Previous Supply Elasticity Estimates For Australian Broadacre Agriculture

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Acronyms and Abbreviations Used in the Report

AAGIS	Australian Agricultural and Grazing Industries Survey
ABARE	Australian Bureau of Agricultural and Resource Economics
APPMA	Aggregate Programming Model of Australian Agriculture
BAE	Bureau of Agricultural Economics
BEEF CRC	Cooperative Research Centre for the Cattle and Beef Industry
CET	Constant Elasticity of Transformation
CRETH	Constant Ratios of Elasticities of Transformation, Homothetic
EDM	Equilibrium Displacement Model
EMABA	Econometric Model of Australian Broadacre Agriculture
LP	Linear Programming
MLA	Meat and Livestock Australia
OLS	Ordinary Least Squares
ORANI	a computable general equilibrium model of the Australian economy
QP	Quadratic Programming
R&D	Research and Development
RPM	Regional Programming Model
WEEDS CRC	Cooperative Research Centre for Weed Management Systems

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Executive Summary

Reliable estimates of the responsiveness of the supply of and demand for agricultural products to prices and other factors are fundamental to accurate economic forecasting, valid analyses of the impacts of new production technologies or promotion campaigns, and effective policy decision making. This requirement holds true whether the estimates are used by academics, government departments such as NSW Agriculture, research institutions such as ABARE or the Beef CRC, or producer organisations such as MLA.

This paper reports a listing and review of some previous supply elasticity estimates for major Australian broadacre agricultural products. The review includes some of the early quantitative work from the 1960s (such as the survey by Gruen *et al.* 1967), the major programming studies of the 1970s (such as APMAA and RPM as reported in Wicks and Dillon 1978 and Longmire *et al.* 1979, respectively), and the mainly econometric studies of the late 1980s and 1990s (such as EMABA, Wall and Fisher 1987, and Kokic *et al*. 1993). However, not all of the studies that have been conducted in the area have been able to be covered in the review.

The studies reviewed vary substantially in terms of geographic coverage, sample periods, estimation method, functional form, other explanatory variables included and reliance on the underlying production theory. Data limitations restrict the majority of studies to estimates of aggregate supply elasticities, although most studies do break down the estimates into different states or agro-climatic Zones. There is a mixture of estimates by length of run. Inspection of the estimates in Tables 1, 2, 3 and 4 reveals major discrepancies. This is indicative of the lack of consensus regarding supply response in Australian agriculture.

An unresolved issue is the relative merit of the mathematical programming and econometric models. In terms of the relative outcomes of the two model types, the main observable difference is that elasticities generated from programming models are generally higher than those from econometric models. Hall, Fraser and Purtill (1988) give several reasons why such a difference can be expected. Programming models permit a higher level of disaggregation, which has served to illustrate variations in supply response by region and by farm type that would be hidden by an aggregate model. However, Kokic *et al.* (1993) have attempted to bring this disaggregation into an econometric model, using AAGIS information at the farm level to provide a highly detailed cross-sectional picture of broadacre agriculture.

There is consensus that when the price of a product rises, the response in supply takes two forms. The first is the expansion effect or the net increase in output of one or more products, and second is the transformation effect which reflects the change in the mix of products along the production frontier, resulting from the greater relative profitability of the product whose price has risen. Generally, as a measure of the expansion effect, own-price supply elasticities for the four products covered in this review are inelastic, although some of the programming estimates exceed unity in the medium to long run. The wheat estimates tend to be larger than the livestock estimates, as there is more flexibility to alter cropping acreages than livestock numbers, especially in the short to medium run. Similarly, the estimates for the Wheat-Sheep Zone tend also to be larger than either the High Rainfall or Pastoral Zones, as transformation possibilities are greater in the former region.

There is little agreement over the values for cross-price elasticities of supply, because there are a variety of assumptions used to restrict the values or the signs of the transformation effects. Vincent, Dixon and Powell (1980) assumed the expansion effect to be positive, and the transformation effect to be negative. Wall and Fisher (1988) used similar assumptions. The ORANI model (Adams 1987) in its treatment of inputs as non-specific to outputs, expresses the jointness of production in terms of production systems or composite products. Cross-price elasticities for these composite products have been constrained to be negative, but no such constraint has been made for individual products, and under certain circumstances, the cross-price elasticity for transformation may also be positive. In the econometric results, some cross-price elasticities are unconstrained while others have been constrained to be positive. Generally however, cross-price elasticities are also inelastic and mostly negative, although sheepmeat and wool are often estimated to have a positive cross-price elasticity as they are joint products.

1 Introduction

Reliable estimates of the responsiveness of the supply of and demand for agricultural products to prices and other factors are fundamental to accurate economic forecasting and valid policy decision making. For example, own-price elasticities of demand indicate the extent to which buyers vary their purchases as the price of the product rises or falls. These variations are measured as movements along the demand curve. Cross-price elasticities of demand provide a framework for understanding the interactions in food and fibre choice decisions by consumers. These are reflected in shifts in the location of demand curves. This understanding is necessary for the accurate analysis of the response of consumers to changes in prices of products due to changes in their external environment.

Similarly, own-price elasticities of supply indicate the extent to which producers will expand or contract output, over different lengths of run, as the price for a product rises or falls. These are measured as movements along the supply curve. Cross-price elasticities of supply provide an understanding of the output and input interactions between different but closely related production enterprises. These are measured as shifts in the location of the supply curve. Such an understanding is necessary for the accurate analysis of the farm level impacts of new production technologies, promotion campaigns or policy changes, in a multi-product farming system. These interactions are particularly important in the Australian broadacre agricultural sector where many different enterprises are practiced on many farms. For example, in a recent Australian Bureau of Agricultural and Resource Economics (ABARE) analysis of broadacre agriculture (Riley *et al.* 2001), the average non-specialist beef producer (with more than 50 cattle) received at least 10 per cent of total cash receipts from each of cattle, sheep, wool and grain sales. There were more than 20,000 properties in this category.

Many of the types of analyses mentioned above are conducted using simulation experiments with structural econometric models (eg, Dewbre *et al.* 1985; Vere, Griffith and Jones 2000), where the relationships describing producer and consumer decision making are estimated using historical data. In such cases, the relevant elasticity values are embedded in the model. Such analyses are preferable if the required data and resources are available.

In other cases, perhaps because of a lack of historical data or a lack of time required to properly estimate an empirical model, analyses are conducted using simulation experiments with a synthetic model of the industry of interest (eg, Hill *et al.* 1996; Zhao *et al.* 2000). In these situations, the elasticity values have to be assumed or synthesised from theory or the empirical literature. The question for researchers constructing such models is which value to choose?

In a companion paper (Griffith *et al.* 2001), previous demand elasticity estimates for the Australian meat industries are reported. In this paper, previous supply elasticity estimates for Australian broadacre agriculture are reviewed and analysed. One aim is to present base parameters for use in policy reviews and for incorporation into equilibrium displacement models (EDMs) of the grazing and cropping sectors. Such exercises could be part of National Competition Policy legislative reviews or for studies on the evaluation of livestock sector R&D or advertising investments. An example of the latter is the study by Zhao *et al.* (2000) which used an EDM of the beef industry and related sectors to evaluate the returns from cost-reducing R&D at different levels of the beef production and marketing chain. Similarly, Hill *et al*. (1996) used an EDM of the fibre market to evaluate the returns from incremental wool promotion expenditure.

Another aim of this Report is to present a range of prior estimates from different sorts of modelling frameworks against which new estimates can be compared and contrasted.

The review reported here considers the major programming studies of the 1970s, such as APMAA and RPM (Wicks and Dillon 1978, Longmire *et al.* 1979), and the mainly econometric studies of the late 1980s and 1990s (of which EMABA, Wall and Fisher 1987, Kokic *et al*. 1993, and Vere *et al.* 2000 are prominent examples). Included are several major surveys including Gruen *et al.* (1967), Adams (1988) and Johnson *et al.* (1990). While these previous reviews provide important evaluations of the state of knowledge about broadacre supply at different points in time, they are now quite dated. Since it is likely that elasticity values vary over time with changes in the external environment, and that there have been major changes in industry structures in recent years with deregulation and the like, it is crucial to have as current an assessment as possible when applying these parameters to current policy or R&D analyses.

Estimates of supply response parameters are reviewed in Section 2 and tabulated in Tables 1, 2, 3 and 4, for cattle, sheep for meat, wool, and wheat, respectively. Australian broadacre agriculture involves the major grazing and cropping enterprises, so supply studies have concentrated on the products from these enterprises. Furthermore, these products dominate the Australian agricultural sector. "Broadacre agriculture accounts for 65 percent of commercial farms in Australia and about 60 percent of value of agriculture output." (Hall *et al*. 1988, p362). Broadacre agriculture is also subject to the greatest change in product mix due to the multi-product nature of these enterprises. As well as disaggregation across these major product lines, most studies disaggregate broadacre agriculture into three main agricultural regions: the Pastoral Zone, the Wheat-Sheep Zone and the High Rainfall Zone. These Zones are geographically defined, aggregating farms with similar climatic and technological conditions. It is usually considered necessary to maintain this separation as each of the regions has a comparative advantage in the production of certain products. The various elasticity values reflect these specialisations. They also highlight the range of products that may be considered to be viable alternatives if economic and seasonal conditions are favourable.

Most of the other agricultural industries in Australia (such as feedlotting, dairying, horticulture, viticulture, pig and poultry production) are very intensive and require an expensive capital infrastructure. This restriction prevents any significant substitution between the products from these industries and broadacre products (although some of these other industries are increasingly being located in the major broadacre regions as described above). Some examples of the types of studies conducted in these industries are Buffier and Freebairn (1975) and Clark *et al.* (1992) for beef feedlots and Lembit and Hall (1987) for dairying.

The comparisons of supply elasticities in Tables 1 to 4 reveal wide disparities. This is due to factors such as the level of disaggregation assumed for the production system, the specification of the underlying production technology, the type of data from which the elasticities were evaluated, the sample period covered, the adjustment period allowed and the estimation technique.

Past work on the estimation of agricultural supply response has followed two very different paths. The first is the positive or econometric approach, which uses time-series data to establish relationships between known variables and to predict supply response on the basis of past trends. The second is the conditionally predictive, normative or programming approach, which typically uses synthetic data generated from cross-sectional surveys, to provide inputs into a complex system of programming equations. It is argued that the latter approach will for various reasons tend to give higher estimates of supply elasticities especially in the medium and long run, and will provide a possibly sounder basis for the estimation of long-run supply response. However in the estimation of cross-price elasticities of supply and the modelling of behavioural equations to express livestock inventory dynamics, the econometric approach has so far been superior.

2 Previous Supply Elasticity Studies

2.1 Background

The supply studies reviewed in this Report are related to broadacre agriculture. This sector of the agricultural economy comprises mainly multi-product farms whose production is influenced by a large number of factors. Some of these such as climate, input prices and technical change can cause large changes in the levels of products produced. However, these effects are typically exogenous to the agricultural sector and have to be taken as given by producers. As for the demand studies discussed in the companion volume (Griffith *et al.* 2001), the principal concern of researchers and policy analysts has been the responsiveness of the output of farm products to changes in their prices. The elasticity estimates derived from these studies form an important component of the economic structure of the agricultural sector and of how the sector will respond to various external shocks.

The nature of agricultural production, with its biological constraints such as cropping seasons, rotation patterns, pasture growth patterns and livestock gestation periods, and the long lead times in bringing new land into use, means that the short-term response to price changes is limited. The short run is long enough to adjust the composition of outputs and the employment of variable inputs such as labour, but too short to adjust fixed endowments of livestock, land and capital. Supply response in agriculture therefore universally exhibits a pattern of rising responsiveness, and thus rising elasticity estimates, with increasing time horizons. However, cropping enterprises are far more elastic in the short run than the grazing animal enterprises as significant changes in planting decisions can be made from year to year. Animal breeding strategies take a much longer period to implement (Vere, Griffith and Bootle 1993).

As previously mentioned, research into supply response in agriculture has proceeded in two major directions. The first is the 'positive' method. Here, a set of time-series data on the actual behaviour in the market for a particular product, or group of products, is used to estimate a **supply function by econometric methods**. Observations on the dependent variables (mainly quantity of the product produced) are related to observations on the set of independent variables (typically price of the product produced, prices of other products capable of being produced from the same factors, prices of these factors, climatic conditions, attitudes to risk, and other factors). These are used in policy analysis and in forecasting future behaviour. Applications of this method to Australian broadacre product supply include among others Gruen *et al.* (1967), Freebairn (1973), Vincent, Dixon and Powell (1980), McKay, Lawrence and Vlastuin (1983), Adams (1987), Wall and Fisher (1987) and Kokic *et al.* (1993).

The second approach to supply response analysis is referred to as the conditionally positive, conditionally predictive or normative method. This involves the construction of a simulation model of the sector or sectors under consideration, to generate of a set of input and output quantity data under the assumption of a profit or utility maximisation objective of producers, subject to physical, financial and behavioural limitations. This is the ***programming approach to supply response***, and it has been applied to the Australian broadacre agricultural sector in two families of programming models. The Bureau of Agricultural Economics (BAE, now ABARE) series of models began in 1974, and has since been developed into the RPM of broadacre agriculture by Hall and Menz (1985) and Hall, Fraser and Purtill (1988). APMAA, developed from 1972 onwards at the University of New England, has produced supply elasticity estimates which were released by Wicks and Dillon (1978). Estimates of Australian broadacre supply elasticities using both types of model are presented in Tables 1, 2, 3 and 4.

2.2 Econometric Studies

The typical broadacre production system in Australia is capable of producing several different products, often at the same time off the same land. In explaining the supply of broadacre farm products, it has been found more useful to design models of the complete broadacre farming system, or as it is sometimes known, the crop/livestock complex. The task of supply response analysis in the econometric tradition particularly has been to develop functional forms and assumptions that recognise this essential jointness of production relations in this component of Australian agriculture.

Gruen *et al.* (1967) (the Monash Study) expressed the range of choices facing the agricultural unit or system in terms of production possibility curves, the producers' equivalent of consumer indifference curves. A model was developed containing a set of transformation surfaces between various products, characterised by the assumption of constant elasticities of transformation (CET) (ie, elasticities of the rate at which the mix of outputs can be altered for a fixed set of inputs). A given agricultural unit with a two-product production frontier was assumed to be equally able to shift from producing product A to producing product B, or from B to A, for the same relative movements in prices. Some of the transformation elasticities were constrained to zero, partly because some of the product pairs would have very low transformability, and partly because the output of some sectors were also intermediate products for other sectors within the system (eg, coarse grains). See also Powell and Gruen (1967) for more detail on this approach.

A six-equation model of Australian agriculture was estimated under the above assumptions. The short-run elasticity of beef supply was estimated at 0.16, but no attempt was made to calculate the intermediate or long-run elasticities owing to autoregression and other estimation problems. The short-run elasticity of wheat supply was 0.16 and in the long run it increased (as expected) to 3.82. Wool was a substitute output for wheat in the short run, and a cross-price elasticity of -0.11 was estimated between these two products. The short-run elasticity of wool supply was 0.05 and in the long run this value rose to 3.59. Wool was found to have no significant substitute products in supply in the short run. Finally, the short-run price elasticity of sheepmeat output was 0.25 and in the long run it increased to 3.20. Sheepmeat was also found to have no significant substitutes in the short run.

The Monash approach was adapted by Freebairn (1973), using less restrictive assumptions on the symmetry constraints of the estimates, to provide inventory response as well as supply response for the cattle and sheep sector in New South Wales. Freebairn found a four-year own-price elasticity of beef supply of 0.11 and a cross-price elasticity with respect to the price of wool of -0.19. Other econometric studies of supply response in mainly single products that were published around this time included Throsby (1974) on beef, Malecky (1975) on wool, Reynolds and Gardiner (1980) on wool and sheepmeat, and Sanderson *et al.* (1980) on wheat.

A major econometric contribution to agricultural supply analysis has been in the form of contributions to the parameter requirements of the ORANI synthetic computable general equilibrium model of the Australian economy (Dixon *et al*. 1982). This followed from the earlier Powell and Gruen (1967) study. The original ORANI model recognised eight agricultural industries. Three of these were multi-product industries in the Pastoral, Wheat-Sheep and High Rainfall Zones, and five were single-product industries. The ORANI system incorporated the multi-product possibilities of the typical Australian broadacre unit, by treating inputs as completely non-specific to outputs, so that no factor had a comparative advantage in the production of any output. This assumption reduced the number of derived elasticities to a manageable level and allowed relatively simple equations to be derived. The function used in the product transformation schedule of this model was a less restrictive version of the CET, known as CRETH (constant ratio of elasticities of transformation, homothetic). The supply response equations used the CRETH function to solve for revenue maximisation, with given prices for inputs and outputs and a given production capacity. Vincent, Dixon and Powell (1980) used the CRETH function and BAE data on output, input, revenue and cost variables for the broadacre sector from 1952/53 to 1973/74 to estimate parameter values required in the ORANI model. Short-run elasticities were estimated for each of the High Rainfall, Wheat-Sheep and Pastoral Zones, where appropriate.

The short-run price elasticity of beef supply was estimated to range from 0.34 in the High Rainfall Zone up to 1.01 in the Pastoral Zone, the short-run elasticity of wheat supply from 0.62 to 2.65, the short-run elasticity of wool supply from 0.06 to 0.26, and the short-run elasticity of sheepmeat output from 0.11 to 0.23, respectively. The cross-price elasticities were generally very small among the various livestock products and especially in the High Rainfall and Wheat-Sheep Zones. Conversely, the cross-price elasticities were generally significant between the various livestock and crop products and especially in the Pastoral Zone. For example, cattle and wheat were found to be significant substitutes with each other (-0.68 and –1.72, respectively) and with wool (-0.33 and –0.93, respectively) in the Pastoral Zone. Neither wool nor sheepmeats supply showed evidence of large cross-price elasticities in the short run.

Later, Adams (1987) produced new estimates for the ORANI model using updated and revised figures derived from BAE data. However, the elasticities were very sensitive to the particular database used, and the preferred figures were generated from a synthetic set of agricultural data constructed to represent a "typical year", over the period 1967/68 to 1979/80. While still relating to the short run, these values were estimated for Australia as a whole rather than for the various Zones as done by Vincent *et al.* (1980). The estimates tended to fall within the ranges produced in the earlier study, with the major difference being evidence of positive cross-price elasticities between the various livestock products, indicating complementarity in these enterprises. These results indicate the differences in estimates that arise from different data periods and levels of aggregation.

An equally tightly-constrained theoretical approach was followed by McKay, Lawrence and Vlastuin (1983), using a translog form of a variable profit function. The advantage of this approach over that used in ORANI (Vincent *et al.* 1980, Adams 1987) was that inputs can be specific to outputs. The model was applied to three multi-product broadacre outputs: sheep and wool, crops, and cattle and "other"; and to five inputs: labor and materials/services (variable), and land, livestock and capital (assumed to be fixed, but valued at shadow prices). Time was also used as an explanatory variable to represent the level of technology. The share equations derived from this function were estimated using BAE Australian Sheep Industry Survey data. Again, the estimates were for the short run and for Australia as a whole, and were broadly comparable with the aggregate estimates of Adams (1987).

Wall and Fisher (1987) also incorporated theoretical restrictions provided by production theory into their model. The model was based on the behaviour of a multiple-input, multiple-output firm facing given prices and a given production technology. They specified and estimated three alternative flexible functional forms for each of the three production Zones, and for a medium-term time horizon instead of the short run. The translog function was the preferred form. For this model and in line with most previous work, almost all estimated elasticities were less than one. For example, the medium-run own-price elasticity of beef supply was estimated to range from 0.16 in the High Rainfall Zone up to 0.27 in the Pastoral Zone, the short-run elasticity of wool supply from 0.19 to 0.26, and the short-run price elasticity of sheepmeat output from 0.46 to 0.49. The cross-price elasticities were generally also small among the various livestock products, especially in the High Rainfall and Wheat-Sheep Zones, although the wool and cattle, and wool and sheepmeat, cross-elasticities were around -0.50.

Conversely, the elasticity of wheat supply was larger, ranging from 0.47 to 1.66 (and up to 2.67 in other functional forms), and the cross-price elasticities were generally significant between the various livestock and crop products. For example in the Wheat-Sheep Zone, sheepmeat and wheat were found to be significant substitutes (-0.49).

In contrast to the relatively complex and restrictive production systems of the preceding studies, Fisher and Munro (1983) used a less tightly-specified model. Data were derived from a cross-sectional survey of properties carrying 200 or more Merino sheep in New South Wales. Intended numbers of livestock were regressed against current output, expected product prices and a technology variable indicative of the proportion of improved pasture on each establishment, using OLS. Medium-term livestock own-price elasticities for three New South Wales statistical divisions were calculated to be broadly in line with previous estimates of around 0.50. However considerably higher cross-price elasticities were estimated – for example –1.35 between cattle and sheepmeat, and –1.27 between cattle and wool, in the New South Wales South-West Slopes region.

The EMABA model (Dewbre *et al*. 1985) also contained econometric estimates of Australian livestock and crop supply response parameters. Medium run estimates of own-price elasticities for beef, lamb and wool were all around the 0.3-0.5 range, close to estimates provided by previous researchers. Cross-price effects were generally small and negative, indicating substitution possibilities in the output of these products. Myers *et al.* (1985) also published on wheat supply response at this time.

ABARE's latest supply response study (Kokic *et al*. 1993) provided own- and cross-price elasticities of supply for the Australian broadacre products of beef, mutton, lamb, wool and wheat. The estimates were disaggregated by ABARE region, for five farm types: beef, sheep, sheep-beef, crops (mostly wheat), and mixed crop-livestock enterprises. The analysis used a farm level econometric model of farm cash income, with a net income maximisation function subject to a fixed land area constraint. Elasticities were expressed as functions of the unit cost of production and unit return to production. The unit land area required to produce each of the products were estimated for each year from 1980 to 1991, using cross-sectional data from the Australian Agricultural and Grazing Industries Survey (AAGIS) for that year, and averaged over the eleven-year period. The estimation involved the use of M-quantile regression techniques. However the study did not incorporate dynamic response functions in the model, and therefore livestock inventory changes could not be included. For beef, the eleven-year national average own-price elasticity of supply was estimated at 0.10. The elasticity in the Wheat-Sheep Zone was highest at 0.15, reflecting the greater opportunities for substitution between different farm products in this region. Conversely, the lowest elasticity was in the Pastoral Zone, where there are few or no alternative uses for land. Other own-price elasticities were broadly in the midinelastic range, as for previous work, with the exception of the sheepmeat elasticities that ranged between 1.37 and 2.17. All estimated cross-price elasticities were very small, with the largest being –0.13.

Following earlier work on the lamb industry (Vere and Griffith 1988, Griffith *et al.* 1995), recent econometric modelling of the grazing livestock industries by Vere *et al.* (2000) was based on a very disaggregated approach to specifying inventory and output decisions. As such, the estimated "supply" response parameters were not directly comparable to the estimates listed above. In addition, the model was based on quarterly data. However, in general the short-term inventory elasticities for cattle and sheep were all quite small, while the long-run estimates were much larger and broadly in line with most previous estimates.

2.3 Programming Studies

The second approach to analysing broadacre supply response involves constructing a normative model of a farm or region, and applying a set of synthetic expected prices to simulate behaviour of that model farm or region under certain assumptions or conditions.

Programming models face rapidly increasing levels of complexity with each additional variable introduced. This usually limits these models to a static form as the introduction of dynamic elements involves the creation of a separate matrix for each time period of the analysis, leading to major problems of size and manageability of the matrix. In the case of APMAA, flexibility constraints were introduced to the model so as to reflect intermediate-run response and give a time or dynamic element to the matrix.

The APMAA model was in fact highly disaggregated, comprising 521 representative farms each modelled as a linear program. The farms were categorised into six farm types (sheep-grain, sheep, grain, beef cattle, dairy cattle and multi-purpose), and three sizes (small, medium or large), within each BAE region. Some simplifying assumptions were used to reduce the number of solutions to a feasible level.

Price data for these products were formulated by selecting high and low points, and adding three equally-spaced intermediate prices to give five price levels for each product. The model was run for each combination of these levels to give 5^3 = 125 points on a four-dimensional response surface. Quadratic functions were fitted to these data using conventional OLS regression, and elasticity estimates derived using two scenarios. In Scenario 1, livestock numbers and cropped land area were allowed to increase by 10 per cent, and in Scenario 2 by 30 per cent, above trend values. Scenario 1 therefore represents a short-run and Scenario 2 more of an intermediate-run analysis. Elasticities were computed for each Zone and for Australia as a whole.

The APMAA short-run elasticities for cattle supply ranged between 0.46 and 0.69, while the longer run values were between 0.64 and 1.01, or about 50 per cent larger. Cross-price elasticities with wool were generally around –0.4, while those with wheat were much more variable and ranged between –0.10 and –1.29. Again, the medium-run values were larger than the short-run values. For wool supply, a similar picture was found – relatively inelastic own- and cross-price elasticities, with cattle and wheat competing for the same resources as required for wool production. Finally for wheat supply, although the cross-price elasticities were relatively small and negative, the own-price elasticities were considerably larger than those for the livestock products. For example, the estimated values for the Wheat-Sheep Zone and Australia as a whole were all elastic, with even the short-run estimates reaching 1.31 and 1.10 respectively.

In contrast to the APMAA model, which assumed no interdependence between representative farms, the BAE's RPM explicitly set out to model links and flows of intermediate products between farms and regions. A complete analysis was first set out in Longmire *et al*. (1979). The RPM used linear programming to optimise a single large matrix, made up of regional submatrices, each using combinations of farm resources and products appropriate to the region's agriculture. Each regional submatrix was subdivided into components modelling feed supply, cropping, sheep, beef cattle, labour and capital. Other activities and resource flows (for example trading and transport) were added to the model at a national level.

The three standard BAE regions were further divided into thirteen relatively homogeneous regions, each comprising a continuous land area. The borders between regions followed local government boundaries for ease of mapping and statistical information. Farm-level data obtained mostly from the 1974-75 AAGIS were used to calculate some 18,500 coefficients that were included in the submatrices and ultimately in the overall matrix. As in the APMAA model, a time dimension was included in the RPM using an adapted recursive programming technique, limiting change to that expected over a five-year period by the use of wide flexibility restraints.

While the initial RPM results were reported in Longmire *et al.* (1979), Hall and Menz (1985) presented supply elasticity estimates derived from an updated version. Boundaries of the regions used in the model were changed in line with revised BAE regions. Product sales and input purchases were now simplified by being modelled at a national level, while the flexibility constraints of the original model were removed. A full factorial design of solutions (as adopted by APMAA) would have yielded an excessive 625 points in this model, and was therefore rejected in favour of a central composite design giving 31 response points.

The intermediate own-price elasticity for cattle supply was found to be 1.34, considerably larger than either the earlier BAE results or the APMAA results. The cross-elasticities with sheepmeat (-0.62) and wool (-0.80) were also considerably larger than the earlier estimates. A similar pattern was found for the sheepmeat and wool elasticities. For wool in particular, the medium run own-price elasticity was estimated to be 2.02, compared with an equivalent value of 0.36 generated by the APMAA model. In contrast, the results for wheat are much more inelastic than those obtained from the APMAA model, 0.59 compared with 1.26, while the cross-elasticities are reasonably similar.

A further updating of the RPM using 1983-84 coefficients (Hall, Fraser and Purtill 1988) produced supply response estimates not only disaggregated by region, but also against an index of price levels for the respective products. The model was further extended into a long-term version. The own-price elasticity estimates from this model, unlike those from ORANI, were different at different price levels. It was shown that in all cases, the supply elasticity decreased as the price increased, and vice versa. The authors used this finding to explain some of the discrepancies in results compared to earlier work. However, the different models used different periods to obtain their data and price in this case was subject to considerable change over time. The elasticity values reflected this.

One interesting result from this study was the differences between the long-run and medium-run estimates. For the three livestock products, the long run values were more than four times as large as the medium run values. For example, the values for the cattle own-price elasticities were

2.40 and 0.50, respectively. This reflected to some extent the biological constraints of increasing the output of livestock products and the time required to overcome these contraints. However for wheat, the medium-run value was 1.10 and the long-run value was only 1.40. This suggests that decisions to increase wheat output do not face the same sorts of biological constraints and they can be implemented in a relatively short period of time.

The studies described above all assumed a neutral attitude to risk, namely that the impact of risk on output levels will be nil assuming other variables remain unchanged. Easter and Paris (1983) explored the opposite case, that Australian agriculture is characterised by variability and risk, both market-related (price variability) and supply-related (yield variability). Previous research had shown (Francisco and Anderson 1972) that the impact of risk was important in determining output levels. Price expectations, alternative resource use prospects, agricultural policies and credit availability were also deemed to be significant in supply determination.

Easter and Paris used a mathematical programming model, assuming a utility-maximisation function with constant risk aversion, expressed as the Arrow-Pratt risk aversion coefficient. The value of this coefficient was in turn dependent on variables representing technological risks, actual realised levels of production, and price levels and fluctuations. A central composite design was used to generate a nonlinear response surface relating variables of total expected net revenue less risk premium, to the usual production variables of beef, wool, sheepmeat and wheat output. The results were quite similar to the relevant APMAA estimates, with comparable inelastic own-price elasticities for cattle and wool, and a larger but still comparable elastic own-price elasticity for wheat.

3 Comparison and Evaluation of Previous Supply Elasticity Estimates

Inspection of the various estimates of own- and cross-price elasticities of supply for the four major broadacre agricultural products reported in Tables 1, 2, 3 and 4 reveals major discrepancies. This is indicative of the lack of consensus regarding supply response in Australian agriculture. The task of comparing and evaluating the great disparity of estimates is if anything even more hazardous than for the demand studies, and would seem to be especially difficult for cross-price elasticities of supply. Differences in elements of the methodology of the various studies will provide a basis for comparison and evaluation.

The models considered for assessment here are APMAA (Wicks and Dillon 1978), ORANI (Adams 1987), Wall and Fisher (1987), RPM (Hall, Fraser and Purtill 1988), Johnson, Powell and Dixon (1990), and the ABARE farm level model (Kokic *et al*. 1993). Differences in datasets is in many cases a complicating factor in making such comparisons. The estimates of Wicks and Dillon (1978) used a level of disaggregation similar to later BAE/ABARE surveys, and most analysts are of the opinion that the data are comparable.

An unresolved issue is the relative merit of the programming as against the econometric models. Even a careful comparison of the two approaches was unable to establish a preference for either (Shumway and Chang 1977). Linear programming techniques are used to simulate farm and whole sector responses under conditions not experienced in time series data. This method is particularly suitable for analysis of new situations involving for example, longer-term shifts in the supply curve, development of new products or markets, and institutional changes such as the application of quotas or subsidies. In these cases the positive method is deficient because it works by summarising and drawing inferences from past observations and responses, and their application in new conditions may violate their underlying assumptions.

The programming approach has the advantage of eliminating data shortages and errors, as its observations are generated from a set of expected price parameters under the assumptions of profit or utility maximisation. The model can thus incorporate “expected” prices directly, instead of assuming relationships between actual and expected prices as in the econometric approach. Structural and technological changes can also be included directly into the model. The major disadvantage of the programming model is its complexity, and the associated problems of ensuring realism and internal consistency in the model’s many equations.

In terms of the relative outcomes of the two model types, the main observable difference is that elasticities generated from programming models are generally higher than those from econometric models. Hall, Fraser and Purtill (1988) give several reasons why such a difference can be expected. Programming models permit a higher level of disaggregation, which has served to illustrate variations in supply response by region and by farm type that would be hidden by an aggregate model. Kokic *et al.* (1993) have tried to bring this disaggregation into an econometric model, using AAGIS information at the farm level to provide a highly detailed cross-sectional picture of broadacre agriculture. Apart from sheepmeat however, their elasticity estimates were if anything lower than comparable estimates using more aggregate data.

By their nature, programming models can also solve for immediate responses to price changes, to produce a new optimum output level. Lags in response will be programmed out altogether, or assumed to be shorter than in the real world. In practice, there are sizeable lags in adjustment of livestock inventories to a change in prices. This means that the timing and level of the new equilibrium stock levels can be almost impossible to predict. Uncertainty regarding future prices also leads to a slower response, as farmers wait and see whether the change is a long-term trend or merely a short-term variation.

The formulation of the RPM allows freedom to estimate elasticities at any price level, unlike the econometric models that usually estimate values for the midpoint or the average of the time series data period. The own-price supply elasticities estimated from the RPM were found to decrease with increasing prices. The authors postulated a plausible explanation for this.

There is little agreement over the values for cross-price elasticities of supply. There is consensus that when the price of a product rises, supply response takes two forms. The first is the expansion effect or the net increase in output of one or more products, and second is the transformation effect which reflects the change in the mix of products along the production frontier, resulting from the greater relative profitability of the product whose price has risen. However, there are a variety of assumptions used to restrict the values or the signs of these effects. Vincent, Dixon and Powell (1980) assume the expansion effect to be positive, and the transformation effect to be negative. Wall and Fisher (1988) use similar assumptions. The ORANI model (Adams 1987) in its treatment of inputs as non-specific to outputs, expresses the jointness of production in terms of production systems or composite products. Cross-price elasticities for these composite products have been constrained to be negative, but no such constraint has been made for individual products, and under certain circumstances, the cross-price elasticity for transformation may also be positive.

A further area of doubt and debate concerns the issue of static versus dynamic modelling. The basis of the ORANI work is that fixed inputs create a fixed production possibility frontier: clearly a short-run scenario, with short-run responses. Implicit in the results is the assumption that “short run” means the same period for all products in the model, perhaps a questionable assumption given that there is no dynamic modelling in ORANI.

4 Conclusions

Accurate and reliable information about the responsiveness both of consumers and producers of products to changes in market prices is crucial if informed decisions are to be taken in various fields of policy. Modelling supply response has been one of the major concerns of agricultural economists in Australia and elsewhere.

The broadacre agriculture sector produces much of Australia's basic food and fibre needs as well as generating a significant amount of export income. So it is important to understand how producers react to price movements, especially for policy makers. When studying or estimating supply elasticities it is important to divide Australia into regions that are depicted by ABARE as the High Rainfall, Pastoral and Wheat-Sheep Zones. These Zones are each unique due to climate and physical limitations and usually have one product that has traditionally been more important. So actions by policy makers will have different effects on different Zones.

As discussed earlier there have been two broad approaches used to estimate supply response in broadacre agriculture - the programming approach and the econometric approach. However, neither of the two approaches can estimate all of the elasticities accurately. They both have strengths and weaknesses that must be taken into account when applying these estimates. The programming approach tends to give higher estimates and would tend to be better for long run estimation, while the econometric approach is better for the estimation of cross-price elasticities of supply. Linear programming techniques are often used to simulate farm and whole sector responses under conditions not experienced in time series data. This method is particularly suitable for analysis of new situations involving for example, longer-term shifts in the supply curve, development of new products or markets, and institutional changes such as the application of quotas or subsidies.

Inspection of the various estimates of own- and cross-price elasticities of supply for the four major broadacre agricultural products reported in Tables 1, 2, 3 and 4 indicates the lack of consensus regarding supply response in Australian agriculture. Generally, own-price elasticities for the four products covered in this review are inelastic, although some of the programming estimates exceed unity in the medium to long run. The wheat estimates tend to be larger than the livestock estimates, as there is more flexibility to alter cropping acreages than livestock numbers. Similarly, the estimates for the Wheat-Sheep Zone tend also to be larger than either the High Rainfall or Pastoral Zones, as transformation possibilities are greater in the former region.

There is little agreement over the values for cross-price elasticities of supply, because there are a variety of assumptions used to restrict the values or the signs of the transformation effects. Generally however, cross-price elasticities are also inelastic and mostly negative, although sheepmeat and wool are often estimated to have a positive cross-price elasticity as they are joint products.

A further issue concerns static versus dynamic modelling. The basis of much of the early econometric work is the idea of fixed inputs creating a fixed production possibility frontier: clearly a short-run scenario, with short-run responses. Implicit in the results is the assumption that "short run" means the same period for all products in the model. Dynamics are much better handled in modern production theory, where long run profit functions can be specified and estimated, and used to generate long run output supply functions.

In spite of the extensive history of supply response studies recorded here, some gaps remain. One is that (with the sole exception of Agbola (1999) for the Pastoral Zone), none of the tabulated studies include data extending beyond 1991. Thus all elasticity estimates have been done in an environment when the wool market, and to a lesser extent the wheat market, have been subjected to market stabilisation arrangements. An area of further research therefore could be an update and re-estimation of one of the more recently published models, so as to examine the hypothesis that price elasticities of supply are likely to be higher in an unregulated environment than in a regulated environment.

Another, related, gap is the lack of attention paid to the role of risk in supply response studies of broadacre agriculture in Australia. Easter and Paris (1983) was the last of the supply response studies reviewed here that had an explicit objective of evaluating producer responses in a stochastic environment. Deregulation of domestic marketing arrangements, increasing globalisation and increasing climatic variability are all good reasons for wishing to understand the role of risk in broadacre supply response.

5 References

Adams, P.D. (1987), "Agricultural supply response in ORANI", *Review of Marketing and Agricultural Economics* **55** (3), 213-29.

Adams, P.D. (1988), "Some comparisons of recent estimates of agricultural supply elasticities for the Australian economy", *Review of Marketing and Agricultural Economics* **56** (3), 352-60.

Agbola, F.W. (1999), The structure of production and investment in Australia's pastoral zone. Paper presented at the 43rd Annual Conference of the Australian Agricultural and Resource Economics Society, Christchurch, New Zealand, January.

Buffier, B.D. and Freebairn, J.W. (1975), "Response function estimates for lot fed beef", *Review of Marketing and Agricultural Economics* **43** (1), 40-51.

Clark, J., Lembit, M. and Warr, S. (1992), *A Regional Model of Australian Beef Supply*, ABARE Research Report 92.8, AGPS, Canberra.

Coelli, T.J. (1996), "Measurement of total factor productivity growth and biases in technological change in Western Australian agriculture", *Applied Econometrics*, **11**, 77-91.

Dewbre, J., Shaw, I., Corra, G. and Harris, D. (1985), *EMABA: Econometric Model of Australian Broadacre Agriculture*, BAE Technical Report, AGPS, Canberra.

Dixon, P. *et al.* (1977), *The ORANI Model of the Australian Economy: Current Specification and Illustrations of Use for Policy Analysis*, First Progress Report of the IMPACT Project, Volume 2, AGPS, Canberra.

Easter, C.D. and Paris, Q. (1983), "Supply response with stochastic technology and prices in Australia's rural export industries", *Australian Journal of Agricultural Economics* **27** (1), 12-30.

Fisher, B. and Munro, R.G. (1983), "Supply response in the Australian extensive livestock and cropping industries: a study of intentions and expectations", *Australian Journal of Agricultural Economics* **27** (1), 1-11.

Francisco, E.M. and Anderson, J.R. (1972), "Chance and choice west of the Darling", *Australian Journal of Agricultural Economics* **16** (2), 82-93.

Freebairn, J.W. (1973), "Some estimates of supply and inventory response functions for the cattle and sheep sector of New South Wales", *Review of Marketing and Agricultural Economics* **41** (2 and 3), 53-90.

Griffith, G., I'Anson, K., Hill, D., Lubett, R. and Vere, D. (2001), *Previous Demand Elasticity Estimates for Australian Meat Products*, Economics Research Report No. 5, NSW Agriculture, Armidale.

Griffith, G.R., Vere, D.T. and Bootle, B.W. (1995), "An integrated approach to assessing the farm and market impacts of new technology adoption in Australian lamb production and marketing systems: the case of large, lean lamb", *Agricultural Systems* **47**(2), 175-198.

Griffiths, W.E. and Anderson, J.R. (1978), "Specification of agricultural supply functions - empirical evidence on wheat in southern NSW", *Australian Journal of Agricultural Economics* **22** (2), 115-128.

Gruen, F.H. *et al.* (1967), *Long Term Projections of Agricultural Supply and Demand, Australia 1965-1980* (2 vols), Department of Economics, Monash University, Clayton.

Hall, N., Fraser, L. and Purtill, A. (1988), "Supply response in broadacre agriculture", *Review of Marketing and Agricultural Economics* **56** (3), 361-73.

Hall, N. and Menz, K.M. (1985), "Product supply elasticities for the Australian broadacre industries, estimated with a programming model", *Review of Marketing and Agricultural Economics* **53** (1), 6-13.

Harris, D. and Shaw, I. (1992), "EMABA: an econometric model of Pacific Rim livestock markets", in Coyle, W.T. *et al.* (eds*), Agriculture and Trade in the Pacific: Towards the Twenty-First Century*, Westview Press, Boulder.

Johnson, D.T., Powell, A.A. and Dixon, P.B. (1990), "Changes in supply of agricultural products", in Williams, D.B. (ed), *Agriculture in the Australian Economy,* 3rd ed., Sydney University Press and Oxford University Press, South Melbourne, 187-200.

Kokic, P., Beare, S., Topp, V. and Tulpule, V. (1993), *Australian Broadacre Agriculture: Forecasting Supply at the Farm Level,* ABARE Research Report 93.7, Australian Bureau of Agricultural and Resource Economics, Canberra.

Lawrence, D. and Zeitsch, J. (1989), Production flexibility revisited. Paper presented at the 33rd Annual Conference of the Australian Agricultural Economics Society, Christchurch, New Zealand, February.

Lembit, M. and Hall, N.H. (1987), Supply response on Australian dairy farms. Paper presented at the 31st Annual Conference of the Australian Agricultural Economics Society, Adelaide.

Longmire, J.L., Brideoake, B.R., Blanks, R.H. and Hall, N.H. (1979*),* *A Regional Programming Model of the Grazing Industry*, BAE Occasional Paper No. 48, AGPS, Canberra.

Low, J. and Hinchy, M. (1990), Estimation of supply response in Australian broadacre agriculture: the multi product approach. Paper presented at the 34th Annual Conference of the Australian Agricultural Economics Society, Brisbane, February.

Malecky, J.M. (1975), "Price elasticity of wool supply", *Quarterly Review of Agricultural Economics* **28**, 240-258.

McKay, L., Lawrence, D. and Vlastuin, C. (1980), "Input demand and substitution in the Australian sheep industry", *Review of Marketing and Agricultural Economics* **48** (2), 57-70.

McKay, L., Lawrence, D. and Vlastuin, C. (1983), "Profit, output supply, and input demand functions for multiproduct firms: the case of Australian agriculture", *International Economic Review* **24** (2), 323-339.

Myers, R.J., Piggott, R.R. and MacAulay, T.G. (1985), "Effects of past Australian wheat price policies on key industry variables", *Australian Journal of Agricultural Economics* **29** (1), 1-15.

Powell, A.A. and Gruen, F.H. (1967), "The estimating of production frontiers: the Australian livestock/cereals complex", *Australian Journal of Agricultural Economics* **11** (1), 63-81.

Reynolds, R.G. and Gardiner, B. (1980), "Supply response in the Australian sheep industry: a case for disaggregation and dynamics", *Australian Journal of Agricultural Economics* **24** (3), 196-209.

Riley, D., Gleeson, T., Martin, P. and Delforce, R. (2001), *Australian Beef Industry 2001*, Report of the Australian Agricultural and Grazing Industries Survey of Beef Producers, ABARE Research Report 01.8, Canberra.

Sanderson, B.A., Quilkey, J.J. and Freebairn, J.W. (1980), "Supply response of Australian wheat growers", *Australian Journal of Agricultural Economics* **24** (2), 129-140.

Shumway, C.R. and Chang, A.A. (1977), "Linear programming versus positively estimated supply functions: an empirical and methodological critique", *American Journal of Agricultural Economics* **59** (2), 344-57.

Throsby, C.D. (1974), "A quarterly econometric model of the Australian beef industry", *Economic Record* **50**, 199-217.

Vere, D.T. and Griffith, G.R. (1988), "Supply and demand interactions in the New South

Wales prime lamb market", *Review of Marketing and Agricultural Economics* **59**(3), 287-305.

Vere, D.T., G.R. Griffith and B.W. Bootle (1993), "Alternative breeding inventory specifications in a livestock market model", *Australian Journal of Agricultural Economics* **37** (3), 181-204.

Vere, D.T., Griffith, G.R. and R.E. Jones (2000), *The Specification, Estimation and Validation of a Quarterly Structural Econometric Model of the Australian Grazing Industries*, CRC for Weed Management Systems, Technical Series No. 5, University of Adelaide, Adelaide.

Vincent, D.P., Dixon, P.B. and Powell, A. A. (1980), "The estimation of supply response in Australian agriculture: the CRESH/CRETH production system", *International Economic Review* **21** (1), 221-242.

Vincent, D.P., Dixon, P.B. and Powell, A. A. (1982), "Changes in supply of agricultural products", in Williams, D.B. (ed.), *Agriculture in the Australian Economy,* 2nd ed., Sydney University Press and Oxford University Press, South Melbourne.

Wall, C.A. and Fisher, B.S. (1987), *Modelling a Multiple Output Production System: Supply Response in the Australian Sheep Industry*, Research Report No. 11, Department of Agriculture Economics, University of Sydney, Sydney.

Wicks, J.A. and Dillon, J.L. (1978), "APMAA estimates of supply elasticities for Australian wool, beef and wheat", *Review of Marketing and Agricultural Economics* **46** (1), 48-57.

Zhao, Xueyan, Griffith, Garry and Mullen, John (2000), Returns to new technologies in the Australian beef industry: on-farm research versus off-farm research. Paper presented to 44th Annual Conference of the Australian Agricultural and Resource Economics Society, Sydney, January.

TABLE 1. ELASTICITIES OF SUPPLY OF BEEF CATTLE IN AUSTRALIA

Year of Publn.	Researcher	Geographic Coverage	Length of run	Change in CATTLE output as a result of a change in the price of				Data Period	Method	Functional form
				Cattle	Sheepmeat	Wool	Wheat			
1967	Gruen *et al.*	Australia	S	0.16					Econometric	CET production frontier
1973	Freebairn	NSW	4 yrs	0.11	-0.01	-0.19			Econometric	2SLS
1978	Wicks/Dillon	High Rainfall Zone	S	0.56		-0.50	-0.10	1975-76	APMAA	
1978	Wicks/Dillon	Wheat-Sheep Zone	S	0.46		-0.23	-0.62	1975-76	APMAA	
1978	Wicks/Dillon	Pastoral Zone	S	0.49		-0.37	-0.22	1975-76	APMAA	
1978	Wicks/Dillon	Australia	S	0.69		-0.38	-0.44	1975-76	APMAA	
1978	Wicks/Dillon	High Rainfall Zone	M	0.89		-0.37	-0.15	1975-76	APMAA	
1978	Wicks/Dillon	Wheat-Sheep Zone	M	1.01		-0.32	-1.29	1975-76	APMAA	
1978	Wicks/Dillon	Pastoral Zone	M	0.64		-0.92	-0.29	1975-76	APMAA	
1978	Wicks/Dillon	Australia	M	0.90		-0.51	-0.65	1975-76	APMAA	
1979	Longmire *et al.*	Australia	S	0.69	-0.10	-0.18	-0.12		RPM	
1980	Vincent *et al.*	High Rainfall Zone	S	0.34	-0.01	-0.02	-0.31 (e)	1952-53 to 1973-74	Econometric	CRETH Production Function
1980	Vincent *et al.*	Wheat-Sheep Zone	S	0.48	-0.02	-0.08	-0.27(e)	1952-53 to 1973-74	Econometric	CRETH Production Function
1980	Vincent *et al.*	Pastoral Zone	S	1.01		-0.33	-0.68 (e)	1952-53 to 1973-74	Econometric	CRETH Production Function
1983	Fisher/Munro	NSW SW slopes	3 years	0.70	-1.35	-0.83		1978-79 (survey)	Econometric	linear
1983	Fisher/Munro	NSW West. Division	3 years	0.40		-1.27		1978-79 (survey)	Econometric	linear
1983	McKay *et al.(a)*	Australia	S	0.12		0.25	-0.48	1952-53 to 1976-77	Econometric	Translog variable profit function
1983	Easter/Paris	Australia	S	0.51 (b)		-0.04	-0.12		Programming	
1983	Easter/Paris	Australia	S	0.62 (c)		-0.20	0.01		Programming	
1985	Dewbre *et al.*	Australia	M	0.30	-0.04	-0.14			Econometric	
1985	Dewbre *et al.*	Australia	L	2.00					Econometric	
1985	Hall/Menz	Australia	M	1.34	-0.62	-0.80	0.02	1982-83	RPM	
1987	Adams	Australia	S	0.41	0.02	0.08	-0.12	1968-69	ORANI	
1987	Adams	Australia	S	1.18	0.19	0.48	0.03	1977-78	ORANI	
1987	Adams	Australia	S	0.60	0.07	0.18	-0.12	1977-78 Typical Year	ORANI	
1987	Wall/Fisher	High Rainfall Zone	M	0.14	-0.14	0.05		1968-69 to 1980-81	Econometric	Normalised Quadratic
1987	Wall/Fisher	Wheat-Sheep Zone	M	0.11	0.03	-0.09	-0.14	1968-69 to 1980-81	Econometric	Normalised Quadratic
1987	Wall/Fisher	Pastoral Zone	M	0.43	-0.28	0.00	0.02	1968-69 to 1980-81	Econometric	Normalised Quadratic
1987	Wall/Fisher	High Rainfall Zone	M	0.12	-0.15	0.03		1968-69 to 1980-81	Econometric	Generalised Leontief
1987	Wall/Fisher	Wheat-Sheep Zone	M	0.11	-0.07	-0.06	-0.05	1968-69 to 1980-81	Econometric	Generalised Leontief
1987	Wall/Fisher	Pastoral Zone	M	0.35	-0.33	-0.01	0.02	1968-69 to 1980-81	Econometric	Generalised Leontief
1987	Wall/Fisher	High Rainfall Zone	M	0.16	-0.11	0.07		1968-69 to 1980-81	Econometric	Translog
1987	Wall/Fisher	Wheat-Sheep Zone	M	0.22	0.16	-0.43	0.26	1968-69 to 1980-81	Econometric	Translog
1987	Wall/Fisher	Pastoral Zone	M	0.27	0.05	-0.55	0.05	1968-69 to 1980-81	Econometric	Translog
1988	Hall *et al.*	Australia	L	2.40	-0.50	-1.90	0.30	1983-84	Updated RPM	
1988	Hall *et al.*	Australia	M	0.50	-0.10	-0.10	0.10	1983-84	Updated RPM	

TABLE 1. (con't) ELASTICITIES OF SUPPLY OF BEEF CATTLE IN AUSTRALIA

Year of Publn.	Researcher	Geographic Coverage	Length of run	Change in CATTLE output as a result of a change in the price of				Data Period	Method	Functional form
				Cattle	Sheepmeat	Wool	Wheat			
1989	Lawrence/Zeitsch	Australia	S	0.19 (d)			0.10 (e)	1972-73 to 1986-87	Econometric	Symmetric Generalised McFadden profit function
1989	Lawrence/Zeitsch	NSW	S	0.19 (d)			0.11 (e)	1972-73 to 1986-87	Econometric	Symmetric Generalised McFadden profit function
1989	Lawrence/Zeitsch	Victoria	S	0.19 (d)			0.11 (e)	1972-73 to 1986-87	Econometric	Symmetric Generalised McFadden profit function
1989	Lawrence/Zeitsch	Queensland	S	0.18 (d)			0.10 (e)	1972-73 to 1986-87	Econometric	Symmetric Generalised McFadden profit function
1989	Lawrence/Zeitsch	South Australia	S	0.18 (d)			0.10 (e)	1972-73 to 1986-87	Econometric	Symmetric Generalised McFadden profit function
1989	Lawrence/Zeitsch	Western Australia	S	0.19 (d)			0.10 (e)	1972-73 to 1986-87	Econometric	Symmetric Generalised McFadden profit function
1989	Lawrence/Zeitsch	Tasmania	S	0.20 (d)			0.11 (e)	1972-73 to 1986-87	Econometric	Symmetric Generalised McFadden profit function
1990	Johnson *et al.*	High Rainfall Zone	S	0.26	-0.01	-0.06	-0.167	1952-53 to 1973-74 1967-68 to 1980-81	Synthetic	
1990	Johnson *et al.*	Wheat-Sheep Zone	S	0.37	-0.01	-0.04	-0.18	1952-53 to 1973-74 1967-68 to 1980-81	Synthetic	
1990	Johnson *et al.*	Pastoral Zone	S	0.68		-0.16	-0.59	1952-53 to 1973-74 1967-68 to 1980-81	Synthetic	
1990	Low/Hinchy (f)	Australia	S	0.79		0.16	0.06	1978 to 1987	Econometric	Symmetric Generalised McFadden profit function
1990	Low/Hinchy (f)	NSW	S	0.87		0.15	0.07	1978 to 1987	Econometric	Symmetric Generalised McFadden profit function
1990	Low/Hinchy (f)	Victoria	S	0.81		0.19	0.06	1978 to 1987	Econometric	Symmetric Generalised McFadden profit function
1990	Low/Hinchy (f)	Queensland	S	0.87		0.16	0.06	1978 to 1987	Econometric	Symmetric Generalised McFadden profit function
1990	Low/Hinchy (f)	South Australia	S	0.84		0.22	0.08	1978 to 1987	Econometric	Symmetric Generalised McFadden profit function
1990	Low/Hinchy (f)	Western Australia	S	0.84		0.16	0.06	1978 to 1987	Econometric	Symmetric Generalised McFadden profit function
1992	Harris/Shaw	Australia	S	-0.04					Econometric	includes expectations
1992	Harris/Shaw	Australia	M	0.10					Econometric	includes expectations
1992	Harris/Shaw	Australia	10years	0.88					Econometric	includes expectations
1992	Harris/Shaw	Australia	L	2.99					Econometric	includes expectations

TABLE 1. (con't) ELASTICITIES OF SUPPLY OF BEEF CATTLE IN AUSTRALIA

Year of Publn.	Researcher	Geographic Coverage	Length of run	Change in CATTLE output as a result of a change in the price of				Data Period	Method	Functional form
				Cattle	Sheepmeat	Wool	Wheat			
1993	Kokic *et al.*	High Rainfall Zone	M	0.07	-0.01	-0.04	0.00	1980-81 to 1990-91	Econometric	
1993	Kokic *et al.*	Wheat-Sheep Zone	M	0.15	-0.01	-0.05	-0.05	1980-81 to 1990-91	Econometric	
1993	Kokic *et al.*	Pastoral Zone	M	0.05	0.00	-0.06	0.00	1980-81 to 1990-91	Econometric	
1996	Coelli	WA Wheat-Sheep Zone	L(g)	0.27(h)		-0.13(i)	-0.01(j)	1953-54 to 1987-88	Econometric	Generalised McFadden profit function

CET: constant elasticities of transformation, CRETH: constant ratio of elasticities of transformation, homothetic, RPM: regional programming model
APMAA: Aggregate Programming Model of Australian Agriculture
S: short term 1yr, M: medium term 5yrs, L:long run >10 yrs
(a) product groups are "cattle and other", "sheep and wool", "crops"
(b) with respect to the price of table beef
(c) with respect to the price of manufacturing beef
(d) all livestock
(e) all crops
(f) used annual data but output prices are lagged one year for wheat, two years for wool and three years for cattle
(g) profit function specified as long run but annual data used
(h) includes cattle and crops other than wheat, oats and barley
(i) includes wool and sheep sales
(j) includes wheat, oats and barley

TABLE 2. ELASTICITIES OF SUPPLY OF SHEEP FOR MEAT IN AUSTRALIA

Year of Publn.	Researcher	Geographic Coverage	Length of run	Change in SHEEP FOR MEAT output as a result of a change in the price of				Data Period	Method	Functional form
				Sheepmeat	Cattle	Wool	Wheat			
1967	Gruen *et al.*	Australia	S	0.25	0.00	-0.05	0.00		Econometric	CET production frontier
1967	Gruen *et al.*	Australia	I	0.94					Econometric	CET production frontier
1967	Gruen *et al.*	Australia	L	3.20					Econometric	CET production frontier
1980	Vincent *et al.*	High Rainfall Zone	S	0.11	-0.01	-0.01	-0.1 (b)	1952-53 to 1973-74	Econometric	CRETH Production Function
1980	Vincent *et al.*	Wheat-Sheep Zone	S	0.23	-0.02	-0.03	-0.12	1952-53 to 1973-74	Econometric	CRETH Production Function
1983	Fisher/Munro	NSW SW Slopes	3 years			0.44		1978-79 (survey)	Econometric	linear
1983	Fisher/Munro	NSW West. Division	3 years	0.49				1978-79 (survey)	Econometric	linear
1983	Easter/Paris	Australia	S		-0.03 (c	0.33	-0.17		Programming	
1983	Easter/Paris	Australia	S		-0.05 (d)	0.33	-0.17		Programming	
1985	Hall/Menz	Australia	M	1.04	-0.62	0.34	0.01	1982-83	RPM	
1985	Dewbre *et al.*	Australia	M	0.47	0.00	-0.20			Econometric	
1987	Adams	Australia	S	0.20	0.05	0.16	-0.03	1968-69	ORANI	
1987	Adams	Australia	S	0.47	0.48	0.75	0.29	1977-78	ORANI	
1987	Adams	Australia	S	0.27	0.09	0.27	0.01	1977-78 Typical Year	ORANI	
1987	Wall/Fisher	High Rainfall Zone	M	0.28	-0.10	-0.14		1968-69 to 1980-81	Econometric	Normalised Quadratic
1987	Wall/Fisher	Wheat-Sheep Zone	M	0.36	0.02	0.01	0.24	1968-69 to 1980-81	Econometric	Normalised Quadratic
1987	Wall/Fisher	Pastoral Zone	M	0.39	-0.25	-0.02	0.00	1968-69 to 1980-81	Econometric	Normalised Quadratic
1987	Wall/Fisher	High Rainfall Zone	M	0.30	-0.11	-0.15		1968-69 to 1980-81	Econometric	Generalised Leontief
1987	Wall/Fisher	Wheat-Sheep Zone	M	0.22	-0.04	-0.08	0.06	1968-69 to 1980-81	Econometric	Generalised Leontief
1987	Wall/Fisher	Pastoral Zone	M	0.42	-0.30	-0.02	-0.02	1968-69 to 1980-81	Econometric	Generalised Leontief
1987	Wall/Fisher	High Rainfall Zone	M	0.49	-0.13	-0.11		1968-69 to 1980-81	Econometric	Translog
1987	Wall/Fisher	Wheat-Sheep Zone	M	0.49	0.16	-0.63	-0.49	1968-69 to 1980-81	Econometric	Translog
1987	Wall/Fisher	Pastoral Zone	M	0.46	0.10	-0.55	0.12	1968-69 to 1980-81	Econometric	Translog
1988	Hall *et al.*	Australia	M	0.30	-0.20	-0.40	0.00	1983-84	Updated RPM	
1988	Hall *et al.*	Australia	L	1.50	-3.00	1.20	-1.40	1983-84	Updated RPM	

TABLE 2. (con't) ELASTICITIES OF SUPPLY OF SHEEP FOR MEAT IN AUSTRALIA

Year of Publn.	Researcher	Geographic Coverage	Length of run	Change in SHEEP FOR MEAT output as a result of a change in the price of				Data Period	Method	Functional form
				Sheepmeat	Cattle	Wool	Wheat			
1989	Lawrence/Zeitsch	Australia	S	0.19 (a)			0.10 (b)	1972-73 to 1986-87	Econometric	Symmetric Generalised McFadden profit function
1989	Lawrence/Zeitsch	NSW	S	0.19 (a)			0.11 (b)	1972-73 to 1986-87	Econometric	Symmetric Generalised McFadden profit function
1989	Lawrence/Zeitsch	Victoria	S	0.19 (a)			0.11 (b)	1972-73 to 1986-87	Econometric	Symmetric Generalised McFadden profit function
1989	Lawrence/Zeitsch	Queensland	S	0.18 (a)			0.10 (b)	1972-73 to 1986-87	Econometric	Symmetric Generalised McFadden profit function
1989	Lawrence/Zeitsch	South Australia	S	0.18 (a)			0.10 (b)	1972-73 to 1986-87	Econometric	Symmetric Generalised McFadden profit function
1989	Lawrence/Zeitsch	Western Australia	S	0.19 (a)			0.10 (b)	1972-73 to 1986-87	Econometric	Symmetric Generalised McFadden profit function
1989	Lawrence/Zeitsch	Tasmania	S	0.20 (a)			0.11 (b)	1972-73 to 1986-87	Econometric	Symmetric Generalised McFadden profit function
1990	Johnson *et al.*	High Rainfall Zone	S	0.31	0.03	0.05	-0.23	1952-53 to 1973-74 and 1967-68 to 1980-81	Synthetic	
1990	Johnson *et al.*	Wheat-Sheep Zone	S	0.37	0.01	0.04	-0.18	1952-53 to 1973-74 and 1967-68 to 1980-81	Synthetic	
1990	Johnson *et al.*	Pastoral Zone (d)	S	0.29		0.06	-0.10	1952-53 to 1973-74 and 1967-68 to 1980-81	Synthetic	
1993	Kokic *et al.*	High Rainfall Zone	M	2.17	-0.03	-0.04	-0.01	1980-81 to 1990-91	Econometric	
1993	Kokic *et al.*	Wheat-Sheep Zone	M	2.02	-0.02	-0.04	-0.04	1980-81 to 1990-91	Econometric	
1993	Kokic *et al.*	Pastoral Zone	M	1.37	-0.01	-0.08	0.00	1980-81 to 1990-91	Econometric	

CET: constant elasticities of transformation, CRETH: constant ratio of elasticities of transformation, homothetic, RPM: regional programming model

S: short term 1yr, M: medium term 5yrs, L: long run >10 yrs

(a) all livestock
(b) all crops
(c) with respect to the price of table beef
(d) with respect to the price of manufacturing beef

TABLE 3. ELASTICITIES OF SUPPLY OF WOOL IN AUSTRALIA

Year of Publn.	Researcher	Geographic Coverage	Length of run	Change in WOOL output as a result of a change in the price of				Data Period	Method	Functional Form
				Wool	Sheepmeat	Cattle	Wheat			
1967	Gruen *et al.*	Australia	S	0.05	-0.01	0.00	-0.05		Econometric	CET production frontier
1967	Gruen *et al.*	Australia	I	0.25					Econometric	CET production frontier
1967	Gruen *et al.*	Australia	L	3.59					Econometric	CET production frontier
1978	Wicks/Dillon	High Rainfall Zone	S	0.32		-0.37	-0.02	1975-76	APMAA	
1978	Wicks/Dillon	Wheat-Sheep Zone	S	0.17		-0.04	-0.27	1975-76	APMAA	
1978	Wicks/Dillon	Pastoral Zone	S	0.49		-0.34	-0.25	1975-76	APMAA	
1978	Wicks/Dillon	Australia	S	0.25		-0.18	-0.20	1975-76	APMAA	
1978	Wicks/Dillon	High Rainfall Zone	M	0.45		-0.52	-0.04	1975-76	APMAA	
1978	Wicks/Dillon	Wheat-Sheep Zone	M	0.28		-0.07	-0.40	1975-76	APMAA	
1978	Wicks/Dillon	Pastoral Zone	M	0.51		-0.34	-0.32	1975-76	APMAA	
1978	Wicks/Dillon	Australia	M	0.36		-0.25	-0.29	1975-76	APMAA	
1980	Vincent *et al.*	High Rainfall Zone	S	0.06	0.00	-0.01	-0.05 (b)	1952-53 to 1973-74	Econometric	CRETH production function
1980	Vincent *et al.*	Wheat-Sheep Zone	S	0.26	-0.01	-0.02	-0.15	1952-53 to 1973-74	Econometric	CRETH production function
1980	Vincent *et al.*	Pastoral Zone	S	0.08		-0.04	-0.043 (b)	1952-53 to 1973-74	Econometric	CRETH production function
1983	McKay *et al.(a)*	Australia	S	0.72		0.08	0.15	1952-53 to 1976-77	Econometric	Translog variable profit function
1983	Fisher/Munro	NSW Sth. Tablelands	3 years	0.26				1978-79 (Survey)	Econometric	
1983	Fisher/Munro	NSW SW Slopes	3 years	0.28				1978-79 (Survey)	Econometric	
1983	Fisher/Munro	NSW West. Division	3 years	0.52				1978-79 (Survey)	Econometric	
1983	Easter/Paris	Australia	S	0.21		-0.02	-0.01		Programming	
1983	Easter/Paris	Australia	S	0.21		-0.06	-0.01		Programming	
1985	Hall/Menz	Australia	M	2.02	1.07	-0.69	-0.45	1982-83	RPM	
1985	Dewbre *et al.*	Australia		0.39		-0.12	0.16			
1987	Adams	Australia	S	0.33	0.05	0.54	-0.11	1968-69	ORANI	
1987	Adams	Australia	S	0.95	0.31	0.49	0.27	1977-78	ORANI	
1987	Adams	Australia	S	0.46	0.10	0.09	-0.01	1977-78 Typical Year	ORANI	
1987	Wall/Fisher	High Rainfall Zone	M	0.04	-0.10	0.03		1968-69 to 1980-81	Econometric	Normalised Quadratic
1987	Wall/Fisher	Wheat-Sheep Zone	M	0.04	0.00	-0.03	-0.04	1968-69 to 1980-81	Econometric	Normalised Quadratic
1987	Wall/Fisher	Pastoral Zone	M	0.10	-0.05	-0.01	0.00	1968-69 to 1980-81	Econometric	Normalised Quadratic
1987	Wall/Fisher	High Rainfall Zone	M	0.05	-0.10	0.02		1968-69 to 1980-81	Econometric	Generalised Leontief
1987	Wall/Fisher	Wheat-Sheep Zone	M	0.10	-0.04	-0.02	0.01	1968-69 to 1980-81	Econometric	Generalised Leontief
1987	Wall/Fisher	Pastoral Zone	M	0.16	-0.05	-0.02	0.03	1968-69 to 1980-81	Econometric	Generalised Leontief
1987	Wall/Fisher	High Rainfall Zone	M	0.19	-0.04	0.03		1968-69 to 1980-81	Econometric	Translog
1987	Wall/Fisher	Wheat-Sheep Zone	M	0.19	-0.13	-0.09	0.06	1968-69 to 1980-81	Econometric	Translog
1987	Wall/Fisher	Pastoral Zone	M	0.26	-0.06	-0.11	0.05	1968-69 to 1980-81	Econometric	Translog

TABLE 3. (con't) ELASTICITIES OF SUPPLY OF WOOL IN AUSTRALIA

Year of Publn.	Researcher	Geographic Coverage	Length of run	Change in WOOL output as a result of a change in the price of				Data Period	Method	Functional Form
				Wool	Sheepmeat	Cattle	Wheat			
1988	Hall *et al.*	Australia	M	0.60	0.00	-0.20	0.00	1983-84	Updated RPM	
1988	Hall *et al.*	Australia	L	2.50	0.50	-2.30	-0.20	1983-84	Updated RPM	
1990	Johnson *et al.*	High Rainfall Zone	S	0.16	0.02	0.04	-0.06	1952-53 to 1973-74 and 1967-68 to 1980-81	Synthetic	
1990	Johnson *et al.*	Wheat-Sheep Zone	S	0.26	0.01	0.02	-0.07	1952-53 to 1973-74 and 1967-68 to 1980-81	Synthetic	
1990	Johnson *et al.*	Pastoral Zone (d)	S	0.29		0.06	-0.10	1952-53 to 1973-74 and 1967-68 to 1980-81	Synthetic	
1990	Low/Hinchy (c)	Australia	S	0.94		0.17	0.21	1978 to 1987	Econometric	Symmetric Generalised McFadden profit function
1990	Low/Hinchy (c)	NSW	S	0.99		0.18	0.23	1978 to 1987	Econometric	Symmetric Generalised McFadden profit function
1990	Low/Hinchy (c)	Victoria	S	0.89		0.16	0.20	1978 to 1987	Econometric	Symmetric Generalised McFadden profit function
1990	Low/Hinchy (c)	Queensland	S	1.22		0.24	0.29	1978 to 1987	Econometric	Symmetric Generalised McFadden profit function
1990	Low/Hinchy (c)	South Australia	S	0.85		0.16	0.19	1978 to 1987	Econometric	Symmetric Generalised McFadden profit function
1990	Low/Hinchy (c)	Western Australia	S	0.99		0.18	0.23	1978 to 1987	Econometric	Symmetric Generalised McFadden profit function
1993	Kokic *et al.*	High Rainfall Zone	M	0.45	-0.03	-0.04	-0.01	1980-81 to 1990-91	Econometric	
1993	Kokic *et al.*	Wheat-Sheep Zone	M	0.45	-0.02	-0.03	-0.10	1980-81 to 1990-91	Econometric	
1993	Kokic *et al.*	Pastoral Zone	M	0.57	0.00	-0.11	-0.01	1980-81 to 1990-91	Econometric	

TABLE 3. (con't) ELASTICITIES OF SUPPLY OF WOOL IN AUSTRALIA

Year of Publn.	Researcher	Geographic Coverage	Length of run	Change in WOOL output as a result of a change in the price of				Data Period	Method	Functional
				Wool	Sheepmeat	Cattle	Wheat			
1996	Coelli	WA Wheat-Sheep Zone	L(d)	0.04(e)		-0.01(f)	-0.09(g)	1953-54 to 1987-88	Econometric	Generalised McFadden profit function
1998	Agbola	Pastoral Zone	S	0.21			-0.17	1979 to 1993	Econometric	Dynamic Generalised Leontief profit function
1998	Agbola	Pastoral Zone	L	0.21			-0.17	1979 to 1993	Econometric	Dynamic Generalised Leontief profit function

CET: constant elasticities of transformation, CRETH: constant ratio of elasticities of transformation, homothetic, RPM: regional programming model
APMAA: Aggregate Programming Model of Australian Agriculture
S: short term 1yr, M: medium term 5yrs, L:long run >10 yrs
(a) product groups are "sheep and wool", "crops" and "cattle and other"
(b) all crops
(c) used annual data but output prices are lagged one year for wheat, two years for wool and three years for cattle
(d) profit function specified as long run but annual data used
(e) includes wool and sheep sales
(f) includes cattle and crops other than wheat, oats and barley
(g) includes wheat, oats and barley

TABLE 4. ELASTICITIES OF SUPPLY OF WHEAT IN AUSTRALIA

Year of Publn.	Researcher	Geographic Coverage	Length of run	Change in WHEAT output as a result of a change in the price of				Data Period	Method	Functional Form
				Wheat	Sheepmeat	Wool	Cattle			
1967	Gruen *et al.*	Australia	S	0.16		-0.11			Econometric	CET production frontier
1967	Gruen *et al.*	Australia	M	0.82					Econometric	CET production frontier
1967	Gruen *et al.*	Australia	L	3.82					Econometric	CET production frontier
1978	Wicks/Dillon	High Rainfall Zone	S	0.89		-0.06	-0.21	1975-76	APMAA	
1978	Wicks/Dillon	Wheat-Sheep Zone	S	1.31		-0.17	-0.13	1975-76	APMAA	
1978	Wicks/Dillon	Pastoral Zone	S	0.29		-0.05	-0.16	1975-76	APMAA	
1978	Wicks/Dillon	Australia	S	1.10		-0.21	-0.21	1975-76	APMAA	
1978	Wicks/Dillon	High Rainfall Zone	M	0.76		-0.08	-0.23	1975-76	APMAA	
1978	Wicks/Dillon	Wheat-Sheep Zone	M	1.55		-0.33	-0.21	1975-76	APMAA	
1978	Wicks/Dillon	Pastoral Zone	M	0.48		-0.06	-0.18	1975-76	APMAA	
1978	Wicks/Dillon	Australia	M	1.26		-0.24	-0.24	1975-76	APMAA	
1978	Griffiths/Anderson	Sthn. NSW	L	2.4 (a)					Econometric	OLS/ML
1980	Vincent *et al.*	High Rainfall Zone (b)	S	0.62	-0.10	-0.20	-0.32	1952-53 to 1973-74	Econometric	CRETH Production Function
1980	Vincent *et al.*	Wheat-Sheep Zone	S	0.77	-0.08	-0.25	-0.11	1952-53 to 1973-74	Econometric	CRETH Production Function
1980	Vincent *et al.*	Pastoral Zone (b)	S	2.65		-0.93	-1.72	1952-53 to 1973-74	Econometric	CRETH Production Function
1983	McKay *et al. (b)*	Australia	S	0.50		0.43	-0.42	1952-53 to 1976-77	Econometric	Translog variable profit function
1983	Fisher/Munro	NSW SW Slopes	3 years	2.05		0.33	0.14	1978-79 (survey)	Econometric	
1983	Easter/Paris	Australia	S	1.73		0.13	-0.01		Programming	
1983	Easter/Paris	Australia	S	1.73		0.13	-0.01		Programming	
1985	Dewbre *et al.*	Australia		0.92		0.33	0.14			
1985	Myers *et al.*	Australia	S	0.49					Econometric	OLS
1985	Hall/Menz	Australia	M	0.59	-0.41	-0.52	-0.04	1982-83	RPM	
1987	Adams	Australia	S	0.60	-0.01	-0.05	-0.09	1968-69	ORANI	
1987	Adams	Australia	S	1.37	0.19	0.42	0.08	1977-78	ORANI	
1987	Adams	Australia	S	0.74	0.02	0.02	-0.09	1977-78 Typical Year	ORANI	
1987	Wall/Fisher	Wheat-Sheep Zone	M	0.62	0.50	-0.17	-0.19	1968-69 to 1980-81	Econometric	Normalised Quadratic
1987	Wall/Fisher	Pastoral Zone	M	2.67	0.03	0.00	0.22	1968-69 to 1980-81	Econometric	Normalised Quadratic
1987	Wall/Fisher	Wheat-Sheep Zone	M	0.75	0.13	0.03	-0.07	1968-69 to 1980-81	Econometric	Generalised Leontief
1987	Wall/Fisher	Pastoral Zone	M	1.42	-0.24	0.11	0.16	1968-69 to 1980-81	Econometric	Generalised Leontief
1987	Wall/Fisher	Wheat-Sheep Zone	M	0.47	-0.08	0.05	0.04	1968-69 to 1980-81	Econometric	Translog

TABLE 4. (con't) ELASTICITIES OF SUPPLY OF WHEAT IN AUSTRALIA

Year of Publn.	Researcher	Geographic Coverage	Length of run	Change in WHEAT output as a result of a change in the price of				Data Period	Method	Functional Form
				Wheat	Sheepmeat	Wool	Cattle			
1987	Wall/Fisher	Pastoral Zone	M	1.66	0.07	0.29	0.07	1968-69 to 1980-81	Econometric	Translog
1988	Hall *et al.*	Australia	M	1.10	0.00	0.00	0.10	1983-84	Updated RPM	
1988	Hall *et al.*	Australia	L	1.40	0.00	0.00	0.20	1983-84	Updated RPM	
1989	Lawrence/Zeitsch	Australia	S	0.20 (c)			0.19 (d)	1972-73 to 1986-87	Econometric	Symmetric Generalised McFadden profit function
1989	Lawrence/Zeitsch	NSW	S	0.20 (c)			0.19 (d)	1972-73 to 1986-87	Econometric	Symmetric Generalised McFadden profit function
1989	Lawrence/Zeitsch	Victoria	S	0.22 (c)			0.21 (d)	1972-73 to 1986-87	Econometric	Symmetric Generalised McFadden profit function
1989	Lawrence/Zeitsch	Queensland	S	0.21 (c)			0.19 (d)	1972-73 to 1986-87	Econometric	Symmetric Generalised McFadden profit function
1989	Lawrence/Zeitsch	South Australia	S	0.18 (c)			0.17 (d)	1972-73 to 1986-87	Econometric	Symmetric Generalised McFadden profit function
1989	Lawrence/Zeitsch	Western Australia	S	0.18 (c)			0.17 (d)	1972-73 to 1986-87	Econometric	Symmetric Generalised McFadden profit function
1989	Lawrence/Zeitsch	Tasmania	S	0.25 (c)			0.24 (d)	1972-73 to 1986-87	Econometric	Symmetric Generalised McFadden profit function
1990	Johnson *et al.*	High Rainfall Zone	S	0.89	-0.19	-0.16	-0.37	1952-53 to 1973-74 and 1967-68 to 1980-81	Synthetic	
1990	Johnson *et al.*	Wheat-Sheep Zone	S	0.55	-0.03	-0.05	-0.06	1952-53 to 1973-74 and 1967-68 to 1980-81	Synthetic	
1990	Johnson *et al.*	Pastoral Zone	S	1.69		-0.43	-1.01	1952-53 to 1973-74 and	Synthetic	
1990	Low/Hinchy (e)	Australia	S	0.26		0.20	0.07	1978 to 1987	Econometric	Symmetric Generalised McFadden profit function
1990	Low/Hinchy (e)	NSW	S	0.44		0.28	0.10	1978 to 1987	Econometric	Symmetric Generalised McFadden profit function
1990	Low/Hinchy (e)	Victoria	S	0.38		0.34	0.06	1978 to 1987	Econometric	Symmetric Generalised McFadden profit function
1990	Low/Hinchy (e)	Queensland	S	0.22		0.19	0.04	1978 to 1987	Econometric	Symmetric Generalised McFadden profit function
1990	Low/Hinchy (e)	South Australia	S	0.14		0.12	0.04	1978 to 1987	Econometric	Symmetric Generalised McFadden profit function
1990	Low/Hinchy (e)	Western Australia	S	0.37		0.22	0.09	1978 to 1987	Econometric	Symmetric Generalised McFadden profit function

TABLE 4. (con't) ELASTICITIES OF SUPPLY OF WHEAT IN AUSTRALIA

Year of Publn.	Researcher	Geographic Coverage	Length of run	Change in WHEAT output as a result of a change in the price of				Data Period	Method	Functional Form
				Wheat	Sheepmeat	Wool	Cattle			
1993	Kokic *et al.*	High Rainfall Zone	M	0.45	-0.03	-0.04	-0.01	1980-81 to 1990-91	Econometric	
1993	Kokic *et al.*	Wheat-Sheep Zone	M	0.23	-0.01	-0.07	-0.03	1980-81 to 1990-91	Econometric	
1993	Kokic *et al.*	Pastoral Zone	M	0.31	-0.01	-0.13	-0.02	1980-81 to 1990-91	Econometric	
1996	Coelli	WA Wheat-Sheep Zone	L (f)	0.50 (g)		-0.10 (h)	-0.09 (i)	1953-54 to 1987-88	Econometric	Generalised McFadden profit function
1998	Agbola	Pastoral Zone	S	0.20			-0.18	1979 to 1993	Econometric	Dynamic Generalised Leontief profit function
1998	Agbola	Pastoral Zone	L	0.29			-0.32	1979 to 1993	Econometric	Dynamic Generalised Leontief profit function

CET: constant elasticities of transformation, CRETH: constant ratio of elasticities of transformation, homothetic, RPM: regional programming model
APMAA: Aggregate Programming Model of Australian Agriculture, OLS: ordinary least squares, ML: maximum likelihood,
S: short term 1yr, M: medium term 5yrs, L:long run >10 yrs
(a) average of 12 estimates, range 1.7 to 3.1
(b) product groups are "crops", "sheep and wool", and "cattle and others"
(c) all crops
(d) all livestock
(e) used annual data but output prices are lagged one year for wheat, two years for wool and three years for cattle
(f) profit function specified as long run but annual data used
(g) includes wheat, oats and barley
(h) includes wool and sheep sales
(i) includes cattle and crops other than wheat, oats and barley

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1 Brennan, J.P. and Bantilan, M.C.S. 1999, *Impact of ICRISAT Research on Australian Agriculture*, Report prepared for Australian Centre for International Agricultural Research, Economic Research Report No. 1, NSW Agriculture, Wagga Wagga.

2 Davies, B.L., Alford, A. and Hollis, G. 1999, *Analysis of ABARE Dairy Data for Six Regions in NSW 1991-92 to 1996-97,* Economic Research Report No. 2, NSW Agriculture, C.B. Alexander College, Paterson.

3 Brennan, J.P. and Singh, R.P. 2000, *Economic Assessment of Improving Nutritional Characteristics of Feed Grains*, Report prepared for Grains Research and Development Corporation, Economic Research Report No. 3, NSW Agriculture, Wagga Wagga.

4 Zhao. X., Mullen, J.D., Griffith, G.R., Griffiths, W.E. and Piggott, R.R. 2000, *An Equilibrium Displacement Model of the Australian Beef Industry*, Economic Research Report No. 4, NSW Agriculture, Armidale.

5 Griffith, G., I'Anson, K., Hill, D., Lubett, R. and Vere, D. 2001, *Previous Demand Elasticity Estimates for Australian Meat Products*, Economic Research Report No. 5, NSW Agriculture, Armidale.

6 Griffith, G., I'Anson, K., Hill, D. and Vere, D. 2001, *Previous Supply Elasticity Estimates for Australian Broadacre Agriculture*, Economic Research Report No. 6, NSW Agriculture, Armidale.

7 Patton, D.A. 2001, *Farming Systems in the Central West of NSW: An Economic Analysis*, Economic Research Report No. 7, NSW Agriculture, Trangie.

8 Brennan, J.P. and Bialowas, A. 2001, *Changes in Characteristics of NSW Wheat Varieties, 1965-1997*, Economic Research Report No. 8, NSW Agriculture, Wagga Wagga.