A Computable General Equilibrium Analysis of Export Taxes in the Australian Wool Industry

Iain Fraser - *Imperial College, London*
and Robert Waschik* - *La Trobe University*

October 2005

Abstract

We solve for Australia's optimal export tax on wool using a computable general equilibrium model - an aggregated version of the Monash Model. A key aspect of the analysis is the way in which we model short-run and long-run comparative statics. As opposed to varying the Armington elasticity which measures the degree of substitutability between domestic and imported goods, we contrast the unrestricted movement of primary factors of production with a specific-factors representation. We find that while results are virtually unchanged for the range of Armington elasticity values we employ in our sensitivity analysis, the specific-factors specification has a significant impact on model results.

J.E.L. Classification Codes: F13, C68, Q17

Keywords: optimal export tax, specific-factors, wool

*Corresponding author: Robert Waschik
Department of Economics and Finance
La Trobe University
Victoria 3086
Australia
(+61 3) 9479 5701
(+61 3) 9479 1654 (fax)
email: r.waschik@latrobe.edu.au

1 Introduction

Despite no longer "Riding on the Sheep's Back" wool is still an important industry for Australia. In 2000-01 Australia exported \$3.9 billon dollars worth of wool, almost 98% of production, second only to wheat in terms of magnitude of agricultural production. These exports accounted for 74% of world raw wool exports while the next largest was New Zealand with 15% (ABARE, 2001a,b). Given the importance of Australian wool production it is of little surprise to find that there is an extensive literature examining many aspects of the industry (e.g., Hinchy and Fisher, 1988, Bardsley, 1994, and Cashin and McDermott, 2002). However, for an industry with such a large share of world trade, and in principle the ability to exert market power, there is minimal research examining the adoption of an export tax for wool. This lack of attention is even more surprising as wool is not a homogeneous product. As Beare and Zwart (1990) explain, the physical characteristics of wool are important in determining end use. Wool from New Zealand is coarse and used in non-apparel production. Wool from Australia is much finer and appropriate for use in the production of apparel. So wool from Australia and New Zealand can be considered different products, providing even greater support for the argument that Australia could exert some market power.

To date, the only papers that examine the effects of an export tax on wool are Alston and Mullen (1992) and Edwards (1997). Alston and Mullen do not directly consider the export tax. They are interested in how R&D in the wool industry should be funded. Alston and Mullen recognise that a wool tax levied on grower output to fund R&D is essentially tantamount to an export tax because almost all wool produced in Australia is exported. Edwards provides a more detailed review of the theory underpinning the adoption of an export tax for wool. Both papers infer the likely size of an optimal export tax for wool based on the approximation of Johnson (1965) and Corden (1974).

The first objective of our paper is to estimate the optimal export tax for wool in a comprehensive modelling framework. We employ a Computable General Equilibrium (CGE) model to examine an export tax on wool for Australia. Our research adds to the literature that examines the economic implications of introducing an export tax for primary commodities (e.g., Warr, 2001 and 2002, Wiig et al., 2001). However, unlike the existing literature we are considering the production of a primary commodity in a developed economy. Existing research on export taxes has focused on developing economies (for example, Bangladesh and the production of jute (Repetto, 1972 and Ahammad and Fane, 2000)).

The second objective of this paper is to show how a specific-factors modelling framework can be used to contrast short-run and long-run comparative static results in a CGE model. Typically, such comparisons between short and long run results are made by varying the Armington elasticity which measures the degree of substitutability between domestic and imported goods. In our model, sensitivity analysis on the Armington elasticity shows that results are insensitive to different specifications of this parameter. Instead we argue that it is more appropriate to model short and long run behaviour by assuming that some share of primary factors in production is specific in the short-run, and then allow these specific factors to become perfectly mobile between sectors in the long-run. The use of the specific factors approach to examine differences between long and short run is not uncommon in the literature (see Mayer, 1974, Mussa, 1974 and Schweinberger, 2002). Indeed, there is a growing body of empirical evidence to indicate the importance of specific factors (e.g., Magee, 1980, Grossman and Levinsohn, 1989 and Hiscox, 2002). However, what differentiates our paper from existing CGE research is the way in which we model specific factors. As Bhagwati and Srinivasan (1983) observe, the conventional all-factors-specific model (Haberler, 1950) and the one specific factor model developed by Jones (1971) are extreme cases *"with few counterparts in reality"* (p. 92). The approach we take is to model a particular share of labour and capital as being specific in the short-run, and we reduce this share until in the long-run we arrive at a specification equivalent to the Heckscher-Ohlin model.

The paper is organized as follows. In Section 2 we review the various strands of literature that our paper draws upon and will add to. The CGE model and dataset, including a description of the industry and commodity aggregations and relevant model parameters, are described in Section 3. In Section 4 we describe results, including the level of the optimal tax on wool exports as a function of the elasticity of demand for wool by Australia's trading partners. Concluding comments and areas for further research are presented in Section 5.

2 Literature Review

We begin by briefly describing the wool industry in Australia, and then review the CGE literature, examining those papers relevant to our research.

2.1 Wool Industry in Australia

Wool production in Australia is broadly restricted to three zones - pastoral, wheat-sheep and high rainfall. The pastoral zone is the arid and semi-arid parts of central Australia, where the production of wool constitutes the majority of agricultural activity. There is minimal cropping due to uncertainty of rainfall. The wheat-sheep zone covers the western division of New South Wales and south western Queensland. Due to more regular rainfall this is the major dry land cropping area as well as being important in beef production. Thus, when primary commodity prices fluctuate, changes in the mix of outputs is possible. Finally, the high rainfall zone contains farms that frequently run cattle in combination with sheep, where sheep are used to produce both wool and prime lambs. Despite large variations in climate and production systems between the zones, the wool produced is relatively homogenous. ABARE farm survey data indicates that between 1992-93 and 2000-01 that average micron size of wool sold from all zones was between 21 and 23.[1]

Almost all wool produced in Australia is exported. Thus, analysts of the Australian wool market frequently assume that domestic consumption of wool is zero. For example, Alston and Mullen (1992) assumed that there was no consumption of wool domestically. However, in the data set we use there is a non-trivial amount of domestic consumption of wool. (see Table 1: 83.7% export intensity which is equal to the value of exports divided by the value of production.) This is because domestic consumption includes the production of semi-processed wool which is in turn exported. Thus, although 98% of wool production is ultimately exported, 64% is in greasy (unprocessed) form while 15% is scoured, 7% is carbonised and 12% is turned into tops.[2] We model the production and export of raw and semi-processed wool as separate activities, since we are interested in the effects of a tax applied to exports of unprocessed wool from Australia. We model this activity because the imposition of an export tax is known to give domestic producers using an input being taxed when exported a competitive advantage compared to other overseas users.

[1]Summary information from ABARE can be accessed via AgSurf at the ABARE website. A micron is one one-millionth of a metre.

[2]A top is a continuous strand of untwisted fibres from which the shorter fibres or noils have been removed by combing. Scouring is a washing process that removes dust, sweat and wool wax. Carbonising is the removal of vegetable matter, such as burrs and seeds, from wool and wool fabrics by chemical treatment.

2.2 CGE Models and Export Taxes

Several papers have looked at the effects of export taxes in CGE models. These papers have focussed on developing economies. For example, Warr (2001) examines the welfare effects (i.e., income distribution implications) of a tax on rice exports from Thailand in a static CGE model. He finds that for a wide range of export demand elasticities, all of which imply some degree of world market power, that the optimal export tax should be set conservatively. Warr identifies an asymmetric relationship between the rate of the tax and welfare. Once the optimal export tax is reached, further increases in the tax quickly lead to reductions in social welfare. Warr (2002) provides a very similar analysis for the Philippines who imposed an export tax on coconuts for several years.

Wiig et al. (2001) examine the impact of a reduction in an implicit export tax on cash crops in a multi-period CGE model of Tanzania. Unlike Warr (2001) and the analysis presented in this paper it is assumed that Tanzania is a price taker for its exports, so it comes as little surprise that as the export tax is reduced the annual growth of real GDP increases. This is because Tanzania is able to sell additional output on the world market at the prevailing world price.

Ahammad and Fane (2000) examine how changes in Bangladesh's exchange rate regime resulted in an effective cut on taxes of exports such as jute. They show that when the price elasticity of world demand for jute is low (i.e., based on econometric estimates) that Bangladesh would have suffered a reduction in welfare by reducing or even removing its exchange rate controls. However, when they employ a price elasticity of world demand that satisfies their preferred assumptions the reduction in exchange controls results in a welfare gain. This happens because the traditional industries that are subject to the "tax" are small relative to GDP.

3 General Equilibrium Model

This section describes the CGE model and Benchmark Equilibrium Data Set (BEDS). The data are an aggregated version of the Monash model, described in Dixon and Rimmer (2002). The Monash model is a dynamic GE model of the Australian economy. Since we are interested in the Australian primary agriculture sectors, especially those industries involved with wool production and usage, we aggregate together those industries and commodities in the Monash model which are associated with mining (6 industries and commodities), processed foods (12 industries and commodities), manufactures (44 industries and commodities), and services (30 industries and commodities).

This reduces the dimensionality of the general equilibrium model from 113 industries and 115 commodities in the Monash model to 25 industries and 27 commodities in our aggregated data set. The commodity and industry aggregations are reported in Tables 1 and 2, respectively.[3] We use data for 1994 from the Monash model.[4] The model is solved using GAMS/MPSGE, described in Rutherford (1998).

The sectoral disaggregation displayed in Table 2 reports the share of total value added used to produce each good, and the share of the total value of production in Australia accounted for by each commodity. For example, 0.20% of value added in Australia is used in wool production, and production of wool accounts for 0.14% of the total value of production in Australia. Since wool represents a small portion of total production in Australia, we can anticipate that the overall welfare effects of increases in the export tax on wool will be relatively small. Table 1 reports the export intensity of each commodity produced in Australia, as well as the trade taxes in the initial equilibrium (1994). Wool is the most export-oriented commodity in Australia, with over 83% of production by value being exported. It is also interesting to note that wool exports in Australia are subsidized in the initial BEDS (i.e., there is a negative export tax). A policy of subsidizing wool exports increases production leading to a deterioration in terms-of-trade if Australia has market power in world wool markets. The subsidy on wool exports in the BEDS accounts for a number of agricultural programs that operated in 1994, including R&D, rural adjustment and government guarantees on borrowings by Wool International to deal with the stockpile after the collapse of the Reserve Price Scheme (RPS) in 1991. The stockpile was finally exhausted in 2001, and the implicit subsidy on wool is now a thing of the past.

3.1 Production Sector

Specific Factors

Commodities are produced using three primary factors—land, labour, and capital—and intermediate inputs. All primary factors are internationally immobile and fully employed in Australia in equilibrium. Land is only used in those industries listed in Table 2 which produce primary agricultural commodities, and is treated as a specific factor.

[3] The complete concordance between the commodity and industry classifications in the Monash model and those used in this paper are reported in the Appendix, available from `http://www.business.latrobe.edu.au/public/staffhp/rwhp/research.htm`. A more detailed description of each of the Monash industries and commodities is available from the Centre of Policy Studies web page at `http://www.monash.edu.au/policy/techdoc.htm`.

[4] The Monash model is a dynamic GE model containing information about levels and rates of return on investment by industry and commodity. Since we are interested in comparative static experiments, we employ a static GE model, using data for 1994. All investment activity is treated as exogenous.

To contrast short-run and long-run responses to comparative statics experiments, CGE models are typically benchmarked to different trade elasticites: Smaller values for trade elasticities are presumed in the short-run, while larger values for trade elasticities generate long-run responses. In our model we take a different approach to that normally presented in the literature. In those industries producing primary agricultural commodities, we suppose that in the short-run, $\lambda = 25\%$ of capital and labour used for production is specific to that particular industry, while the remaining capital and labour used in production is completely mobile between industries. In the short-run, industries are essentially faced with a production cost which they treat as sunk. But in the long-run, $\lambda \rightarrow 0$, so all capital and labour becomes perfectly mobile between industries. An alternative way of thinking about this modelling approach is that we estimate an intermediate version of the specific factors model, and then relax this assumption gradually to arrive at a model that is equivalent to the more traditional Heckscher-Ohlin model. This approach to modelling specific factors is different from that generally employed in the CGE literature. For example, while Warr (2001, 2002) assumes that land is specific, he also models capital as an industry-specific fixed factor. This implies that changes in relative prices will not result in a reallocation of this specific factor in the short-run. Warr argues that the comparative statics he reports relate to the medium term - two to four years. We view this as being too restrictive, since we are also interested in the long-run responses to changes in the export tax on wool.

Production Function

For each industry i, commodities (y_i) are produced using intermediate inputs from sector j (x_{ij}) and primary inputs: land (H_i), labour (L_i), and capital (K_i). We assume that production technology displays constant returns to scale, and is represented by nested CES production functions of the form:

$$y_i = \left[\sum_j \delta_j x_{ij}^{\frac{\epsilon_i - 1}{\epsilon_i}} + \delta_{VA} VA_i^{\frac{\epsilon_i - 1}{\epsilon_i}} \right]^{\frac{\epsilon_i}{\epsilon_i - 1}} \quad (1)$$

$$\text{where} \quad VA_i = \left[\alpha_L L_i^{\frac{\gamma_i - 1}{\gamma_i}} + \alpha_K K_i^{\frac{\gamma_i - 1}{\gamma_i}} + \alpha_{\bar{H}} \overline{H}_i^{\frac{\gamma_i - 1}{\gamma_i}} + \alpha_{\bar{L}} \overline{L}_i^{\frac{\gamma_i - 1}{\gamma_i}} + \alpha_{\bar{K}} \overline{K}_i^{\frac{\gamma_i - 1}{\gamma_i}} \right]^{\frac{\gamma_i}{\gamma_i - 1}}, \quad (2)$$

where x_{ij} is the amount of good j used in production of good i and a $^{-}$ denotes usage of specific factors. In all non-wool producing industries the substitution elasticity between primary inputs γ_i is initally set equal to unity. For wool production we set γ_i equal to 0.75. This value is consistent with the estimates previously used in CGE models (Adams, 1987 and Warr, 2001, 2002) and generated by econometric research of wool

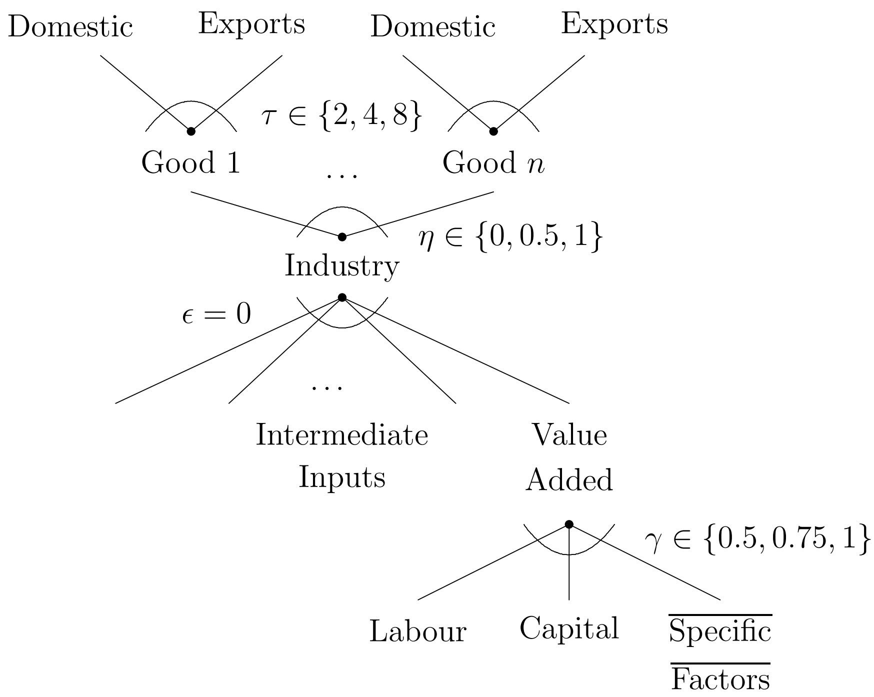

Figure 1: Structure of Production of Output

production in Australia (Wall and Fisher, 1987). Given the potential importance of this parameter in the model we undertake sensitivity analysis on this parameter such that we allow it to take the values $\gamma_i \in \{0.5, 0.75, 1\}$.

All intermediate inputs x_{ij} and the aggregate value added VA_i are combined using fixed-coefficients production technology, so $\epsilon_i = 0 \ \forall \ i$. The structure of production employed in the model is shown in Figure 1.

The uppermost nest in Figure 1 shows how output of any commodity in Australia is either exported or consumed within Australia, according to the transformation elasticity τ. For the purposes of this paper we choose a central case value of $\tau = 4$, and then conduct sensitivity analysis around this parameter, allowing it to take values $\tau \in (2, 4, 8)$.

Finally, we assume that all markets are perfectly competitive, with free entry and exit of firms, so economic profits are equal to zero in all industries in equilibrium. Producers take all output and input prices as given, and these are all normalized to unity in the initial equilibrium.

3.2 Multi-Commodity Industries

An important feature of the Monash model is that it reflects multi-commodity production by primary agricultural industries. For example, the commodity Wool is produced by three distinct industries or zones: The Pastoral zone, the Wheat sheep zone, and the High rainfall zone. Likewise, each of these industries or zones produces different commodities. For example, commodities produced in the Pastoral zone include wool, sheep, wheat, barley, and other primary agricultural commodities.

The upper part of Table 3 gives the share of production of each primary commodity by industry, while the lower part of Table 3 gives the share of production of each industry, by commodity. For example, the Pastoral zone produces 15.9% of all of the wool produced in Australia by value. This represents 43.8% of total production (by value) in the Pastoral zone. This feature of the model allows producers in a particular industry or zone to switch out of a particular commodity in response to a particular shock. Producers in the Pastoral zone could respond to an increase in the export tax on wool by reducing wool production and increasing production of other commodities subject to pastoral lease arrangements.

The use of industry-specific factors allows us to realistically rule out inappropriate supply responses in the short-run given prevailing institutional and market arrangements. Multi-commodity production in these industries is reflected by the nest immediately above each industry in Figure 1. Output can be transformed into different commodities according to the transformation elasticity $\eta \in (0, 0.5, 1)$. The central case values of the exogenously specified elasticities in Figure 1 imply an output supply elasticity in wool production of 0.6 in the short-run when $\lambda = 25\%$ of capital and labour is specific, 1.3 when $\lambda = 12.5\%$ of capital and labour is specific, and 2.9 in the long-run when all capital and labour is mobile ($\lambda = 0.0$).[5] Furthermore, for the purposes of this paper, it was necessary to separate wool production out of the multi-commodity industries, to avoid unrealistic output responses in production of commodities other than wool in these industries. An increase in the export tax would decrease the price of wool in Australia, causing wool production to fall. Even with the highest output transformation elasticity $\eta = 1$, while the ratio of output of these other commodities to wool would rise, the level of output of these commodities would fall in response to a change in the export tax on wool. Since we are assuming that world prices of all commodities other than wool are fixed, it was appropriate to separate wool production out of the multi-commodity industries.

[5]See Appendix C of Rutherford et al (1993) for a description of the methodology used to benchmark to output supply elasticities in a CGE model with a specification of production technology as shown in Figure 1.

3.3 Final Consumption and Trade

In our model final goods are consumed by industry as intermediate inputs, and by the public and private sector. To simplify the analysis, we aggregate together the public and private sectors, and represent public and private demand by assuming the existence of a single representative consumer who owns all primary factors of production, and supplies all land, labour and capital to the production sector. The representative consumer maximizes utility represented by a Cobb-Douglas utility function:

$$U \;=\; \prod_i z_i^{\theta_i} \qquad \sum_i \theta_i \;=\; 1,$$

where z_i is the consumption of commodity i by the representative consumer in Australia. Because we employ a Cobb-Douglas utility function the elasticity of substitution in consumption is equal to one.

In the Monash model, Australia produces, imports and exports all goods. Trade must be balanced, so in equilibrium, Australia's exports of each commodity must equal total imports from Australia by the rest of the world (ROW). The model is closed by ensuring that the balance of payments is equal to zero, or that the trade (current account) balance is always equal to the (negative of) capital flows, which as noted in footnote 4 are fixed. Trade is accommodated using the so-called Armington assumption, so that the same goods produced in Australia and imported from the ROW are imperfect substitutes for one another.

$$z_i \;=\; \left[\gamma_d y_i^{\frac{\sigma_i - 1}{\sigma_i}} + \gamma_f m_i^{\frac{\sigma_i - 1}{\sigma_i}}\right]^{\frac{\sigma_i}{\sigma_i - 1}} \qquad \forall\; i$$

The central case value for the substitution elasticity between domestic and imported goods is set at $\sigma_i = 4$, implying that Australia's (uncompensated) elasticity of demand for imports is approximately equal to 4.[6] We conduct sensitivity analysis around this parameter, allowing it to take values $\sigma \in (2, 4, 8)$. This Armington function is illustrated in the lower level nest of Figure 2 for wool, with a corresponding description of the structure of consumption goods applying for all other goods.

Finally, Australian exports are consumed by the rest-of-the-world, which is presumed to have an infinitely elastic demand for all Australian exports except wool. Since Australian wool accounts for such a large share of the world wool market, we presume that Australia has some amount of market power. Thus, we benchmark the model to an elasticity of demand for wool which is finite. Of course, as noted by Edwards (1997),

[6]See Mansur and Whalley (1984) pp.106-7, for a description of the relationship between domestic/import substitution elasticities and the (uncompensated) import demand elasticity.

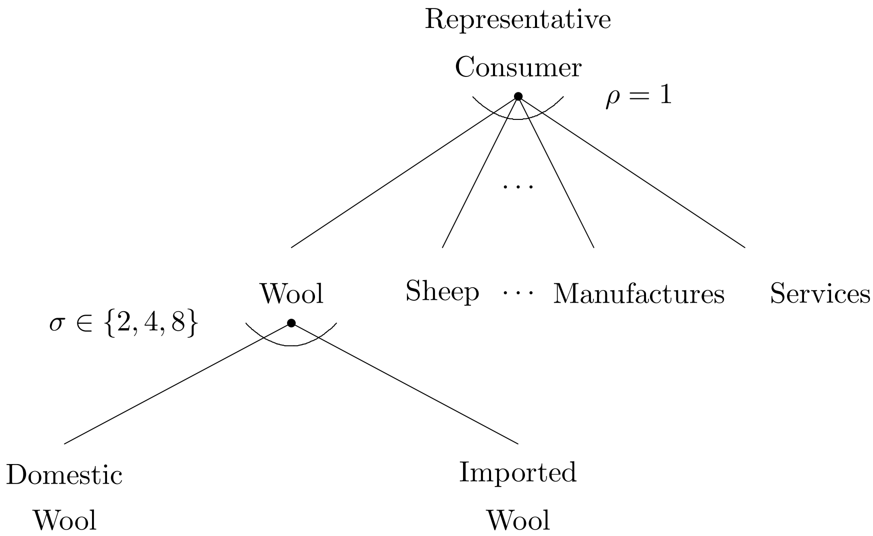

Figure 2: Structure of Consumption in the BEDS

the potential benefits of an export tax depend to a large extent on the magnitude of the demand elasticity for wool. In terms of the empirical evidence in the literature the magnitude of the own price demand elasticity for wool has been the subject of several studies in Australia. Haszler et al. (1996) provide a useful summary of estimates. A striking feature of the estimates is that in the short-run they are inelastic, frequently less than -0.5, while in the long-run some estimates are in excess of -1.5. The estimates reported in the literature have lead researchers to assume that the own price demand elasticity for Australian wool is -1. The Monash model itself uses a value of -1.3 for the export demand elasticity for wool (Dixon and Rimmer (2002), p.224).

However, in the trade literature it is well known that many estimates of export demand elasticities are biased downwards. In particular it has been argued that existing elasticity estimates are biased towards -1 (see Athukorala and Riedel, 1991). For example, in a study of export demand elasticities for Philippine coconut oil, Warr and Wollmer (1996) find that long-run elasticities lie between -1 and -2 depending on various assumptions employed as part of the estimation process. However, Warr (2002) in a CGE model of the Philippines argues that these estimates should only be viewed as a lower bound. Similarly, Warr (2001) reviews the appropriate magnitude of the export demand elasticity for rice from Thailand. He is guarded as to the magnitude of the true elasticity: *"Statistically based estimates of long-run export demand elasticities must surely be regarded with caution and probably represent lower bound estimates of the absolute values of true long-run export demand elasticities."* (p. 906)

Another line of argument that can be used to highlight the likely downward bias of the elasticity estimate is the collapse of the Reserve Price Scheme (RPS) in 1991. As Alston and Mullen (1992) observe, the collapse of the RPS is difficult to reconcile with inelastic demand for wool. Therefore, given the evidence on own price demand elasticities of wool we employ a range of estimates in our analysis. We assume a lower bound of -1.5 and an upper bound of -4.5. The difference between these values allows us to demonstrate the impact of the choice of a particular value on the results produced.

4 Results

Our results are presented in two parts. In Section 4.1 we describe the behaviour of the model by examining the general equilibrium effects of a 25 percentage point increase in the export tax on wool, to illustrate how the most relevant elements of the model respond to a change in the export tax on wool. Then in Section 4.2 we solve for Australia's optimal tax on wool exports, highlighting the effects on production in the different wool-producing zones as well as those industries associated with value-addition in wool. When not otherwise specified, results are presented for the central case values for exogenously specified parameters in the model displayed in Table 4. The results of sensitivity analysis conducted around these parameters are reported in Section 4.3.

4.1 Model Behaviour

In the initials BEDS, Australia applies an export subsidy of 20.4% on wool exports. Suppose that this (negative) export tax is increased from -20.4% to 4.6% (an increase in the export tax of 25 percentage points). The volume of trade effect of this policy change will be a reduction in wool exports. This will lead to an improvement in Australia's terms-of-trade, which will be larger the smaller is the rest-of-world elasticity of demand for Australian wool.

The welfare effects of this increase in Australia's export tax on wool are shown in Figure 3, for three chosen values of the rest-of-world export demand elasticity for wool. The horizontal axis measures the share of specific factors λ. When $\lambda = 0.25$, 25% of labour and capital used in industries which produce agricultural commodities is industry-specific, and when $\lambda = 0$, all labour and capital is perfectly mobile between industries.[7]

[7]While there is a body of empirical literature that indicates that specific factors are important, there is no evidence to guide a choice of the share λ of primary factors which are specific in the short-run. Our choice of $\lambda = 25\%$ is therefore somewhat arbitrary. While our results explicitly indicate outcomes if λ is less than 25%, the implications of λ being greater than 25% should be clear from our analysis.

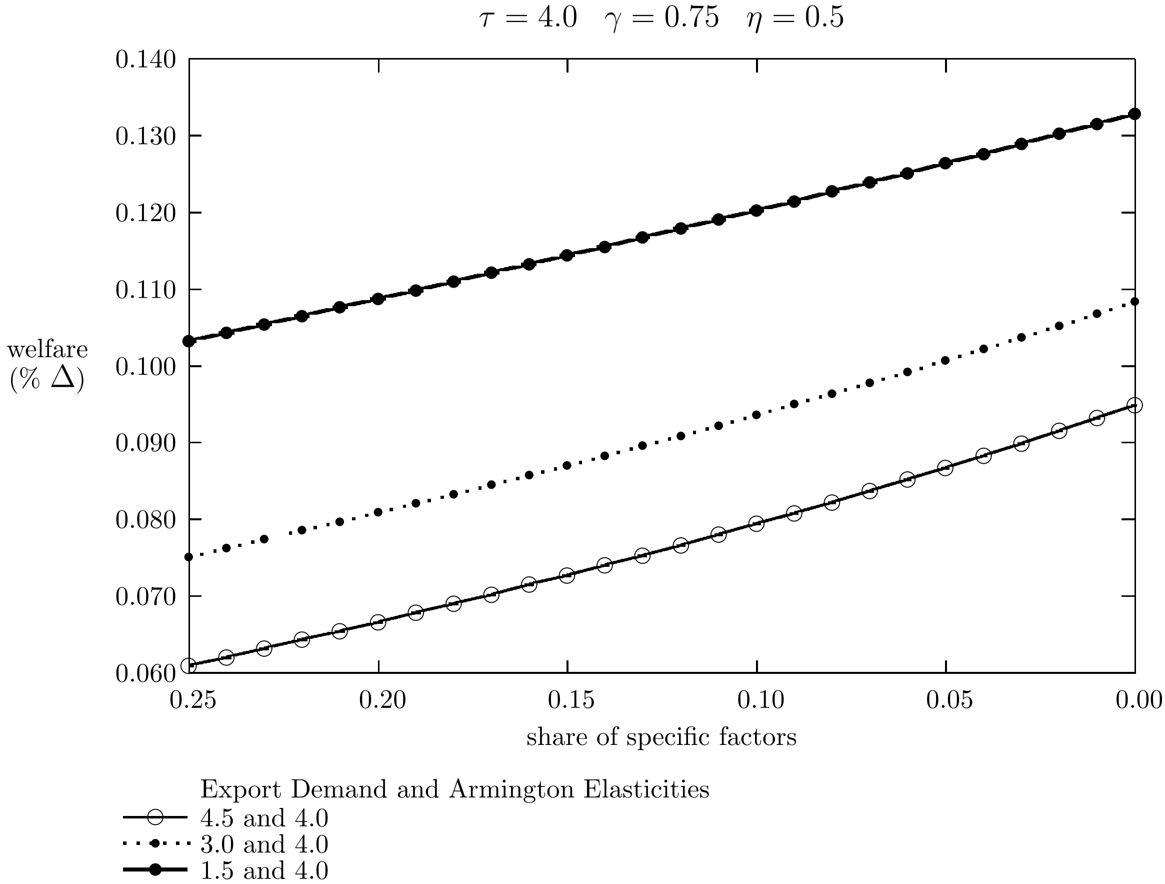

Figure 3: Welfare effects of a 25 percentage point increase in the export tax on wool

As expected, the increase in the export tax on wool has a positive welfare effect which is larger the greater is Australia's market power in world wool markets (ie: the smaller is the rest-of-world export demand elasticity) and the greater the degree of inter-sectoral factor mobility.

It is also worth noting the behaviour of the price and volume of wool exports for different values of the export demand elasticity and different degrees of factor specificity. These are plotted in Figure 4. The 25 percentage point increase in the export tax translates into a larger increase in the export price for wool and a smaller decrease in wool exports the greater is Australia's market power in world wool markets. The export price and volume responses are larger (in absolute value) the greater the degree of intersectoral factor mobility. Even when all capital and labour is perfectly mobile between industries, the 25 percentage point increase in the export tax on wool causes the export price of wool to rise by almost 14% when the rest-of-world export demand elasticity is -4.5. This modest increase in the price of wool causes a decrease in the volume of wool exports of almost 37%. Alternatively, when the model is benchmarked to a rest-of-world demand elasticity is -1.5, the same increase in the export tax on wool

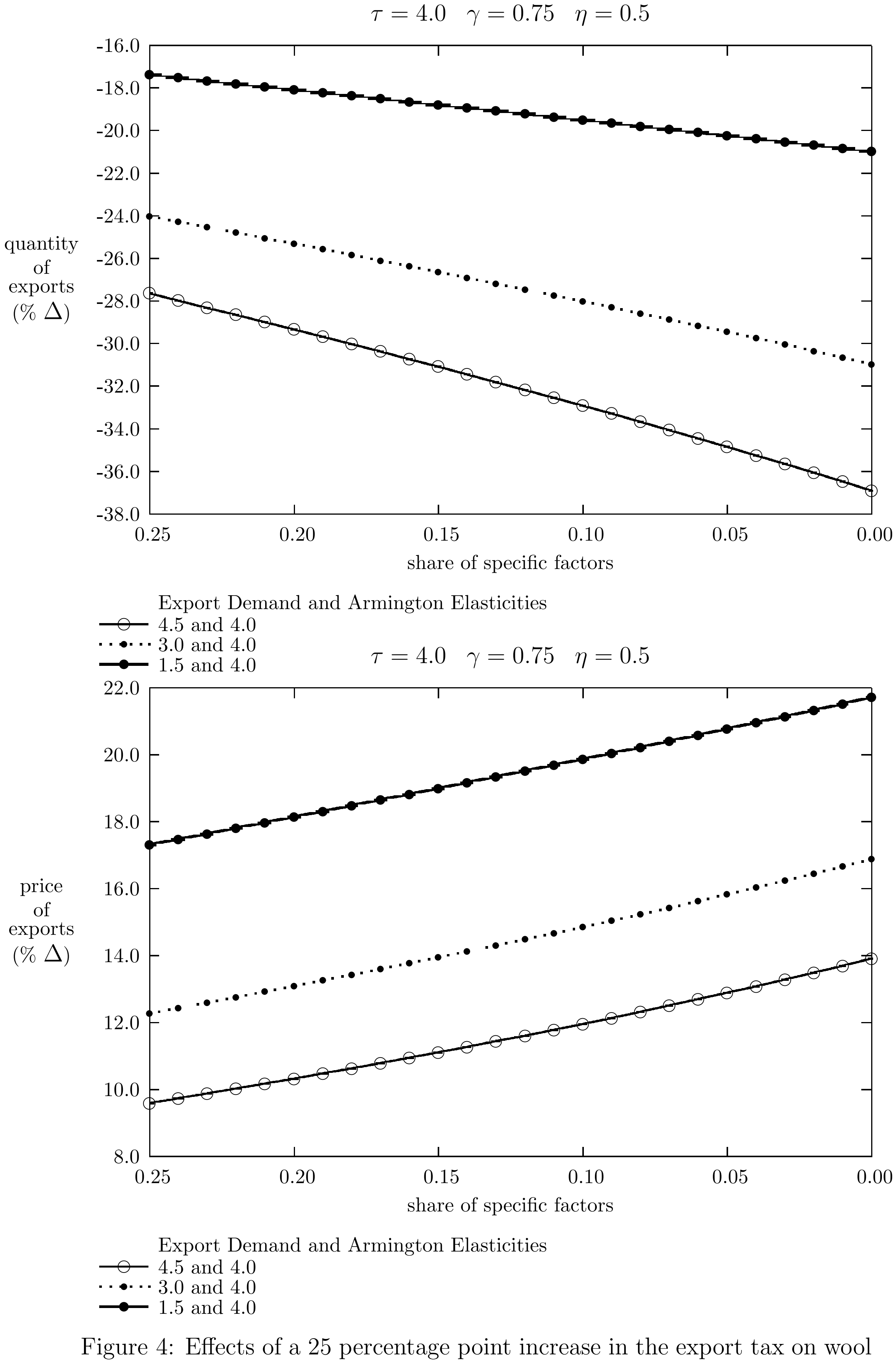

Figure 4: Effects of a 25 percentage point increase in the export tax on wool on volume and price of wool exports

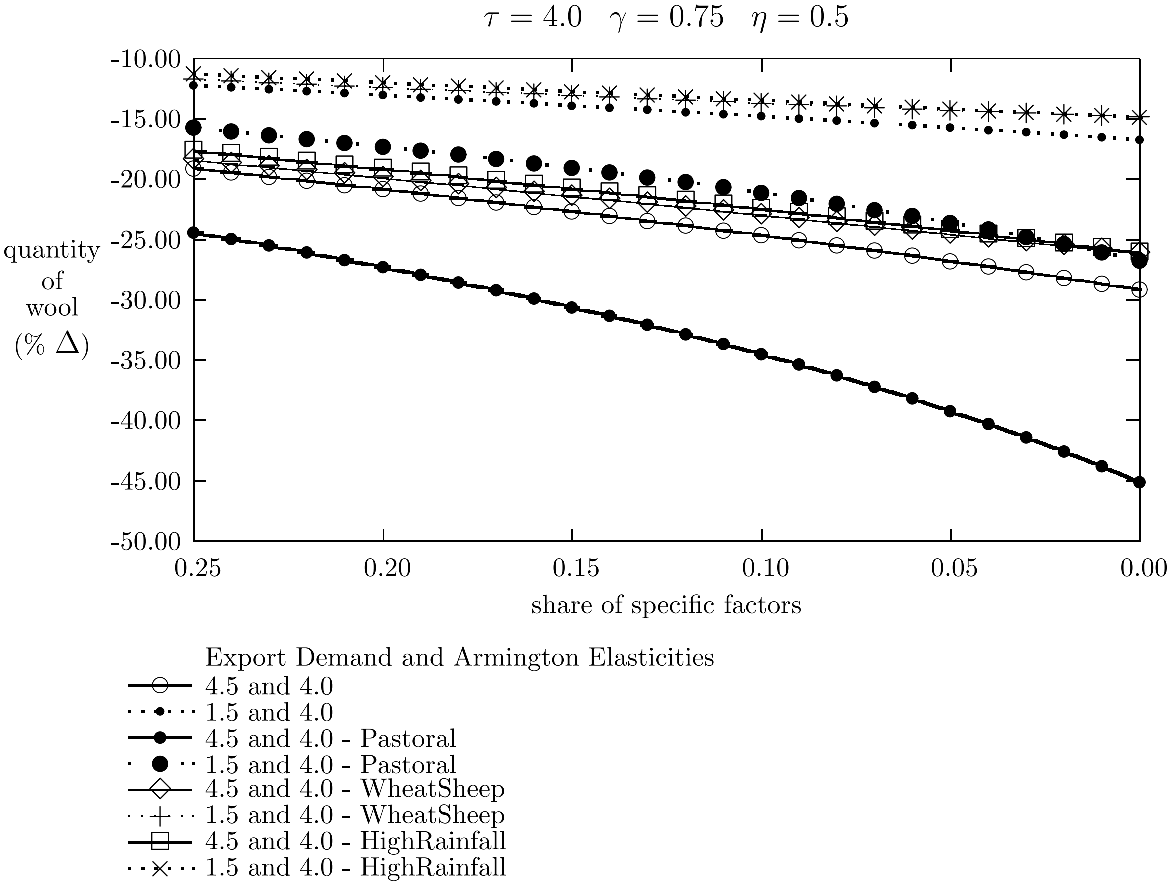

Figure 5: Effects of a 25 percentage point increase in the export tax on wool on volume of wool production

translates into a rise in the export price of wool of almost 22%, and wool exports fall by only 21%.

Finally, we note the effects of this export tax increase on the volume of wool production in Figure 5. In an economy with no market power at all, an increase in the export tax would cause no change in the price faced by the rest-of-world, and would decrease the domestic price of wool. This would cause a decrease in production of wool and a decrease in the return to factors specific to wool production through the magnification effect.[8] Of course, the decrease in the domestic price of wool would be smaller if the economy had more market power (ie: smaller values for the rest-of-world demand elasticity), implying smaller decreases in production, reflected in Figure 5. In the long-run, labour and capital which were specific are free to move out of the wool-producing industries, so the decrease in wool production will be larger as the share of specific factors falls from 0.25 to 0. Also note that the decrease in wool production is much larger in

[8]See Jones (1965), p.561 for a description of the magnification effect in the specific factors model.

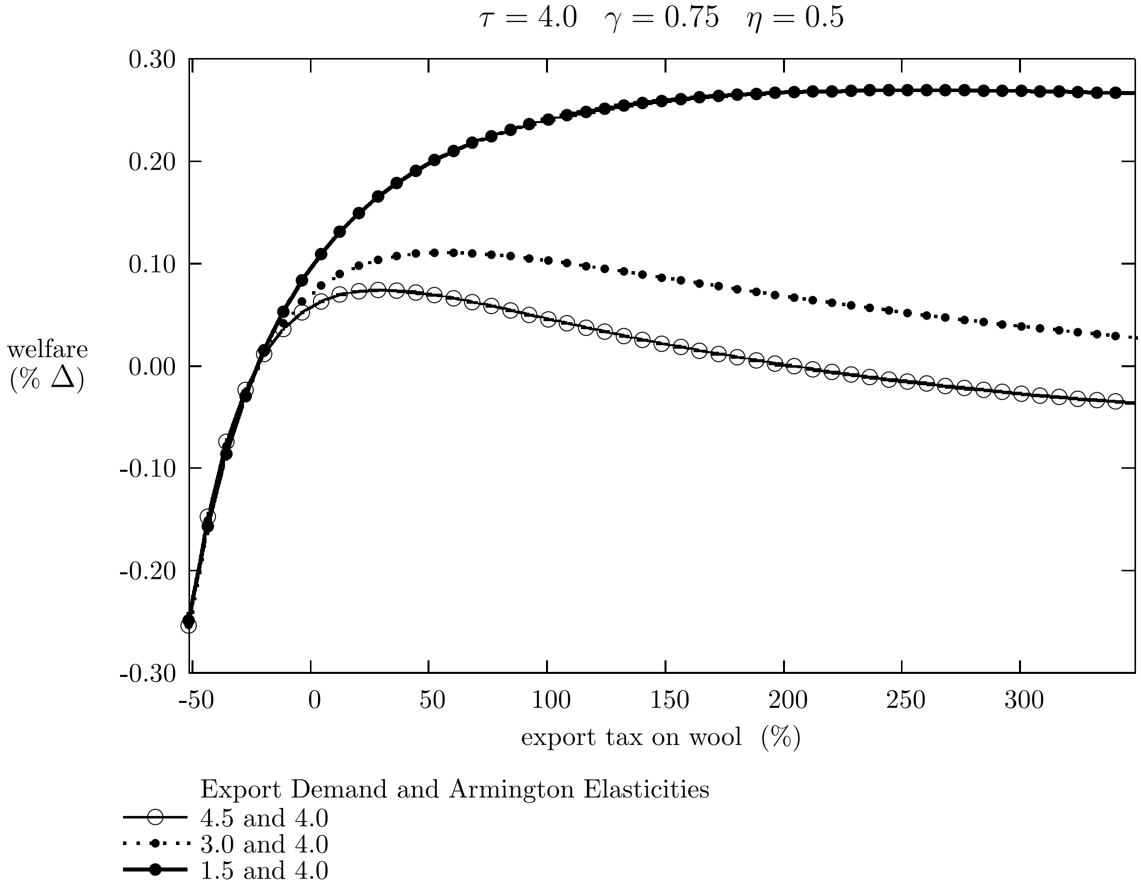

Figure 6: Welfare effects of changes in the export tax on wool

the Pastoral zone. As shown in Table 3, wool production accounts for a greater share of total output in the Pastoral zone, so the export tax has a larger (negative) effect on production in the Pastoral zone than in the Wheat sheep or High rainfall zones.

4.2 Optimal Export Tax

Before solving for the optimal tax on wool exports, we show how welfare changes as a function of the export tax on wool, for different specifications of the rest-of-world export demand elasticity. These results are presented in Figure 6.[9]

Clearly, the welfare effects and the optimal export tax are larger the more market power Australia has on world wool markets. But it is interesting to compare Figure 6 to similar Figures in Warr (2001, 2002). In both papers Warr finds that the welfare cost of getting the optimal export tax wrong is higher the larger is the export tax. That is, he finds that welfare falls off very quickly when the export tax is increased beyond its optimal level. In our analysis Figure 6 shows that there is a greater loss in welfare

[9]Figure 6 is drawn for a share of specific factors $\lambda = 0.125$.

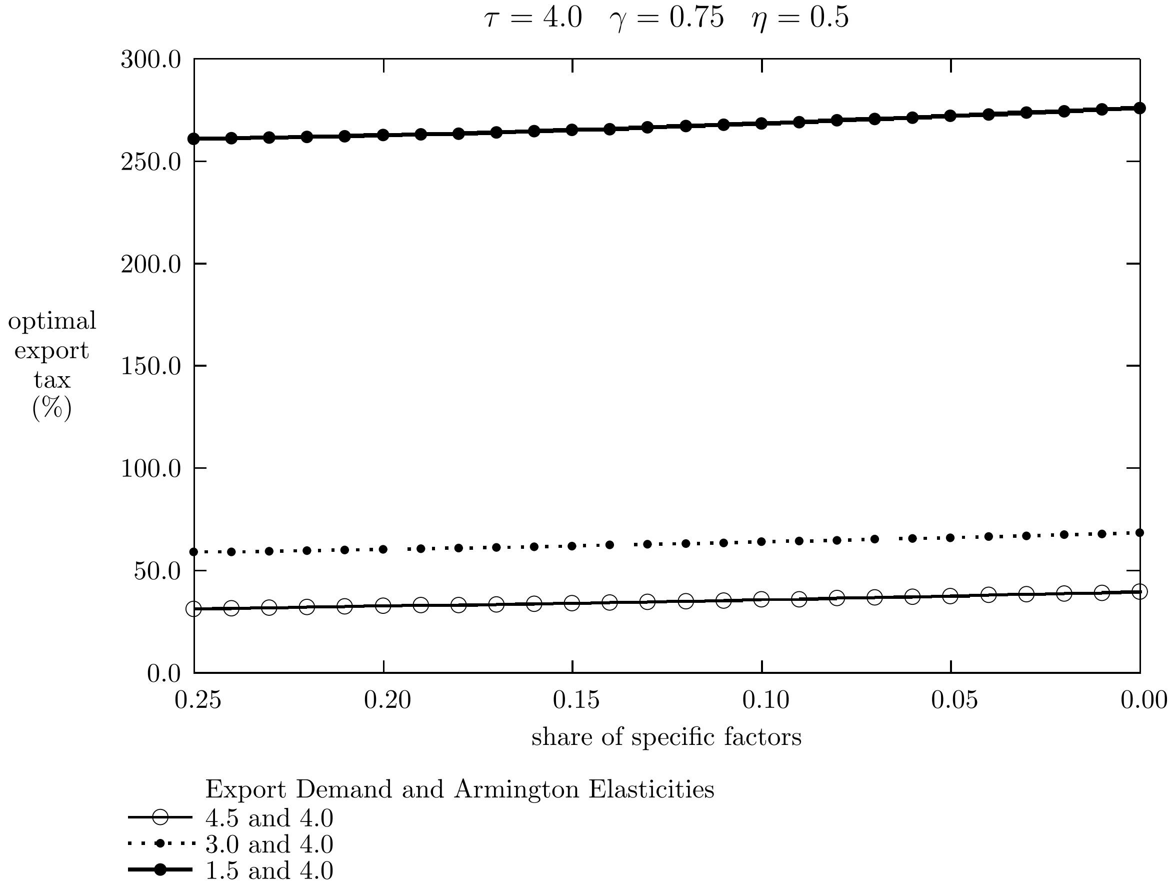

Figure 7: Optimal export tax on wool

from the imposition of a subsidy (i.e., baseline position), while increasing the export tax beyond its optimal level leads to relatively smaller decreases in welfare, especially for the lowest export demand elasticity. The fact that an export subsidy is so much more costly in our model is likely due to the fact that such a large share of wool produced in Australia is exported.

We now solve for the optimal export tax, assuming that Australia takes the behaviour of its trading partner (the rest-of-world) as given, and that the rest-of-world behaves passively and does not change its behaviour in response to Australia's application of an optimal export tax. We use a grid search to identify Australia's optimal export tax on wool, given the behaviour of the rest-of-world. This optimal export tax is plotted in Figure 7, for different values of the rest-of-world elasticity of demand for Australia's wool exports and different degrees of intersectoral factor mobility.

As expected, the size of the optimal export tax is very sensitive to the specification of the rest-of-world export demand elasticity. For the most inelastic specification of the rest-of-world export demand elasticity ($\epsilon = -1.5$), the optimal export tax on wool is

260.8% in the short-run and 275.9% in the long-run, while for $\epsilon = -3.0$ ($\epsilon = -4.5$), the optimal export tax is between 59.0-68.4% (31.4-39.7%).

How do these optimal taxes compare to those generated by back-of-the-envelope calculations using the export demand elasticity? Following Johnson (1965: 58, equation (5)), the optimal export tax should be given by $t = 1/(\epsilon - 1)$, where ϵ is the absolute value of the export demand elasticity. For export demand elasticities of 1.5, 3.0, and 4.5, this would suggest an optimal export tax of 200%, 50%, and 28.6%, respectively, all lower than the estimates we present. Three features of our model are important in understanding the difference between the optimal export tax predicted by our model and that predicted by the "inverse elasticity" rule. The optimal export tax will be smaller (i) the larger the share of specific factors, (ii) the larger the transformation elasticity τ between domestic and exported goods, and (iii) the larger the substitution elasticity between intermediate inputs in production. Sensitivity analysis results in Section 4.3 show how, for the larger value of $\tau = 8$, the optimal export tax on wool is 53.7% in the long-run for an export demand elasticity of 3.0, which is close to that predicted by the simple "inverse elasticity" rule. However, it is important to understand that we assume fixed coefficients production technology, making the demand elasticity for intermediate inputs lower than it would otherwise be. Since the Ginning industry in Australia uses about 15% of the wool produced by Australia, the optimal export tax on wool is higher than would be the case if there were more substitutability between intermediate inputs in production.

While the size of the optimal export tax varies only slightly with the degree of intersectoral factor mobility, this is not true of the welfare effects of the optimal export tax on wool, displayed in Figure 8. As intersectoral factor mobility increases (share of specific factors falls from 0.25 to 0), previously immobile capital and labour can be allocated more efficiently, so welfare gains are larger in the long-run when labour and capital are perfectly mobile between industries. It is also worth noting that the influence of the degree of factor specificity is more pronounced as the export demand elasticity becomes more inelastic.

While the welfare effects of the optimal export tax are all positive but relatively small (less than 0.34% of base period welfare for the central case parameter values), it must be recalled that the wool-producing industries only contribute a small share of total output to the economy. Of course, the welfare increases are significantly larger the greater the degree of market power Australia has on world wool markets. And in monetary terms, the welfare gain is certainly non-trivial. For the most inelastic export demand elasticity,

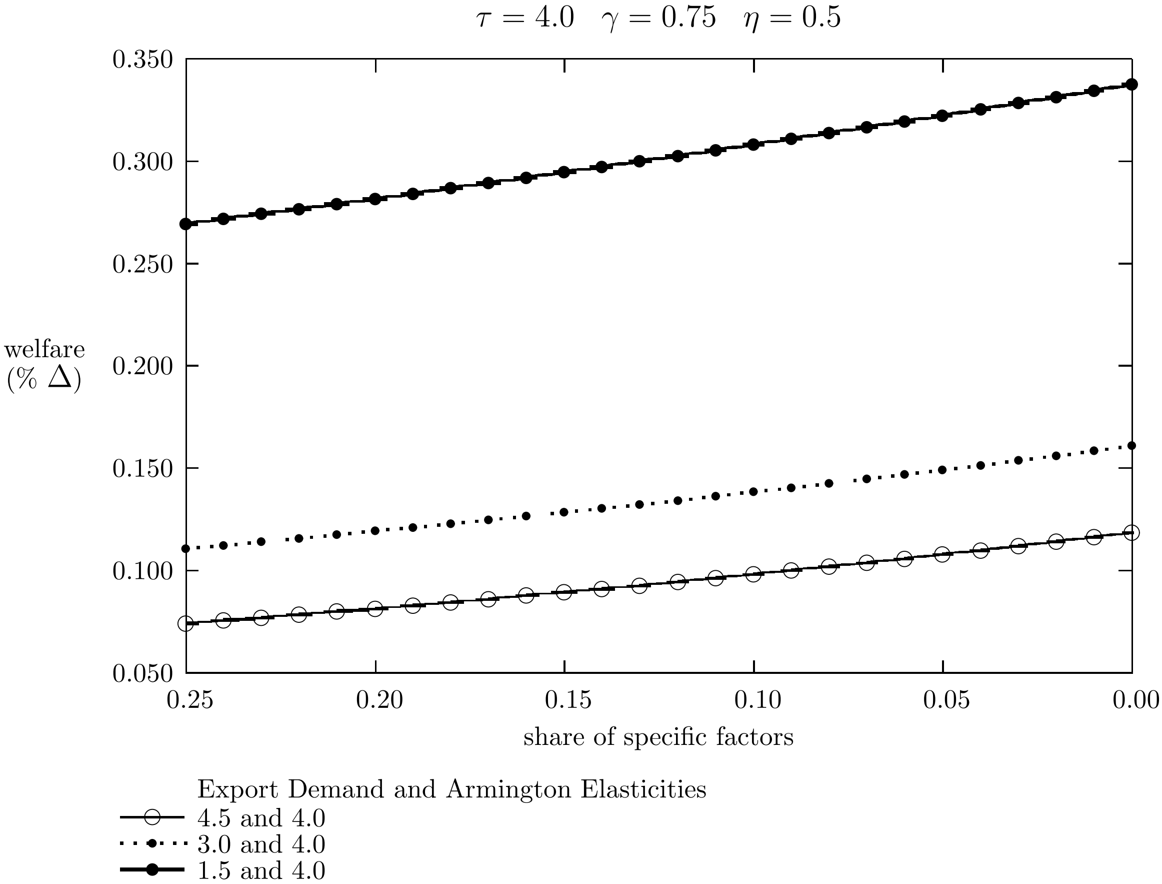

Figure 8: Welfare effects of an optimal export tax on wool

the static long-run welfare gain is \$1.40 billion, while even for the case where the export demand elasticity is -4.5, the static welfare gain is \$0.49 billion.[10]

Irrespective of the size of the potential welfare gains, as Alston and Mullen (1992) observed, it is difficult to argue that an export tax on wool in excess of 300% is politically credible. However, as noted in Section 3.3 it is possible that the demand for wool is more responsive to price than existing econometric estimates suggest. If this is the case our results suggest that when Australia is modelled as facing a relatively elastic demand for its wool exports (ROW export demand elasticity of -4.5), an optimal export tax of 31% (40%) would yield short-run (long-run) static welfare gains of \$307.6 (\$492.3) million.

Finally, because the export tax introduces a wedge between the domestic and export prices of wool, it decreases the price of wool in Australia and increases the export price of wool. So an increase in the export tax on wool leads to an increase in the competitiveness of those industries in Australia which use wool as an input. In the Monash model, these are the Ginning (including wool scouring) and Wool Yarn industries, and to a lesser

[10] Income in Australia in the base period (1994) was \$415,060.5 million. All dollar values reported are 1994 Australian dollars.

extent the textile and clothing industries. As shown in Table 5, under an optimal export tax policy, the output of the Ginning industry rises by 45-64% in the short-run.[11]

But this result is not nearly as strong in the long-run when all labour and capital are mobile between industries. For all export demand elasticity values, the long-run increase in output in the Ginning and Wool Yarn industries is much lower than the short-run increase, due to the fact that in the long-run, the drop in the domestic price of wool is much smaller than the immediate short-run decrease in the domestic price of wool. This shows that policy-makers should be skeptical of the argument that an export tax on wool might be used to stimulate the long-run development of value-adding industries associated with wool production.

4.3 Sensitivity Analysis

While we have discussed the sensitivity of results in Sections 4.1 and 4.2 to the elasticity of demand for Australia's wool exports, we need to investigate whether our results are sensitive to specification of other parameters in the model.[12]

First, sensitivity of the Armington elasticity ($\sigma \in (2, 4, 8)$) illustrates that the choice of this parameter has very little effect on the results generated by the model. This can be taken as evidence to support our use of specific factors to model long-run and short-run model responses. Second, our results are almost completely insensitive to alternate specifications of the production transformation elasticity ($\eta \in (0, 0.5, 1)$). Third, the choice of the capital/labour substitution elasticity in wool production ($\gamma \in (0.5, 0.75, 1)$) yields only minor changes to our comparative statics. In the long-run with all labour and capital perfectly mobile between industries, the optimal export tax is 71.3% (67.5%) for $\gamma = 0.5$ ($\gamma = 1$), implying a welfare gain of 0.1472% (0.1716).

However, our results are sensitive to specification of the domestic/export transformation elasticity ($\tau \in (2, 4, 8)$). Higher values of τ imply a higher degree of integration of domestic and export markets, while lower values of τ imply a greater ability on the part of the producer to discriminate between domestic and export markets. Together with the export demand elasticity, τ influences the derived demand elasticity for wool

[11]Note that this result would change if the world price of outputs of the Ginning and Wool Yarn industries responded to the export tax on wool, and if these industries were allowed to substitute between intermediate inputs. We assumed that the world price of all goods other than wool was fixed, and that the substitution elasticity between intermediate inputs was zero. Australia's optimal export tax on wool would be lower if industries using wool as an intermediate input could substitute between intermediate inputs, and if the world price of these industries responded (increased) when Australia applied an optimal export tax on wool.

[12]Graphs of all sensitivity analysis can be found in the Appendix, available from `http://www.business.latrobe.edu.au/public/staffhp/rwhp/research.htm`.

in the model. To illustrate, the general equilibrium response of demand for wool to a 25 percentage point increase in the export tax on wool for different values of τ are presented in Table 6.[13]

Since the model is benchmarked to an export demand elasticity, higher values of τ imply higher domestic demand elasticities for wool. Values of $\tau \in (2, 4, 8)$ are chosen to be consistent with observations about market behaviour (Simmons and Hansen, 1997). While the domestic market only forms a small part of total demand for Australian wool, higher values of τ nevertheless imply that Australian wool producers have less market power, implying a lower value for the optimal export tax and smaller welfare increases when an optimal export tax is charged. For example, for $\tau = 2$, the long-run optimal export tax is 75.0%, leading to a welfare gain of 0.164%, while for $\tau = 8$, the optimal export tax and welfare gain are 53.7% and 0.146%, respectively.

5 Conclusion

In this paper we have modelled and examined the imposition of an optimal export tax for Australian wool. Since Australian wool exports account for almost 3/4 of world trade in wool, we model Australia as facing a less-than-perfectly elastic demand curve for wool. We use a Computable General Equilibrium model and an aggregated version of the dataset in the Monash Model to solve for Australia's optimal export tax, for different export demand elasticities for Australian wool. When the model is benchmarked to a rest-of-world demand elasticity consistent with estimates in the literature, an optimal tax on wool exports leads to static long-run welfare gains of over \$1.4 billion 1994 Australian, slightly less than 0.34% of GDP. Even when the model is benchmarked to a much more elastic export demand elasticity, an optimal export tax of 40% would yield static long-run welfare gains of over \$492 million 1994 Australian.

Since wool is produced in three distinct zones in Australia, results of the model show how the export tax on wool affects different wool producing regions. Wool production is most important in the Pastoral zone, which suffers a much larger decline in wool production under an optimal export tax policy than the Wheat sheep and High rainfall zones. The export tax on wool also gives a competitive advantage to domestic wool users. While these domestic value-adding industries in wool see a large increase in production in the short-run, these gains are much smaller in the long-run and as such provide little

[13] Results in Table 6 are derived for central case values of all other parameters. Total demand elasticities are the percent change in demand for wool divided by the percent change in the price of wool after all adjustments to the new equilibrium after a 25% increase in the export tax on wool.

support for increased investment in wool processing.

While short-run and long-run results in CGE models are typically contrasted by varying the Armington elasticity to which the model is benchmarked, our model results are insensitive to different specifications of the Armington elasticity. Instead, we assume that some share of primary factors in production are specific in the short-run, and model the long-run by allowing this share of specific factors to go to zero, so that results in the long-run are consistent with the traditional Heckscher-Ohlin model. What is apparent from the results we generate is that our specific factors specification does yield important differences in modelling results between the short and long run.

An important feature of our model is the choice of the share of primary factors assumed to be specific in the short-run. The literature gives no indication of how this share parameter should be chosen, so we set this parameter at 25% and acknowledge that there is no empirical evidence to support this choice. Since our results indicate that this specific factors approach is important in proxying short-run and long-run outcomes, further empirical research is warranted to provide guidance on appropriate choice of this important parameter.

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Table 1: Commodity aggregation for benchmarked general equilibrium data set, 1994 (%)

Commodity Description	Export Intensity*	Export Tax	Import Tariff
Wool	83.7	−20.4	0.0
Sheep	14.5	−8.1	0.2
Wheat	57.2	31.4	0.0
Barley	43.8	−23.0	0.0
Other Grains	30.9	23.0	3.3
Meat Cattle	3.3	−25.9	1.2
Milk Cattle	0.1	29.3	46.7
Cane, Fruit, Nuts	24.5	4.8	9.5
Other Farming	8.3	−4.3	5.1
Poultry	0.1	−17.6	29.6
Agric. Services	4.8	−13.3	0.7
Forestry	2.9	−3.3	0.1
Fishing	23.2	24.1	0.0
Mining	60.0	7.0	0.2
Processed Food	23.2	3.1	5.5
Ginning	77.0	−3.3	1.4
Synthetic	11.2	−7.5	17.6
Cotton Yarn	12.1	5.9	19.8
Wool Yarn	5.3	7.2	8.1
Textile Fabrics	1.5	3.4	34.5
Carpets	9.0	12.1	23.0
Canvas	8.5	7.3	10.2
Knitting	6.4	12.3	38.7
Clothing	4.2	−10.5	39.8
Footwear	7.1	−0.7	34.7
Manufactures	14.5	−2.0	9.0
Services	3.2	−3.8	0.0

* Export intensity = value of exports / value of production

Table 2: Industry aggregation for benchmarked general equilibrium data set, 1994 (%)

Industry Description	Share of Australian Value of Production	Share of Australian Value Added	Labour as a Share of Value Added	Capital as a Share of Value Added
Pastoral	0.14	0.20	63.9	17.4
Wheat Sheep	1.00	1.24	50.9	16.3
High Rain	0.42	0.58	59.5	10.1
Northern Beef	0.14	0.18	58.1	16.0
Milk Cattle	0.36	0.43	58.1	9.1
Cane, Fruit, Nuts	0.23	0.23	57.9	7.2
Other Farming*	0.46	0.63	83.8	7.1
Poultry	0.20	0.13	58.3	41.7
Agric. Services	0.24	0.40	75.7	24.3
Forestry	0.17	0.15	85.3	14.7
Fishing	0.16	0.11	66.5	33.5
Mining	3.85	3.78	40.4	59.6
Processed Food	5.14	2.05	72.7	27.3
Ginning**	0.21	0.00	72.6	27.4
Synthetic	0.08	0.06	78.0	22.0
Cotton Yarn	0.09	0.06	80.1	19.9
Wool Yarn	0.03	0.03	89.6	10.4
Textile Fabrics	0.06	0.03	90.0	10.0
Carpets	0.07	0.04	77.3	22.7
Canvas	0.11	0.10	69.8	30.2
Knitting	0.12	0.08	91.2	8.8
Clothing	0.45	0.35	89.2	10.8
Footwear	0.08	0.08	90.8	9.2
Manufactures	16.97	9.05	80.3	19.7
Services	69.23	79.99	68.6	31.4

* Vegetables, cotton, oilseeds, and tobacco.

** Cotton ginning and wool scouring.

Table 3: Production of multi-commodity industries (%)

Commodity	Pastoral	Wheat Sheep	High Rain	Northern Beef	Milk Cattle	Cane, Fruit, Nuts	Other Farming
				Industry			
			Commodity, by Industry				
Wool	15.9	50.0	34.1	0.0	0.0	0.0	0.0
Sheep	6.5	56.6	36.9	0.0	0.0	0.0	0.0
Wheat	4.0	94.1	1.9	0.0	0.0	0.0	0.0
Barley	3.1	85.7	11.3	0.0	0.0	0.0	0.0
Other Grains	2.4	75.2	22.4	0.0	0.0	0.0	0.0
Meat Cattle	8.4	33.4	27.3	24.2	6.7	0.0	0.0
Milk Cattle	0.1	6.9	2.4	0.0	90.6	0.0	0.0
Cane, Fruit, Nuts	0.0	0.3	0.5	0.0	0.0	99.2	0.0
Other Farming	1.2	4.1	5.6	0.0	0.0	0.0	89.1
			Industry, by Commodity				
Wool	43.8	19.8	31.9	0.0	0.0	0.0	0.0
Sheep	4.6	5.7	8.8	0.0	0.0	0.0	0.0
Wheat	8.1	27.2	1.3	0.0	0.0	0.0	0.0
Barley	3.0	11.9	3.7	0.0	0.0	0.0	0.0
Other Grains	2.6	11.3	7.9	0.0	0.0	0.0	0.0
Meat Cattle	33.7	19.3	37.3	100.0	10.7	0.0	0.0
Milk Cattle	0.2	2.5	2.1	0.0	89.3	0.0	0.0
Cane, Fruit, Nuts	0.0	0.1	0.3	0.0	0.0	100.0	0.0
Other Farming	4.1	2.1	6.8	0.0	0.0	0.0	100.0

Table 4: Central case values for exogenously specified parameters

Rest-of-world export demand elasticity for wool	3.0
Armington elasticity (σ)	4.0
Domestic-export transformation elasticity (τ)	4.0
Transformation elasticity in multi-commodity industries (η)	0.5
Substitution elasticity between capital and labour in wool-producing industries (γ)	0.75

Table 5: Percent change in volume of production when optimal export tax is charged

Export Demand Elasticity	λ	Wool	Ginning	Wool Yarn
-1.5	0.25	-46.9	64.1	3.5
	0.0	-60.4	11.5	1.2
-3.0	0.25	-36.1	50.6	2.9
	0.0	-51.7	13.2	1.2
-4.5	0.25	-32.0	44.9	2.7
	0.0	-49.4	13.3	1.2

Table 6: General equilibrium response of wool demand to a 25 percentage point increase in export tax on wool

τ	Total Export Demand Elasticity	Total Domestic Demand Elasticity
0.5	−1.88	−1.18
1.0	−1.86	−1.56
2.0	−1.85	−2.03
4.0	−1.83	−8.19
8.0	−1.80	−11.04
12.0	−1.78	−14.99
25.0	−1.73	−23.90
50.0	−1.69	−32.78
100.0	−1.66	−41.06