbred wool would lead to an 8 per cent increase in the demand for crossbred wool by the spinning sector while a similar fall in the relative price of merino wool would lead to a 4 per cent increase in demand. The substitutability between the two wool types means, however, that some of the increased demand for wool comes at the expense of the other wool type. For instance, the 10 per cent fall in the relative price of crossbred wool leads to a 4.5 per cent fall in the demand for merino wool as well as the 8 per cent increase in the demand for crossbred. Demand for both crossbred and merino wool is relatively unaffected by changes in the prices of the other four fibres. However, decreases in wool prices would significantly reduce the demand for some synthetics. The 10 per cent decrease in the relative price of crossbred wool would, for instance, reduce nylon and polyester consumption by 7 and 4 per cent, respectively.

Table 5.3: Mean Fibre Input Demand Elasticities for the UK Worsted Spinning Sector — 1971 to 1990

		With respect to price of:					
		Crossbred	Merino	Hair	Acrylic	Polyester	Nylon
Change in Quantity of:	Crossbred	-0.762	0.603	0.058	0.011	0.022	0.067
	Merino	0.455	-0.441	-0.005	0.040	0.017	-0.066
	Hair	0.097	-0.011	-0.044	-0.014	-0.027	-0.001
	Acrylic	0.028	0.128	-0.020	-0.254	-0.068	0.187
	Polyester	0.360	0.380	-0.309	-0.457	-0.392	0.419
	Nylon	0.657	-0.932	0.040	0.841	0.250	-0.856

The demand for hair fibres is extremely inelastic with an own-price elasticity of demand of less than 0.1 in absolute value. All the cross elasticities between hair and the other fibres are also near zero (with the exception of the response of polyester to a change in the price of hair where some degree of complementarity exists). This appears to indicate that hair is almost used in fixed proportion to aggregate spinning sector fibre consumption.

The demand for nylon is relatively price responsive with an own-price elasticity of -0.9 . A 10 per cent increase in the price of nylon would reduce nylon demand by 9 per cent while increasing the demand for polyester and acrylic by 4 per cent and 2 per cent, respectively. It would have a negligible impact on the demand for the natural fibres. The major synthetic, acrylic, is less price responsive with an own-price elasticity of around -0.3 . A 10 per cent increase in the price of acrylic would reduce acrylic consumption by 3 per cent and reduce polyester consumption by 5 per cent while increasing nylon consumption by 8 per cent. It would also have a negligible impact on the consumption of natural fibres. Polyester demand is moderately price responsive with an own-price elasticity of -0.4 . A 10 per cent increase in the relative price of polyester would increase nylon consumption by around 3 per cent but have little impact on the other fibres.

The main picture to emerge from these results is that the major fibre substitution possibilities exist between crossbred and merino wools and between the three synthetic fibre types. All other inter-fibre group effects are quite small with the exception of the effects of wool price changes on the consumption of the minor synthetics, polyester and nylon. The demand for both wool types remains relatively unaffected by a change in the relative price of hair or any of the three synthetics.

6. Imperfect Adjustment

The response of fibre demand to relative price changes can often take a long time to work its way through the system and be felt in terms of changed demand for woolgrowers' output. The process of fibre substitution is inherently dynamic and the existence of adjustment costs mean that the response to changes in relative prices is likely to be spread out over a number of years. However, the cost function model of the preceding section and most previous studies of fibre demand assume there is instantaneous or full adjustment within the current observation period. Studies that have attempted to allow for slow adjustment have usually done so by incorporating ad hoc lag structures on prices. In the case of the six fibre model reported in the preceding sections, all adjustment is assumed to have been completed within one year.

Ball, Beare and Harris (1989) introduced dynamics into the study of fibre demand in a more systematic way than earlier studies. They found substantial differences in magnitude between long-run and short-run demand elasticities with only around half the adjustment having occurred after five years. However, their study used an ad hoc 'partial adjustment translog' approach which has the disadvantage of imposing the same rate of adjustment across the

demand for all fibres. It would be preferable to have a dynamic model which allows different rates of adjustment for different fibres as the constraints on adjusting fibre consumption are likely to differ between fibre types.

The question of how long it takes fibre demand to respond to a change in relative prices has assumed a new importance with the demise of the wool Reserve Price Scheme. How long it will take for the increased demand for wool following the substantial reductions in auction prices to be fully taken up will have important implications for growers' incomes and the disposal of the wool stockpile. To help shed light on these dynamic processes a planning price model of demand in the UK worsted spinning sector is reported in this section.

6.1 The Planning Price Approach

An approach to modelling imperfect adjustment which has received little attention is the use of "planning prices" as developed by Woodland (1976, 1977) and applied by Lawrence (1987). Under this approach producers do not adjust fully to current prices within the observation period. Instead they adjust fully within the period to planning prices which in turn adjust gradually to actual prices. This behaviour may be interpreted in one of two ways. First, firms may have to commit themselves to input decisions before current prices are known or, even if current prices are known, the firm may wish to wait and see if price changes are permanent before fully adjusting to a new current price. This may be likened to a partial adjustment process whereby producers adjust only part-way towards a new price in the current period depending on their expectations of future price movements. Either way, planning prices will adjust to actual prices only gradually.

An alternative interpretation is that the use of planning prices is a dual representation of a quantity adjustment path. For instance, if input prices change to a new level and then remain at that level then producers faced with adjustment costs and quasi-fixed inputs will gradually change their input mix to approach the new optimal quantities if the adjustment path is stable. Thus, it may not be possible or profitable to fully adjust inputs such as capital, particularly that in the form of buildings, in the current period. Rather, capital would be increased towards its new optimal level over a number of periods. If producers are technically efficient then the quantity adjustment path will follow the boundary of the transformation frontier. However, corresponding to each point on the boundary of the transformation frontier there will be a normal vector of prices for which that quantity decision is optimal. Hence, a planning price path

which approaches the new price vector will be a dual representation of, and observationally equivalent to, an optimal adjustment path.

The planning price approach has the advantage, over early attempts to model quantity adjustment paths, of automatically ensuring technical efficiency at each point. It has the disadvantage that an adjustment relationship of planning to actual prices must be specified to make the approach operational. This introduces a degree of arbitrariness.

In this application the following adaptive price adjustment model is used.

$$(6.1) \quad q_{it} - q_{i,t-1} = \lambda_i (p_{it} - q_{i,t-1})$$

where the q_{it} are planning prices and p_{it} actual prices. If $\lambda_i = 1$ then adjustment of planning to actual prices is instantaneous. For the adjustment process to be stable the adjustment parameters λ_i must lie in the interval (0, 2). If λ_i is in the range (0, 1) then adjustment to the new price is monotonic while it is cyclical if λ_i is in the range (1, 2). To make this mechanism implementable the following version is estimated:

$$(6.2) \quad q_{it} = \lambda_i \sum_{j=0}^{t-1} (1 - \lambda_i)^j p_{i,t-j} + (1 - \lambda_i)^t q_{i0}$$

where the base period planning price q_{i0} is treated as a parameter and estimated along with the adjustment coefficient λ_i . Embedding this price relationship within a standard functional form for the cost function means that non-linear regression techniques must be used. The Davidson-Fletcher-Powell non-linear algorithm in the SHAZAM package was again used.

The planning price model estimated uses a unit Generalised Leontief cost function. Given the computational complexity of the estimation procedure, use of the Generalised McFadden form would be prohibitive. Although the number of parameters to be estimated is only increased by two for each price term, if there are 20 observations there are now around 20 highly non-linear components within each planning price. A functional form which is sparing in its use of price terms is thus required. The translog form is not suited to the planning price procedure because the dependent variables of the share equations contain the planning price terms which are not known before estimation.

Estimation of a six fibre input demand system analogous to that of the preceding section is also computationally prohibitive. Consequently, the three major fibres (crossbred and merino wools and acrylic) were included in the planning price model estimated. Constant returns to scale were imposed with respect to the aggregate consumption of these fibres. The three minor fibres (hair, polyester and nylon) were assumed to enter in fixed proportions to output.

The 3 fibre unit Generalised Leontief cost function is given by:

$$(6.3) \quad C(p, y) / y = \sum_{i=1}^3 \sum_{j=1}^3 b_{ij} q_i^{\frac{1}{2}} q_j^{\frac{1}{2}} + \sum_{i=1}^3 b_{ii} q_i t + \sum_{i=1}^3 b_{in} q_i t^2$$

where time subscripts have been deleted, y is the aggregate consumption of wool and acrylic fibres and the q_i are planning prices as given by (6.2). The parameters b_{ij} satisfy the following symmetry restriction:

$$(6.4) \quad b_{ij} = b_{ji} \quad \text{for all } i, j = 1, 2, 3.$$

The fibre demand equations derived from (6.3) by differentiating with respect to prices are:

$$(6.5) \quad x_i / y = \sum_{j=1}^3 b_{ij} (q_j / q_i)^{\frac{1}{2}} + b_{ii} t + b_{in} t^2 ; i = 1, 2, 3.$$

The estimating system thus consists of (6.5) subject to (6.4) where the planning prices are given by (6.2). The parameters of the net output supply equations (b_{ij} , b_{ii} and b_{in}), the planning price adjustment coefficients (λ_i) and the base period planning prices (q_{i0}) are all chosen simultaneously to maximise the concentrated likelihood function of (6.5).

Estimation of this model enables tests to be carried out of the validity of the instantaneous adjustment model normally used by testing whether $\lambda_i = 1$ for $i = 1, 2, 3$. The relationship between planning and actual prices, and instantaneous and imperfect quantity adjustment paths, will be plotted by tracking the effects of simulated price changes.

6.2 Results

The maximum likelihood parameter estimates for the Generalised Leontief models using both actual prices and planning prices are presented in Table 6.1. Both estimated cost functions are positive at all observation points and satisfy the curvature requirements of being concave in prices at all observation points. The gradients with respect to prices have the correct signs and so both estimated cost functions are well behaved. The non-linear model was estimated using the linear estimates of the instantaneous adjustment model as starting values for the price and technology parameters in the planning price model along with values of 0.8 and 1.0 for the adjustment coefficients and base period planning prices, respectively.

Table 6.1: Estimated Actual and Planning Price Model Equations

Coefficient ¹	Instantaneous Adjustment Model		Planning Price Model	
	Estimate	t-statistic	Estimate	t-statistic
b_{XX}	-0.147	-0.45	-0.592	-5.20
b_{XM}	0.374	1.15	1.090	7.61
b_{XA}	0.087	1.39	-0.410	-7.48
b_{Xt}	0.011	2.31	0.245	5.38
b_{Xtt}	-0.000	-1.35	-0.077	-3.02
b_{MM}	0.236	0.69	-0.617	-3.12
b_{MA}	-0.075	-0.96	0.405	5.17
b_{Mt}	-0.010	-1.57	-0.398	-6.92
b_{Mtt}	0.000	0.44	0.118	3.95
b_{AA}	0.145	2.32	-0.001	-0.01
b_{At}	0.012	1.73	0.334	6.20
b_{Att}	-0.000	-0.43	-0.098	-4.19
λ_X			0.186	41.56
λ_M			0.328	19.94
λ_A			0.380	14.93
q_{XO}			0.144	1.87
q_{MO}			1.129	8.51
q_{AO}			3.458	15.24
System log likelihood		162.02		195.74

¹ The subscripts X, M and A refer to crossbred wool, merino wool and acrylic, respectively.

The first result of interest to be examined is whether the two models are significantly different; ie., are the adjustment coefficients in the planning price model significantly different from 1.0 indicating that imperfect adjustment is of importance? The hypothesis that all adjustment coefficients are equal to unity (subject to the base period planning prices being unrestricted) may be tested by use of the likelihood ratio test. The test statistic has a value of 67.44 (twice the difference between the two log likelihood values) compared to a 1 per cent critical Chi-square value of 11.34 with 3 degrees of freedom. Consequently, the hypothesis of instantaneous adjustment is strongly rejected by the model. This indicates that it is important to allow for imperfect adjustment when modelling fibre substitution and fibre demand response. This result is not unexpected but it remains to establish whether the planning price model provides reasonable estimates of the imperfect adjustment process.

As the base period planning prices are estimated in this model, examination of the estimated base period values and the relationship between actual prices and the estimated planning price series provides one method of checking the reasonableness of the model. In the estimated model the base period planning price refers to the planning price for the year 1970. While the complete data set was only available from 1971 onwards it is reasonable to assume that the actual prices prevailing in 1970 would be close to the 1971 price index values of 1.0. The base period planning price estimated for merino wool is around 1.1 which is close to what might be expected. The estimated initial prices for crossbred wool and acrylic fibre, however, appear less reasonable with values of around 0.1 and 3.5, respectively. The high value for acrylic fibre is particularly implausible.

Comparisons of the actual price and estimated planning price series for the observation period tend to confirm these impressions. The planning price series for merino wool closely follows the actual price series, ranging from 1.08 to 6.19 compared to the actual price range of 1.00 to 6.21. Crossbred wool planning prices also follow but lag further behind actual prices, ranging from 0.30 to 4.89 compared to the actual price range of 1.00 to 5.20. Acrylic fibre planning prices, however, track actual acrylic prices less well, being considerably higher than actual prices for the first half of the period. These comparisons would appear to indicate that less reliance can be placed on the model's results with regard to acrylic fibre than its predictions for both merino and crossbred wool.

The parameter estimates of most interest in the model are those of the planning price adjustment coefficients. Using one interpretation, these parameters indicate how quickly planning prices change when there is a change in the actual price. The three parameters all lie in the range (0, 2)

required for stability of the adjustment process. Furthermore, they all lie in the range (0, 1) indicating that adjustment in all three cases is monotonic rather than cyclical. All three adjustment coefficients are relatively low indicating that it takes considerable time for adjustment to a relative price change to work its way through the system. The demand for crossbred wool is the slowest to adjust with an estimated adjustment coefficient of around 0.2. Starting from a position of long run equilibrium where the initial actual and planning prices are equal, a decrease in the actual price of crossbred wool of 10 per cent would lead to a decrease in the planning price of 2 per cent in the first period. The adjustment of the planning prices to the actual price changes under these conditions is graphed in Figure 6.1. In the case of crossbred wool the planning price approaches the new actual price relatively slowly. After 3 years 46 per cent of adjustment has taken place and after 5 years 65 per cent of the process is complete.

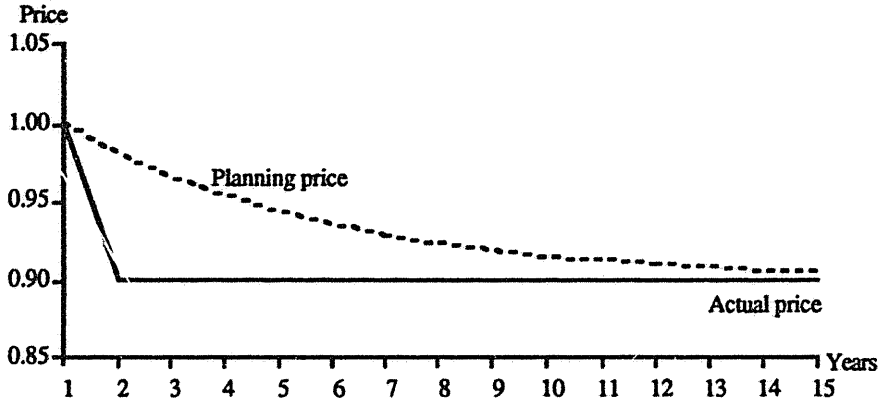
In the case of merino wool the estimated adjustment coefficient is around 0.3. The planning price would decrease 3.3 per cent in the first year in response to a 10 per cent decrease in the actual price of merino wool. The time elapsed between the initial price increase and the effective adjustment of the merino wool planning price is around 10 years.

The acrylic fibre planning price adjusts the most quickly to a change in its actual price with an estimated adjustment coefficient of around 0.4. The planning price adjusts 3.8 per cent in the first year in response to a 10 per cent decrease in the actual price of acrylic. After 3 years three quarters of the adjustment has occurred with the process effectively being completed after about 8 years.

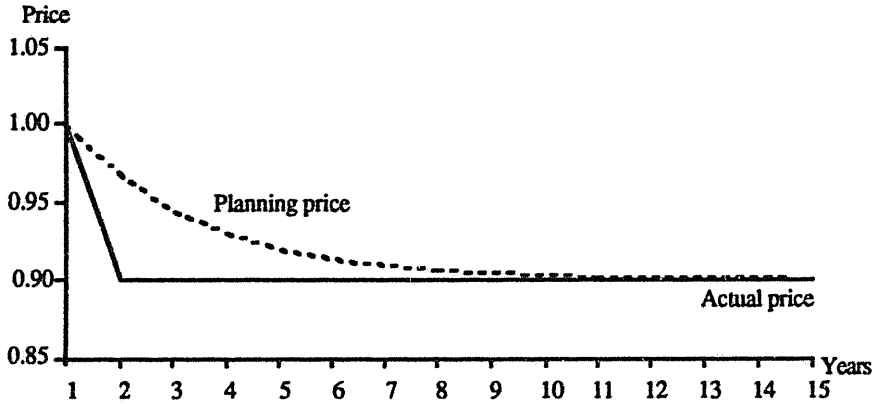
The alternative interpretation of the model is that the planning prices are simply part of the dual representation of a quantity adjustment path. The adjustment path will depend on the initial prices, the magnitude of the price changes and the characteristics of the cost function. Within this context it is difficult to interpret the individual adjustment coefficients directly in terms of their implications for the quantity adjustment paths. To gain a better understanding of the quantity adjustment process a series of simulations were carried out. The price of each net output was in turn assumed to decrease by 10 per cent and then remain at this lower level. The effects of these price changes on fibre demand were simulated subject to the technology level existing in 1980 and a constant level of output. The results of these simulations are presented in Figure 6.2. The quantity adjustment paths are monotonic in each case which follows from the monotonic rather than cyclical adjustment of the three planning prices.

Figure 6.1: Adjustment of planning prices

a) 10 per cent decrease in the price of crossbred wool



b) 10 per cent decrease in the price of merino wool



c) 10 per cent decrease in the price of acrylic fibre

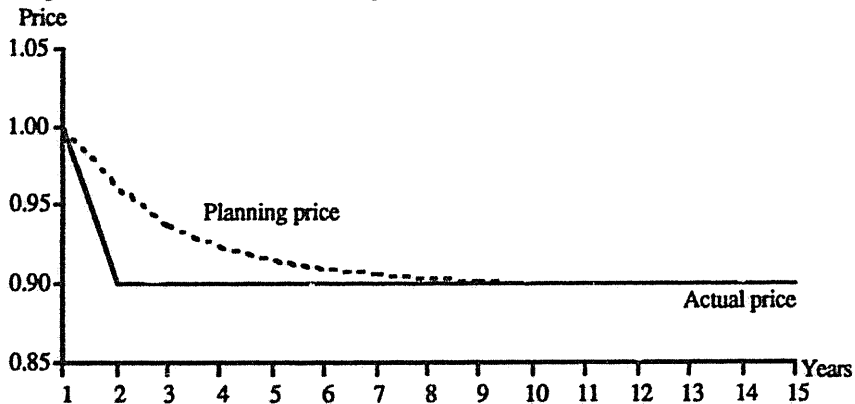
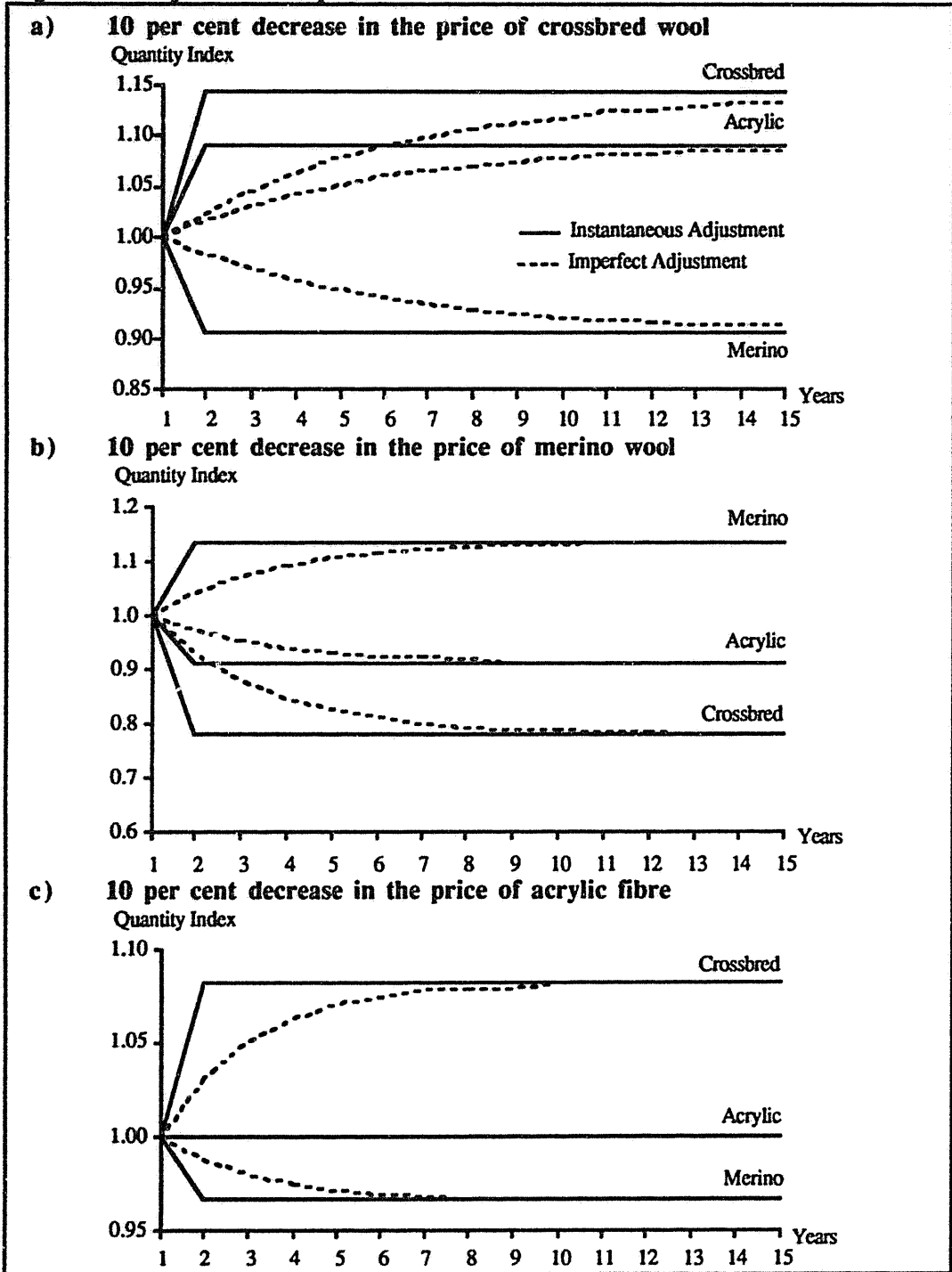


Figure 6.2: Adjustment of quantities



Adjustment of fibre quantities to a 10 per cent decrease in the relative price of crossbred wool is again slow, taking many years to be completed. Demand for crossbred wool increases substantially in the long-run but this takes a number of years to be felt. Acrylic demand also increases eventually while demand for merino wool falls. The reverse occurs in response to a 10 per cent decline in the relative price of merino wool. Demand for merino wool increases substantially while demand for acrylic and crossbred wool both fall. In this case the response to the relative price change occurs more quickly and a large proportion of the response has been completed after 5 years. The response time is quickest to a fall in the relative price of acrylic although this had negligible impact on the demand for acrylic itself. There is, however, some change in the composition of wool demand. These results serve to highlight the fact that it will take several years for the large falls in wool prices following abandonment of the Reserve Price Scheme to be fully translated into increased demand for wool by processors.

Finally, the conventional fibre demand elasticities obtained from the two models are presented in Table 6.2. It should be noted that the instantaneous adjustment model elasticities represent the one period response to a change in actual prices while the planning price model elasticities represent the response to a change in the planning price, not the actual price, and can be interpreted as long-run elasticities. Accordingly, the planning price model own-price elasticities are all substantially larger than the corresponding instantaneous adjustment elasticities because considerably more adjustment is allowed for in the planning price case. In the case of crossbred wool the long-run demand elasticity is around twice the size of the instantaneous adjustment elasticities with a value of -1.1 . The merino wool long-run demand elasticity is around four times the size of the instantaneous adjustment elasticity with a value of -1.5 . Although the long-run acrylic fibre demand elasticity is around twice the magnitude of the equivalent instantaneous adjustment elasticity, both elasticities are very small.

The long-run cross-price elasticities are also considerably larger than their instantaneous adjustment equivalents. The two wool types are considerably more substitutable in the long-run. The relationship between acrylic and the two wool types reverses between the two models. In the instantaneous adjustment model the relationship between acrylic and wool is weak with acrylic being slightly complementary with merino wool. In the long-run, planning price case acrylic is found to be complementary with crossbred wool and to exhibit significant substitutability with merino wool. The results regarding acrylic have to be interpreted with caution given the relatively poor correspondence between planning and actual prices. The pattern and size of elasticities in the instantaneous adjustment model is generally similar to that

obtained in the 6 fibre Generalised McFadden model reported in the preceding sections, although somewhat less responsiveness is found in the three fibre model as more constraints are being placed on the estimation process with the exclusion of the three minor fibres.

Table 6.2: Mean Short-run and Long-run Fibre Input Demand Elasticities for the UK Worsted Spinning Sector — 1971 to 1990

		Instantaneous Adjustment Model		
		With respect to price of		
		Crossbred	Merino	Acrylic
Change in quantity of:	Crossbred	-0.595	0.498	0.097
	Merino	0.408	-0.340	-0.068
	Acrylic	0.196	0.169	-0.028
		Planning Price Model		
		With respect to price of		
		Crossbred	Merino	Acrylic
Change in quantity of:	Crossbred	-1.065	1.538	-0.473
	Merino	1.108	-1.464	0.357
	Acrylic	-0.914	0.958	-0.044

In conclusion, then, while the planning price model requires further refinement, it has served to demonstrate the importance of allowing for imperfect adjustment when modelling fibre substitution and demand response. For both crossbred and merino wool as well as acrylic fibre, adjustment to relative price changes is found to take several years to complete. This finding reinforces the earlier study of Ball, Beare and Harris (1989) who found that after 5 years only around half of the adjustment was complete. Using a far less restrictive model this study has found that after 5 years the amount of adjustment completed ranges from 65 per cent for crossbred wool to 90 per cent for acrylic fibre. These results have important policy implications

for the Australian wool industry. It will take a lengthy period for the effects of the large price reductions following the collapse of the Reserve Price Scheme to work their way through into increased demand for wool by processors.

7. Forecasting Wool's Worsted Market Share

The estimated model provides insights into how movements in relative fibre prices affect fibre demand — given that the total demand for fibre is held constant. However, fibre price movements also affect retail prices which indirectly affects fibre demand via changes in retail demand. These so-called 'expansion' effects need to be taken into account to obtain the complete picture of the effect of fibre price changes on fibre demand.

The effects of substitution possibilities at different levels in the production technology can be incorporated into an aggregate fibre demand price elasticity using the methodology developed by Fuss (1977). The original formula related to a technology with two production stages but was extended to a many level production process by Zeitsch (1987). In the four stage technology illustrated in Figure 7.1, for example, the gross price elasticity for fibres can be calculated using the following formula;

$$(7.1) \quad \xi_{ij} = s_j^p \sigma_{im} + s_j^c \sigma_{ir} + \tau_j \sigma_{mm} + s_j^m \sigma_{ij}$$

where: ξ_{ij} is the gross price elasticity of demand for fibre i with respect to the price of fibre j;

$s_j^p, s_j^c, s_j^r, s_j^m$, are the value shares of fibre j in variable profit, in the cost of cloth, in the cost of yarn and in the cost of fibres, respectively;

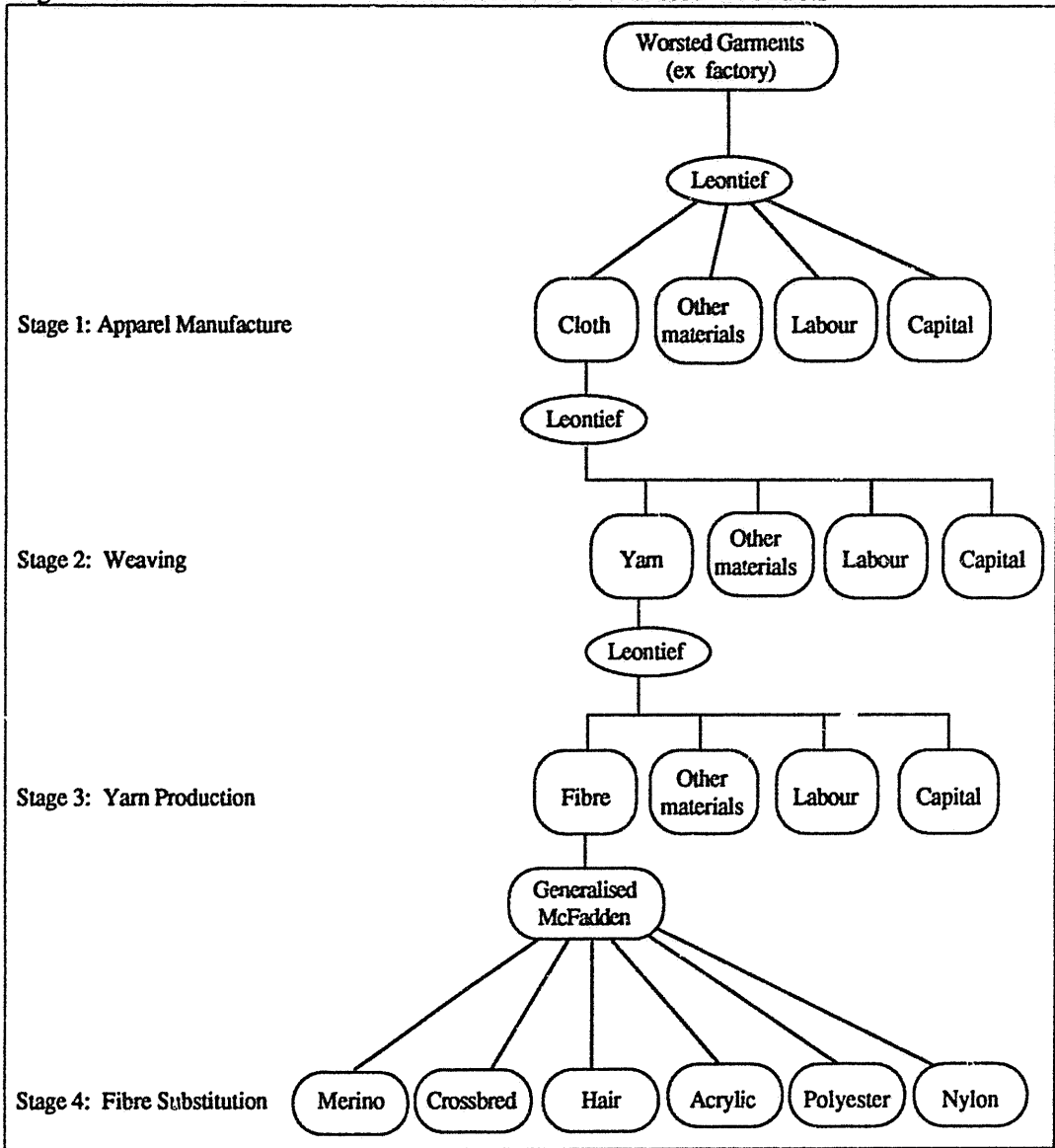
σ_{im} is the Allen-Uzawa own elasticity of substitution for apparel (given total inputs used to make apparel are held constant);

σ_{ir} is the Allen-Uzawa own elasticity of substitution for cloth (given total inputs in cloth manufacture are held constant);

σ_{mm} is the Allen-Uzawa own elasticity of substitution for fibre (given total inputs to yarn production are held constant); and

σ_{ij} is the Allen-Uzawa elasticity of substitution between fibre i and fibre j (given total fibre consumption is held constant).

Figure 7.1: Assumed Production Structure for Worsted Products



If, as depicted in Figure 7.1, there is no substitution between yarn and other inputs at the weaving stage, and if there is no substitution between cloth and other costs at the apparel manufacturing stage, then (7.1) reduces to;

$$(7.2) \quad \xi_{ij} = s_j^x \sigma_{nm} + s_j^m \sigma_{ij}$$

In terms of price elasticities (7.2) can be rewritten as;

$$(7.3) \quad \xi_{ij} = s_j^c \xi_{jm}^E + \eta_{ij}$$

where s_j^c is the share of the j th fibre in total garment costs, ξ_{jm}^E is the ex-factory demand elasticity for apparel and η_{ij} is the compensated price elasticity of demand for fibre i with respect to the price of fibre j .

The first term in (7.3) captures the effect of fibre price movements on the aggregate demand for apparel. The second term picks up the effects of substitution amongst fibres generated by fibre price movements.

The gross fibre demand elasticities calculated using (7.3) are set out in Table 7.1. The compensated fibre demand elasticities used were those derived from the Generalised McFadden cost function model reported in Sections 4 and 5. An own-price elasticity of demand for worsted apparel of -1.07 was used. This is the short-run price elasticity for apparel estimated by Dewbre, Vlastuin and Ridley (1986) for 8 OECD countries including the United Kingdom.

Table 7.1: Gross Price Elasticities of Fibre Demand

		With respect to price of:					
		Crossbred	Merino	Hair	Acrylic	Polyester	Nylon
Change in Quantity of:	Crossbred	-0.78	0.58	0.05	0.00	0.02	0.07
	Merino	0.44	-0.46	-0.01	0.03	0.02	-0.07
	Hair	0.08	-0.03	-0.05	-0.02	-0.03	0.00
	Acrylic	0.01	0.11	-0.03	-0.26	-0.07	0.19
	Polyester	0.35	0.36	-0.32	-0.46	-0.39	0.42
	Nylon	0.64	-0.95	0.03	0.83	0.25	-0.86

These gross price elasticities can be used to calculate the gain in market share which wool is likely to achieve following the abandonment of the wool Reserve Price Scheme in February 1991.

The prices paid by United Kingdom spinners for the 6 fibre types for the first 8 months of 1991 are set out in Table 7.2. After falling by around 40 per cent in March 1991, wool fibre prices rose steadily in subsequent months to be about 25 per cent below levels received under the floor price scheme by August 1991. Over the same period, prices for the major synthetic fibre used in worsted spinning — acrylic — have remained relatively constant. The removal of the wool Reserve Price Scheme has thus led to a fall in the relative price of wool of around 25 per cent. This should allow wool to increase its market share in the United Kingdom Worsted Spinning Sector.

Table 7.2: Fibre Prices Paid by United Kingdom Spinners (pounds sterling/kg) - 1991

Month	Fibre					
	Crossbred	Merino	Hair	Acrylic	Polyester	Nylon
January	2.03	2.86	6.45	1.21	0.97	1.91
February	2.08	2.92	3.82	1.17	0.96	1.7
March	1.31	1.74	2.47	1.29	1.04	2.03
April	1.54	1.91	3.59	1.38	0.99	1.94
May	1.81	2.25	3.49	1.17	1.08	1.9
June	1.93	2.49	2.77	1.29	1.01	2.17
July	na	na	3.47	1.25	0.95	2.25
August	1.9	2.21	3.07	1.17	0.95	2.37

na not available

Source: Australian Wool Corporation and Business and Trade Statistics Ltd.

The fibre price information in Table 7.2 can be combined with the estimated price elasticities in Table 7.1 to forecast what recent fibre price movements imply for wool's market share in the worsted spinning sector. Specifically, the percentage change in fibre shares can be calculated as follows:

$$(7.4) \quad \hat{x}_i = \sum_{k=1}^I \xi_{ik} \hat{p}_k$$

$$(7.5) \quad \hat{x} = \sum_{j=1}^I s_j \hat{x}_j$$

$$(7.6) \quad m\hat{s}_i = \hat{x}_i - \hat{x}$$

where: \hat{x}_i is the percentage change in the demand for fibre i ;

\hat{p}_k is the percentage change in the price of the k th fibre;

\hat{x} is the percentage change in aggregate fibre demand;

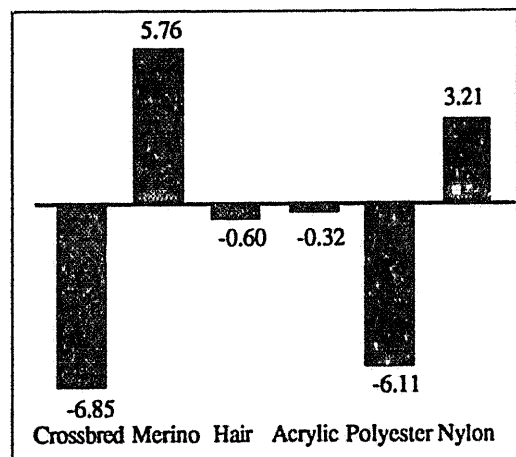
s_j is the value share of the j th fibre in total fibre costs; and

$m\hat{s}_i$ is the percentage change in the volume market share of the i th fibre.

The forecast impact of recent fibre price movements on fibre market shares is shown in Figure 7.2. Merino wool is forecast to increase its market share in the worsted sector by around 6 per cent. However, this gain is largely at the expense of crossbred wool which is simulated to suffer a 7 per cent decline in its market share.

The major policy implications to arise from these calculations are that major fibre substitution takes place between wool of different grades and between the synthetics. However, there is only mild substitution between wool and synthetics. Thus, in the short run the recent major realignments of fibre prices in favour of wool are unlikely to lead to large increases in wool's market share in the worsted sector.

Figure 7.2: Short-run Percentage Change in Fibre Market Volume Shares from Recent Changes in Fibre Prices

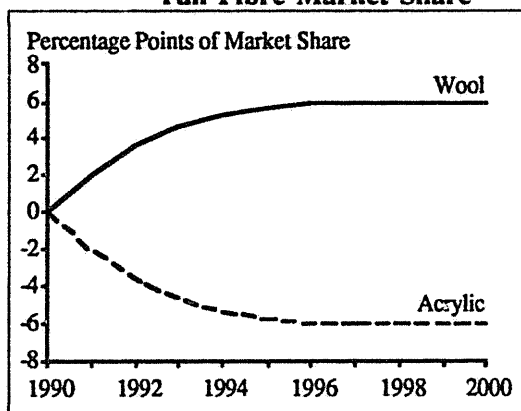


Prospects for a price-induced improvement in wool's market share are brighter in the long-run. According to the results of the planning price model, it takes around 10 years for price movements to have their full effect on fibre demand although a large proportion of adjustment will be completed after around 5 years.

The estimated planning price model was used to calculate the gain in market share wool can expect to achieve in the worsted sector following recent fibre price realignments. If relative fibre prices in August 1991 were maintained for the next 10 years, wool would increase its market share in the worsted sector by over 6 per cent (Figure 7.3). There would, however, be a major reorientation of demand away from crossbred wool towards merino wool.

The gain in wool's market share may seem modest given the size of the price movements which generated it. This is because the demand for wool in aggregate is price inelastic. This may suggest that the Australian wool industry would be better off if it could control the supply of wool entering the market. Recent experience would suggest that there would be severe practical and political problems in successfully running such a scheme.

Figure 7.3: Forecast Change in Long-run Fibre Market Share



APPENDIX 1: DATA SOURCES

To estimate the fibre substitution models, data is required on the price and quantity of each fibre consumed by the UK worsted spinning sector. Annual data for the 20 year period 1971 to 1990 on the actual weight of fibre consumed in the production of tops and noils was obtained from the UK Wool Industry Bureau of Statistics (Confederation of British Wool Textiles Limited, various years). Consistent time-series information is available for three wool, two hair and four man-made fibre categories. The two crossbred wool categories were aggregated to form a total crossbred series as were the mohair and other hair categories to form a total hair series. Information on the consumption of synthetic fibres was available for acrylic, polyester, nylon and other man-made fibres. The other man-made fibres category was combined with the polyester series with which it moved in unison.

The price of crossbred and merino wool fibre was taken to be the Australian auction price plus transport margins converted to pounds Sterling using annual exchange rate data. Annual average Australian auction prices for 23 and 27 micron grade wool were obtained from Australian Wool Corporation (various years) and used as proxies for the price of merino and crossbred wool, respectively. Transport margins between Australia and the UK were approximated by sea freight rates for wool obtained from Gabrys (1991). Exchange rates were obtained from OECD (various years).

Comparable prices of synthetic and hair fibre were obtained from UK import statistics. Standard International Trade Classification (SITC) category 266.5 provides information on "synthetic staple fibres, not carded, combed or otherwise processed for spinning" while the subcategories 266.51, 266.52 and 266.53 provide information on nylon, polyester and acrylic, respectively. Separate information for each of the subcategories was available for the period 1978 to 1990 but only the aggregate of the three was available for the years 1971 to 1977. Prices for the earlier years were estimated by regressing the prices of the three components against the total synthetic price for the years 1978 to 1990 and forecasting the individual prices given the known aggregate price for the earlier period. SITC category 268.3 provides information on "fine animal hair, not carded or combed". The UK import data were obtained from Business and Trade Statistics Limited of Surrey.

REFERENCES

- Australian Wool Corporation (various years), *Wool Market News Annual Price Summary*, Melbourne.
- Ball, K., S. Beare and D. Harris (1989), 'The Dynamics of Fibre Substitution in the Raw Fibre Market: A Partial Adjustment Translog Model', Contributed Paper to Conference of Economists, Adelaide.
- Confederation of British Wool Textiles Limited (various years), *Wool Industry Bureau of Statistics Monthly Bulletin of Statistics*.
- Dewbre, J., C. Vlastuin and H. Ridley (1986), 'An Analysis of Demand for Apparel and Apparel Fibre including Wool', Contributed Paper presented to the 30th Annual Conference of the Australian Agricultural Economics Society, Canberra.
- Diewert, W.E. (1974), "Applications of Duality Theory", in M.D. Intriligator and D.A. Kendrick (eds), *Frontiers of Quantitative Economics*, vol. II, North-Holland, Amsterdam, pp. 106-171.
- Diewert, W.E. and C.J. Morrison (1986), 'Export Supply and Import Demand Functions: A Production Theory Approach', Department of Economics Discussion Paper No. 86-10, University of British Columbia.
- Diewert, W.E. and T.J. Wales (1987), 'Flexible Functional Forms and Global Curvature Conditions', *Econometrica* 55, 43-68.
- Egan, H. (1991), 'Fibre Share Statistics', Australian Wool Corporation, April.
- Fuss, M.A. (1977), "The Demand for Energy in Canadian Manufacturing: an Example of the Estimation of Production Structures with Many Inputs", *Journal of Econometrics* 5, 89-116.
- Gabrys, M. (1991), 'Sea Freight Rates for Wool', Australian Wool Corporation, facsimile communication.
- Griffith, R., M. Potter and B. Corbman (1970), *Fibre to Fabric*, McGraw-Hill, Sydney.
- Harris, D. (1989), 'Substitution between Raw Fibres: Apparel Manufacturing in the United States', M.Ec Thesis, Faculty of Economics and Commerce, Monash University.

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- Jorgenson, D.W. and B.M. Fraumeni (1981), "Relative Prices and Technical Change", in E. Berndt and B. Field (eds), *Modelling and Measuring Natural Resource Substitution*, MIT Press, Cambridge.
- Kornreich, E. (1966), *Introduction to Fibres and Fabrics: Their Manufacture and Properties*, Heywood, London.
- Lawrence, D.A. (1987), 'Export Supply and Import Demand Elasticities', PhD Thesis, University of British Columbia.
- Lawrence, D.A. (1989), "An Aggregator Model of Canadian Export Supply and Import Demand Responsiveness", *Canadian Journal of Economics* 22, 503-21.
- Lawrence, D.A. (1990a), "An Adjustment Costs Model of Export Supply and Import Demand", *Journal of Econometrics* 46, 381-98
- Lawrence, D. (1990b), 'A Generalised McFadden Cost Function for Australian Agriculture', Contributed Paper to the 34th Annual Conference of the Australian Agricultural Economics Society, Brisbane.
- Lawrence, D. (1990c), 'The Supply Response of Australian Agricultural Exports', Contributed Paper to the 34th Annual Conference of the Australian Agricultural Economics Society, Brisbane.
- Lawrence, D. and J. Zeitsch (1989), 'Production Flexibility Revisited', Contributed Paper to the 33rd Annual Conference of the Australian Agricultural Economics Society, Christchurch, New Zealand, 7-9 February.
- Lawrence, D. and J. Zeitsch (1990), 'A Disaggregated Model of Agricultural Production Response', Invited Paper Presented to the 34th Annual Conference of the Australian Agricultural Economics Society, Brisbane.
- Organisation for Economic Co-operation and Development (OECD) (1991), *National Accounts, Main Aggregates 1960-1989*, Vol. 1, Paris.
- Shephard, R.W. (1953), *Cost and Production Functions*, Princeton University Press, Princeton.
- Short, C. and S. Beare (1990), 'Fibre Substitution in Retail Demand for Apparel', Contributed Paper presented to 34th Annual Conference of the Australian Economics Society, Brisbane.

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- Veldhuizen, J and R. Richardson (1984), 'Price Competition between Wool and Synthetic Fibres — Some Empirical Results', Contributed Paper presented to the 28th Annual Conference of the Australian Agricultural Economics Society, Brisbane.
- White, K.J., S.D. Wong, D. Whistler and S.A. Haun (1990), *SHAZAM User's Reference Manual Version 6.2*, McGraw-Hill.
- Wiley, D.E., W.H. Schmidt and W.J. Bramble (1973), "Studies of a Class of Covariance Structure Models", *Journal of the American Statistical Association* 68, 317-23.
- Woodland, A.D. (1976), 'Modelling the Production Sector of an Economy: A Selective Survey and Analysis', Department of Economics Working Paper No. 76-21, University of British Columbia.
- Woodland, A.D. (1977), "Estimation of a Variable Profit and of Planning Price Functions for Canadian Manufacturing, 1947-70", *Canadian Journal of Economics* 10, 355-77.
- Zeitsch, J. (1979), 'The Impact of Woolmark on Wool Fibre Demand in the United Kingdom Worsted Spinning Sector', Contributed Paper presented to 23rd Annual Conference of the Australian Agricultural Economics Society, Canberra.
- Zeitsch, J. (1987), 'A Methodology to Add Input Demand Equalities to the MTM Model', Paper prepared for Appraisal by Consultants, Directorate for Food, Agriculture and Fisheries, OECD, Paris, Mimeographed.