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# The Economic Incidence of R&D and Promotion Investments in the Australian Beef Industry


**Abstract**

*The issue of the relative returns to farmers from R&D and promotion is examined using a multi-sectoral equilibrium displacement model of the Australian beef industry. Total economic surplus changes and their distributions among various industry groups resulting from 1% cost reductions in various farm and off-farm sectors, and from 1% price premiums from domestic and export market promotion, are estimated. The results are consistent with previous studies in showing that in general, the share of total benefits to farmers is larger from on-farm research than from most off-farm research, and is larger from most types of research than from domestic promotion. The share of total benefits to farmers is larger from export promotion than from off-farm research, and from domestic promotion. The net returns from the different cost-reduction or demand-enhancing scenarios depend on the costs of achieving them.*

# The Incidence of Gains and Taxes Associated with R&D and Promotion in the Australian Beef Industry

## Introduction

The cattle and beef industry is a major component of the Australian agricultural sector. Its farm-gate earnings are over $4 billion per annum and about two-thirds of its output is exported, earning over $3 billion per annum, or about 15 % of all farm export revenue (ABARE 2000). In recent years, the beef industry has faced more competition both domestically and internationally. On the domestic market, chicken and pork have gained an increased share of meat consumption at the expense of beef (ABARE 2000). Drought episodes have curtailed herd expansion plans and raised concerns about cattle availability. Overseas, liberalisation of some Asian markets has provided more opportunities for the industry, but the recent Asian economic crisis has also imposed challenges. The beef import quota in the United States has again become binding, and some South American exporters have achieved foot-and-mouth free status and are seeking a greater share of the United States market. In addition, there have been a greater number of chemical residue and food safety incidents in the world meat market, seriously depressing global demand. Exchange rates have fluctuated widely also, leading to highly variable farm incomes. In such a competitive and rapidly changing environment, it is vital that the scarce research and development (R&D) and market promotion funds available to the beef industry be used in the most efficient way to enhance industry competitiveness.

Both the benefits from research and promotion and the incidence of levies to fund these activities are shared by farmers, feedlotters, processors, exporters, retailers, and domestic and export consumers. Hence, for say, cattle farmers, to know the returns from their levy investments in on-farm R&D they need to know not only total industry costs and benefits from such research but also their share of these benefits and costs. As demonstrated in Alston and Scobie (1983), Mullen, Alston and Wohlgenant (1989) and Wohlgenant (1993), it is only for farm level research that the incidence on farmers of levies and benefits is the same. Because of substitution between the farm product and processing and marketing inputs, the share of benefits to farmers from research and promotion downstream is less than from farm level research. In most previous studies a very limited disaggregation of an industry into a farm and processing sector has been used. In practice the Australian beef industry confronts a much broader range of options than simply farm and off-farm research and promotion. The tradeoffs it confronts include R&D versus promotion, domestic promotion versus overseas promotion, R&D into grass-finishing cattle versus grain-finishing cattle, and traditional on-farm R&D versus off-farm R&D in sectors such as feedlotting, processing and marketing. Hence a highly disaggregated model is required and this issue of the divergence in incidence of levies and benefits must be considered. For example, when the levies collected from one sector of farmers are used to fund on-farm research in another sector of the chain, the incidence of levies and returns will differ.

An important objective of this paper is to report the incidence of gains and taxes associated with various types of R&D and promotion in the Australian beef industry, using a multi-sectoral partial equilibrium displacement model (EDM) of the Australian beef industry. The EDM methodology, reviewed in Piggott (1992) and in Alston, Norton and Pardey (1995), has a history going back at least to Muth (1964). It applies comparative static analysis to the structural model in general functional form of an industry to linearly relate the changes in prices and quantities of inputs and outputs throughout the industry with exogenous shocks to the industry such as research or promotion activities. Generally it has been applied to much more stylised representations of industries than required to answer questions posed by allocation of research and promotion funds in an industry as multi-faceted as the Australian beef industry. Hence, a second objective of this work has been to explore some of the methodological issues associated with greater disaggregation that arise from jointness in production and products that are related in supply and demand. Thurman (1991) raised concerns about the accurate attribution of welfare changes to market participants under such conditions.

The paper is arranged as follows. The current arrangement for the R&D fund collection and expenditure is reviewed in the next section. The model is presented and results are discussed in the following two sections. Issues involved in the application of a disaggregated EDM and the implications of the study are examined in the end.

## Levy Collection and Expenditure

Most of the larger agricultural industries in Australia (e.g., wool, beef, wheat and dairy) use compulsory levies (checkoffs) to fund research and promotion. Levies are paid by farmers but in some cases (e.g., beef), post-farm sectors (e.g. cattle finishing and processing firms) are also required to contribute. Most of the dollars collected for research are allocated to research providers through a highly-competitive application process as occurs in the US. These funds are allocated in accordance with strategic plans designed by industry "research corporations" which are comprised of farmer and processor representatives, and sometimes consumer and government representatives. The degree of sophistication of the allocation process varies across industries but in general the process does not make use of ex-ante evaluation methods which account for supply and demand responses. However, the highly competitive process at least ensures that research funds go to providers with good "track records". Much less is known about the process whereby funds are allocated for promotion. Anecdotal evidence suggests, though, that competition among providers of promotion services is much less open. Even though there is some economic theory relating to commodity market characteristics favourable to successful outcomes from promotion activity, it almost certainly does not get used in ex ante evaluation of promotion programs. Moreover, agricultural economists and farmers have been critical of the fact that, despite the seemingly weaker mechanism for allocating promotion dollars compared with that used in allocating research dollars, typically much more has been spent on promotion than on research at least until recently (Piggott 1998).

R&D and promotion activities relating to the Australian beef, sheep meat and goat industries are undertaken by Meat and Livestock Australia (MLA 2001). In 2000/01, cattle producers and finishers paid $38.8 million in levies to fund these activities, based on $3.50 per head per transaction for grown cattle and $0.90 per head per transaction for calves. Sheep, lamb and goat producers similarly paid $20.6 million in levies, comprised of a mix of flat rate per head and per cent of value depending on type of sale and value of the animal. Other MLA income included contributions from meat processors, live exporters and other sources totalling about \$18.9 million, and from the Commonwealth government totalling about \$20.9 million. Income from all sources was \$99.5 million, of which producer levies accounted for \$59.4 million or 60 % of the total (MLA 2001).

R&D funds can be used for on-farm investments targeting farm productivity, or for off-farm investments aimed at improving efficiency in the feedlotting, processing, or domestic or export marketing sectors. Promotion funds can be allocated to either the domestic market or any of a number of export markets. In 2000/01, \$35.7 million or 38 % of the available funds were spent on promotion, well down from previous years. This included \$8.6 million specifically on domestic beef promotion and \$12.5 million on export beef promotion. Almost \$50 million or 52 % of funds were spent on R&D programs across the beef, sheep meat and goat industries. Of this, \$18.6 million or 20 % was spent on traditional R&D in the farm, feedlot and processing sectors; \$16.0 million or 17 % on product integrity and eating quality issues; and almost \$15.0 million or 16 % on marketing-related R&D programs and R&D infrastructure issues. Total annual expenditure by MLA on R&D and promotion for the beef, sheep meat and goat industries reached \$94.5 million in 2000/01 (MLA 2001).

## A Model of the Australian Beef Industry

A disaggregated equilibrium displacement model of the Australian beef industry developed in Zhao (2000) is used in this paper to examine the returns from different types of R&D and promotion investments. The approach involves estimating changes in economic surplus from efficiency gains or increased willingness to pay in a partial equilibrium displacement framework. With this approach, profit maximizing behavior and constant returns to scale are assumed for all sectors, and the equilibrium of the industry is represented by a system of demand and supply relationships among sectors of the industry, following the theoretical requirement in for example Chambers (1991). The impacts of new technologies, promotional campaigns and government policies, are modelled as shifts in demand or supply curves in the relevant markets. Comparative static analysis is used to linearly relate changes in prices and quantities of all outputs and inputs to exogenous changes such as reductions in production or processing costs or increases in demand in the case of promotion (see

Zhao, Mullen and Griffith 1997). A review of the equilibrium displacement modelling approach can be found in Alston, Norton and Pardey (1995).

The Australian beef industry involves multiple markets and multiple production and marketing stages. In order to study the returns from various types of R&D and promotion and the distribution of benefits among different industry sectors, a model disaggregated along both vertical and horizontal directions is required. About two-thirds of Australian-produced beef is sold overseas, so both domestic and export markets need to be included. We also separate beef into grass-finished and grain-finished products. About 14% of exported beef and 18% of domestically consumed beef are grain finished in feedlots. Vertically, production of retail beef products involves breeding, backgrounding, grain- or grass-finishing, processing, and domestic or export marketing.

The structure of the model reflects these requirements. Importantly, the model includes four end products – domestic grass- and grain- fed beef and export grass- and grain-fed beef. These four products have different market specifications at all production and marketing stages and each comprises a significant share of the industry. This disaggregated specification enables the analysis of technical changes in individual sectors and promotion in different markets. It also enables the identification of benefits to individual industry sectors. A formal technical account of the model specification and assumptions made is given in Zhao, Mullen, Griffith, Griffiths and Piggott (2000). A listing of the model in equilibrium displacement form is given in the Appendix. Variable definitions are given in Table 1.

Changes in prices and quantities arising out of the comparative static analysis were used to estimate consequent changes in economic surplus to various industry groups. Care was taken to ensure that the welfare measurements were consistent with theoretical requirements (Zhao, Mullen and Griffith 2001).

## Data Requirements

The information required for operating the equilibrium displacement model is in three parts: (1) initial price and quantity values for all inputs and outputs, which define the equilibrium status of the system before the introduction of new technology or promotion; (2) market elasticities, which describe the market responsiveness of quantity variables to price changes; and (3) the values of all the variables which quantify the effects of new technologies and promotions.

The initial equilibrium values are specified as the average prices and quantities for the period 1992-97. Significant effort was invested in Zhao (2000) to compile a set of equilibrium prices and quantities for all sectors and product types at the required level of disaggregation. This includes prices and quantities of weaners, backgrounded cattle, grass/grain finished cattle, processed beef carcass, and final products as f.o.b. (free on board) export boxes and domestic retail cuts. Zhao (2000) used published data from various government and industry agencies and other available sources and made assumptions regarding the relationship of cattle prices and quantities at different levels to derive nonrecorded prices and quantities required in the model. Details about the data sources, the assumptions made and the derivation of prices and quantities of all sectors for each year of 1992 to 1997 are given in Zhao, *et al.*(2000).

Market elasticities were required to solve the displacement model. These include supply elasticities of factor inputs, demand elasticities of final products, and input substitution and output transformation elasticities among inputs and outputs of all sectors. Values for these elasticities were specified based on economic theory, reviews of existing empirical estimates (Griffith *et al.*2001a, Griffith *et al.*2001b) and subjective judgement. They are provided in Table 2. Full details of the selected specification of the market elasticities are given in Zhao (2000). Since non-zero input substitution elasticities are assumed for all sectors in the study, the welfare distribution among industry groups will be different when the R&D occurs at different points of the production and marketing chain (Alston and Scobie 1983). A stochastic approach to sensitivity analysis is also used later in the paper to systematically study the robustness of results to uncertainty in market elasticities.

New technologies were modelled as reducing the costs of production or processing, or in other words, as shifts in supply. Promotion was modelled as an increase in consumers "willingness to pay" represented by a vertical shift in demand. There were 12 different technology and promotion scenarios and equal 1 % shifts in the relevant supply or demand curves were assumed for all scenarios. This allows for the simulation of the impacts of equal proportionate cost reductions in various production and processing sectors and increases in consumer's 'willingness to pay' in the end product or retail markets.

## Results

Using the specified initial prices and quantities and market elasticities, the results of the total economic surplus changes and their distribution among industry groups for each of the specified scenarios are given in Tables 3 and 4. For the same 1% exogenous shift, the size of the total welfare change from a scenario is predominantly determined by the gross revenue of the market where the exogenous shift occurs. Consequently, as can be seen from the last row of Tables 3 and 4, for equal 1% shifts in the relevant markets, domestic promotion of grassfed beef (scenario 12), domestic beef marketing research (Scenario 7), export promotion of grassfed beef (scenario 10) and weaner production research (Scenario 1) result in the largest total returns: $31.55m, $23.88m, $20.38m and $19.60m, respectively. These are followed by grass-finishing research (Scenario 2, $13.32 million). The total benefits from 1% cost reductions in the backgrounding, feedlot, processing and export marketing sectors are much smaller (mainly less than $2 million) due to the small value added to the cattle/beef products in these sectors.

For all research and promotion scenarios, the majority of the total benefits accrue to domestic consumers and cattle farmers. Domestic consumers gain the largest share of total benefits (48.3% to 65.6%) in all cases. This is due to the large domestic retail value, the inelastic supply assumed for post-farm sectors and the far from perfectly elastic retail demand elasticities assumed for beef which are similar in magnitude to the elasticity of supply. Farmers, including weaner producers, grass-finishers and backgrounders, receive between 19.8% to 33.7% of total benefits for the seven scenarios. Overseas demand for Australian beef (both grainfed and grassfed) is substantially more elastic than domestic demand. As a result, overseas consumers gain much less surplus, from 5.1% to 11.7%, than domestic consumers in all cases. Domestic retailers gain only 3.6% to 6.8% of total benefits in all scenarios because the supply of marketing inputs is assumed to be highly elastic (elasticity of 5). The shares of benefits to feedgrain producers, feedlotters, processors and exporters are very small for all investment scenarios (mostly less than 3%). The values added to the cattle/beef products in the feedlots and abattoirs are small, and the supply curves of other inputs in these sectors are assumed to be highly elastic (elasticities of 5).

Some qualification of the results should be noted before any further comparison is undertaken. First, the results relate to equal 1 % exogenous shifts in the relevant supply and demand curves. The question of how much money is required to bring about these shifts in the relevant sectors is not discussed here. Previous studies that have addressed this issue in an R&D context include Lemieux and Wohlgenant (1989), Scobie, Mullen and Alston (1991), Mullen and Cox (1995) and Cox, Mullen and Hu (1997). Thus, the monetary returns from alternative scenarios in Tables 3 and 4 are only comparable under the assumption of *equal investment efficiency*, in the sense that the investment costs of the 1 % shifts in all sectors are the same.

Second, although the same amount of monetary investments at different points of the industry may result in supply shifts of different magnitudes, and although the actual returns in dollar terms are dependent on the magnitudes of the initial shifts, the distribution of the total benefits among industry groups for a particular scenario is independent of the size of the initial shift (Zhao, *et al.* 2000, p.84). For example, the farmers' percentage share of the total benefits from processing technology (i.e. 25.9 % for Scenario 6 in Table 3) is the same regardless of whether the technology reduces the processing cost by 1 % or 10 %. Therefore, comparison of *benefit shares* among alternative investment scenarios is always meaningful even without knowledge of the efficiency of research investments. This result follows from the assumed competitive structure of the beef industry and the assumed parallel supply and demand shifts.

In this paper, because farmers pay the majority of the levies, the focus of attention is on the extent to which farmers benefit from the alternative research and promotion scenarios and the discussion is in terms of a number of the key choices that confront them. The implications for other sectors of the industry can be drawn from Table 2 and are discussed in Zhao *et al*. (2000). However two general principles apply. First, each sector of the industry captures a larger share of the benefit from exogenous demand or supply shifts that occur *within* their sector than they do from new technologies or promotion in other sectors. This occurs because once input substitution and product transformation is allowed there is a 'leakage' of benefits associated with differences in supply elasticities in different sectors (see also Freebairn et al. 1982, Holloway 1989).

Additionally, also related to input substitution, the incidence of benefits from research or promotion and of taxes are only coincident when both occur in the same sector (Alston and Mullen 1992). The share of benefits to farmers from research or promotion downstream is always less than the incidence of levies they pay. For example, a levy on the producers of weaners is distributed in exactly the same way as the benefits of new technology in growing weaners – these farmers pay 30.6% of the levy and gain 30.6% of the benefits. However if the levy collected from the weaner producers is used to fund domestic marketing research for example, they bear 30.6% of the actual levy burden but receive only 17.2% of the benefits. Domestic marketing research may still be a profitable investment for weaner producers but the total returns to investments in this area will have to be higher than from weaner R&D to give the same net returns to weaner producers.

***Research versus Promotion***

Scenarios 1 to 8 are research scenarios relating to farm, feedlot, processing and export and domestic marketing sectors of the beef industry. Export promotion is represented by Scenarios 9 and 10, and domestic promotion is modelled by Scenarios 11 and 12.

Although the percentage of available funds spent on R&D has increased over the years, almost two-thirds of the research and promotion dollars for the red meat industries were spent on promotion during the 1990s. Existing studies indicate that primary producers should not be indifferent about spending levy money on research versus promotion. With an input substitution elasticity of 0.72 for the U.S. beef industry, Wohlgenant (1993) found that farmers gain a much larger share of benefits from production research than from promotion[1], although processing/marketing research is shown to be much less preferable to farmers than promotion. As noted above, Piggott (1998) has pointed to the less rigorous manner in which promotion investments are made compared

[1] The total surplus changes in his three scenarios of production research, marketing research and promotion are the same. As a result, the same benefit share for a particular group from different scenarios implies equal absolute benefits in dollars.

with R&D investments.

In Tables 3 and 4, export promotion and domestic promotion are shown to have different implications for farmers in comparison to research. In terms of the share of the total benefits, domestic promotion is less preferable to farmers (23.2% to 23.4%) than all types of on-farm research (27.6 to 33.7%) and research in the feedlot, processing and export marketing sectors (25.9% to 30.2%), but is more preferable than domestic marketing research (19.8%). In contrast, export promotion brings the farmers bigger surplus shares (31.3% to 31.6%) than all research types (19.8% to 28.8%) except for weaner production research (33.7%). In fact, to farmers, domestic marketing research has similar effects as the two types of domestic promotion, while export marketing research has a similar implication to that of export promotion. In summary, in terms of percentage share of total benefits, farmers should prefer research (except for domestic marketing research) to *domestic* promotion, but they should prefer export promotion to all research types except for weaner production research.

Wohlgenant (1993) gave an intuitive explanation of the result that producers prefer production research to promotion by examining the determinants of retail-to-farm price transmission resulting from a retail demand shift due to promotion (p646). He showed that, when input substitution is possible, the effect of an increase in retail demand is not generally passed along completely to the farm price. Although deriving similar analytical expressions is more difficult with the more disaggregated model in this study, the finding that the share of benefits to farmers is higher from a new weaner production technology than from both domestic and export promotion can be explained in a similar way.

Australian consumers prefer increased efficiency in the domestic retailing sector the most since they receive 65.6% of the total benefits. Other types of research in the farm, feedlot, processing and export marketing sectors will give them lower shares of the total welfare gains (48.3% to 55.4%) than domestic promotion (61.7% to 61.9%). However, export promotion results in smaller shares of benefits to domestic consumers (50.1% to 50.6%) than all research scenarios (50.8% to 65.6%) except for export marketing research (48.3%).

Other industry participants each strongly prefer research in their own sector. For example, feedlots will receive 2.1% of the total gains from feedlot research, but less than 0.3% of the total benefits from all other research and promotions. Otherwise, there is no significant difference in the welfare shares to these industry groups from various types of research and promotion.

***Domestic Promotion versus Export Promotion***

The majority of the promotional effort for the Australian beef industry has been on overseas markets, primarily in Japan, Korea and South East Asia.

As can be seen from the results in Table 4, domestic promotion and export promotion have very different welfare implications to both producers and consumers. Cattle producers receive 31.3% to 31.6% of the total welfare gains from overseas promotion, but only 23.2% to 23.4% from domestic promotion. Conversely, Australian consumers receive larger shares of gains from domestic promotion (61.7% to 61.9%) than from overseas promotion (50.1% to 50.6%). Feedlotters, processors and exporters are also shown to receive larger shares from export promotion than from domestic promotion.

The explanation for these results lies in the highly elastic demand assumed for Australian beef exports, which means that increases in market share can be achieved with little impact on price to Australia.

***Returns from On-farm versus Off-farm Research***

Farmers receive a larger share of the total benefits from on-farm research (33.7%, 27.6% and 28.8% for Scenarios 1, 2 and 3 respectively) than from feedlot (26.8%) and processing (25.9%) research. However, the comparison between farm research and marketing research shows different results for domestic and export marketing. The domestic marketing sector research is shown to give farmers a much lower proportion of benefit (19.8%) than all types of farm production research. However, export marketing research is shown to give farmers a larger share of the benefits (30.2%) than for some types of on-farm research.

In summary, the results from the present model are consistent with the previous literature in concluding that, in terms of the shares of total benefits, farmers should prefer on-farm R&D to R&D

in feedlots, processing and domestic marketing sectors. However, they should also be interested in export marketing research, which may provide them with an even larger share than some post-weaning farm research. This comparison is discussed in more detail in Zhao, Griffith and Mullen (2001).

***Research in Grain-Finishing versus Grass-Finishing***

In the model, research into the backgrounding and feedlot sectors only directly affects the grain-finishing cattle stream (Scenarios 3 and 5), and research on reducing costs in the grass-finishing sector focuses on grassfed cattle (Scenario 2). In practice, some research projects such as those aiming to improve pasture management may reduce the costs in both backgrounding and grass-finishing sectors, and even in the breeding sector. However, research projects targeting new technologies in backgrounding cattle to meet feedlot requirements may be modelled by Scenario 3. Examples of feedlot research in Scenario 5 include research in feedlot nutrition and management.

Due to the expansion of the Japanese and other Asian markets, and the increasing standard of product specifications of grainfed beef in these markets, R&D in the grain-finishing sectors has received greater attention. Consider the seven-year, $19 million venture of the Cooperative Research Centre for the Cattle and Beef Industry (Beef CRC) for example. A major portion of its resources are invested in research programs targeting high-quality grainfed cattle, such as the long-feed heavy grade Japanese ox (B2 and B3). These include projects on pre-boosting and backgrounding cattle in order to meet feedlot entry requirements and to increase feedlot performance. There are also projects on animal nutrition aimed at increasing the growth rate of cattle in feedlots.

A comparison of grassfed research versus grainfed research can be drawn from the results in Table 3. Because of the non-zero but small input substitution elasticities in the grass-finishing, backgrounding and feedlot sectors, the farmers' shares of benefits are slightly higher for backgrounding (28.8%) and grass-finishing (27.6%) research than for feedlot research (26.8%). Thus, in terms of the shares of the total benefits, the farmers should be slightly in favour of research in the areas of backgrounding and grass-finishing than in feedlots. Note that research into more efficient production of weaners delivers an even larger share of benefits to producers.

For the feedlotters, the benefit share is, of course, higher from feedlot research (2.1%) than from research in backgrounding (0.1%) and grass-finishing (0.3%). As for other industry groups (i.e. processors, marketers and domestic and export consumers), there is almost no difference in their percentage shares of total benefits whether the research occurs in the grass-finishing or in the grain-finishing sectors.

This comparison is discussed in more detail in Griffith, Mullen and Zhao (2002).

***Some More Insights about the Results***

As we do not have information on the costs involved in bringing about the same 1% shifts in the various markets, the conclusions that can be drawn from comparing the actual dollar returns from alternative investment scenarios are limited. Thus, the above discussion and comparisons are focused on the percentage shares of the total benefits for each individual group, irrespective of total dollar benefits of different scenarios.

Although the percentage distributions of benefits are not significantly different between many of the research and promotion scenarios, the total welfare gains in *dollar* terms for the same 1% changes are significantly different. For example, grass-finishing research may generate up to ten times more dollars ($13.32 million) as research in the backgrounding ($1.74 million) and feedlot ($1.13 million) sectors. In other words, if an assumption of *equally efficient* investments in all sectors can be made (same $ investment for same % shift), because of their small sizes, research in the backgrounding and feedlot sectors needs to reduce the cost of other inputs by 10% in order to bring the same total welfare benefits as a 1% cost reduction in grass-finishing inputs; that is, the investment needs to be ten times more efficient in the grain-finishing sectors than in the grass-finishing sector.

The rankings of preferences to *farmers* among the twelve alternative investment scenarios, in terms of their percentage shares of total benefits and in terms of their absolute monetary benefits respectively, are given in Table 5. The ranking in the first column is always true even though the information on the investment costs involved in the initial 1% shifts is unavailable. The ranking in the second column is conditional on the assumption of equal efficiency across the various scenarios. Obviously, the ranking of preferences in the two columns is rather different, although Scenarios 1, 2 and 10 are all ranked in the top half of both columns.

More insights may also be gained from the information given in Table 6, which lists the initial percentage shifts required in all scenarios that are necessary to achieve the same dollar benefits as that from Scenario 1. For example, in order for *farmers* to receive the same monetary benefit of $6.61 million as from a 1% cost reduction in weaner production (Scenario 1), costs in cattle processing need to be reduced by 5.46% (Scenario 6), or costs in feedlotting need to be reduced by 22.79% (Scenario 5). Similarly, in order for *farmers* to be indifferent about investing in grass-finishing research (Scenario 2) or in export marketing research (Scenario 8), the cost of creating a technology that reduces grass-finishing costs by 1.79% needs to be the same as the R&D investment that reduces export marketing costs by 11.60%. Conversely, the demand for grassfed beef on the domestic market needs to be raised only 0.90% to provide farmers with $6.61 million. Thus, which of the various investment scenarios is preferable to producers is dependent upon the investment costs in bringing about the required shifts in the relevant demand or supply curves. These calculations may also be done in terms of c/kg rather than percentage changes, as shown in Table 6.

**Sensitivity to Market Elasticity Values**

The results presented above are based on a particular set of market-related elasticities which were chosen from published estimates, economic theory and the authors' subjective judgement. For some parameters, there are relatively more empirical studies available and the possible values of the parameters can be narrowed down to small ranges. However, for others, and in particular given the level of disaggregation in this study, very little empirical evidence is available. Specification of these parameter values in the base model has had to rely substantially on subjective judgement. Further, there are some researchers who argue that input supply elasticities in food processing sectors may be a lot less elastic because of specialisation of labour and management, and that the export demand for Australian beef may be similarly less elastic because of Australia's clean green image. For all these reasons, it is essential to study the sensitivity of model results and their policy-related conclusions to changes in values of parameters.

A stochastic approach to sensitivity analysis is used in this study, as proposed in Zhao, Griffiths, Griffith and Mullen (2000) (see also Davis and Espinoza 1998; Griffiths and Zhao 2000). This is one of several options for handling the problem of uncertainty in input parameters, or more generally, in benefit estimation. Discrete sensitivity analysis is a possibility, but given the large number of parameters involved, it is difficult to obtain a complete picture of the impacts on model results using these methods. Scobie and Jacobsen (1992) argue that there is a close parallel between investment in research and other forms of investment and they propose a portfolio allocation approach to deal with the risk of investing in research programs. However Bardsley (1999) has questioned the assumptions underlying application of this approach to research portfolios, in particular, the nature of the principal-agent relationship in the two cases.

In the chosen method, subjective probability distributions are specified to characterise both the uncertainty in parameter values and the correlations among different parameters. These distributions are carefully chosen (including truncations and combinations of distributions in order to be consistent with the subjective probability belief of value ranges) so that 'unfavourable' draws (such as the ones with wrong signs) will not occur. Additionally, "integrability" restrictions and any inequality restrictions among parameters required by economic theory are imposed to make sure that each set of parameter draws is a proper set of possible parameters. The implied probability distributions for the benefit measures are then obtained through Monte Carlo simulation of the model. From these distributions, mean values, standard deviations and 95% probability intervals can be calculated for the results given in Tables 3 and 4.

Some selected results are reported in Table 7. First, it is evident that total benefits are almost completely insensitive to different elasticity values. This confirms prior expectations (Zhao, Mullen and Griffith 1997). Second, the distribution of total benefits is quite sensitive to different elasticity values. For example, given the uncertainty in elasticities specified in the subjective distributions, we can state that we are 95% confident that farmers will gain between $4.67 million and $11.53 million from weaner research (Scenario 1). The 'best bet' estimate in the base run is $6.61 million. Similarly, we can also state that we are 95% confident that farmers will gain between 23.8% and 58.8% of the total benefits from weaner research. The 'best bet' estimate in the base run is 33.7%. Conversely, while the point estimate for farmers' gain from domestic marketing research (Scenario 7) is $4.72 million, the 95% probability interval is -$0.2 million to $7.3 million, which suggests a possible welfare loss. In fact, from the simulation data, it can be calculated that there is a 3.2% chance that cattle farmers will lose from research dollars invested in the domestic marketing sector. This arises because of some large values allowed in the distributions of input substitution elasticities. Other results in Table 5 also suggest that some sectors can lose from research conducted in another sector.

The mean error in a welfare measure was proposed as a measure of the importance of uncertainty about a particular parameter. Based on this measure, experiments with our model suggested that large mean errors in welfare measures were more likely to be associated with the choice of input substitution elasticities because of the greater uncertainty surrounding these parameters than demand and supply elasticities.

Overall though, the conclusions about *farmers'* preferences among different types of on-farm and off-farm research, in terms of their shares of the total benefits, are shown to be robust with very high probabilities.

## Some Lessons from the use of EDM models

Zhao, Mullen and Griffith (1997) showed analytically that, when the exogenous technology and promotion shifts are assumed to result in small parallel shifts in demand and supply curves, the functional forms of the demand and supply curves are irrelevant and the local linear approximation approach of EDM will provide good approximations of both the price and quantity changes and the economic welfare changes for any true functional forms. However, when proportional shifts are assumed, significant errors are possible in the measures of welfare changes from using the wrong functional forms, even when the initial shifts are small.

Zhao, Mullen and Griffith (2001) also discussed the issue of welfare measures in multi-market EDMs. They concluded that, when two goods are related in both demand and supply, the sum of the economic surplus changes measured sequentially off the partial equilibrium curves is a good approximation to the exact economic welfare measures for the joint producer or consumer group so long as the initial shift considered is small, even though the surplus measures may suffer from path dependency when integrability conditions are not assured. They have also noted that significant errors can arise by estimating changes in surplus areas based on different partial equilibrium curves in the same market.

**Conclusions**

In recent years, around $100 million has been spent annually on R&D and promotion in the Australian red meat industries. The money comes mainly from levies paid by farmer groups and from government contributions for research. Decisions have to be made on how to allocate these funds between R&D and promotion, and between various programs within these broad categories. In this paper, some of these trade-offs were examined using a multi-sectoral equilibrium displacement model of the Australian beef industry.

Total economic surplus changes and their distributions among various industry groups resulting from 1% cost reductions in various farm sectors (weaner production, cattle backgrounding and grass-finishing) and off-farm sectors (feedlotting, processing, and domestic and export marketing), and from 1% demand improvements in various domestic and export markets, were estimated. The results are consistent with previous studies in showing that farmers will receive higher shares of total benefits from all types of farm research than research in the feedlotting, processing and *domestic* marketing sectors. However, research into *export* marketing was shown to be more preferable to farmers, in terms of their shares of the total returns, than some on-farm investments such as those in the cattle backgrounding and post-weaner grass-finishing. Note also that it is only when levies are invested in the sector in which they are raised that the distribution of the benefits from the technology is exactly the same as the incidence of the levy.

Despite the high level of disaggregation the EDM methodology was found to be useful. The results are critically dependent on assumptions of competitive industry sectors and parallel shifts in demand and supply from research and promotion. During the course of the research, a systematic simulation approach to explore uncertainty in parameter values was developed. In general, as sources of equilibrium feedback increase it becomes increasingly difficult to attribute welfare changes to particular industry sectors. In this case, few problems were encountered because there was only one source of feedback between domestic consumers of grassfed and grainfed beef. Although other sources of feed back in consumption and production from outside the industry were ignored.

Complete cost-benefit analyses of alternative investments in the beef industry requires information on both the costs and the benefits of the modelled 1% initial shifts. The results presented in this study provide information about the benefits of alternative investment scenarios, but the costs involved in bringing about the 1% shifts were not examined. Without the cost information, only the percentage shares of the total benefits are strictly comparable among alternative investment scenarios, although more information can be obtained if an assumption of equally efficient research is invoked. However, the model reported in this paper provides a framework for a complete cost-benefit analysis of alternative investments once the information on the investment costs or efficiency in different sectors is available.

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**Appendix: The Model in Equilibrium Displacement Form**

The structural model underlying this research is reported in Zhao (2000) and Zhao, Mullen, Griffith, Griffiths and Piggott (2000). When a new technology or promotion disturbs the system of equations defined by the structural model through an exogenous shifter, a displacement from the base equilibrium results. The relationships among changes in all of the endogenous price and quantity variables and the exogenous shifters can be derived by totally differentiating the system of equations at the initial equilibrium points. The model in equilibrium displacement form is given below, where *E(.)=Δ(.)/(.)* represents a small finite relative change of variable (.). All market parameters refer to elasticity values at the initial equilibrium points. Local linear approximation is implied while totally differentiating the model and approximating the finite changes. The approximation errors in the resulting relative changes of all variables are small as long as the initial exogenous shifts are small (Zhao, Mullen and Griffith 1997). Definitions of all parameters are given in Table 1.

*Input Supply to Backgrounding and Grass-Finishing Sectors:*

(1) $EX_1 = \varepsilon_{(X1, w1)}(Ew_1 - t_{X1})$

(2) $EX_1 = \rho_{Xn1}EX_{n1} + \rho_{Xs1}EX_{s1}$

(3) $EX_{n2} = \varepsilon_{(Xn2, wn2)}(Ew_{n2} - t_{Xn2})$

(4) $EX_{s2} = \varepsilon_{(Xs2, ws2)}(Ew_{s2} - t_{Xs2})$

*Output-Constrained Input Demand of Backgrounding and Grass-Finishing Sectors:*

(5) $EX_{n1} = \tilde{\eta}_{(Xn1, w1)}Ew_{n1} + \tilde{\eta}_{(Xn1, wn2)}Ew_{n2} + EF_{n1}$

(6) $EX_{n2} = \tilde{\eta}_{(Xn2, w1)}Ew_{n1} + \tilde{\eta}_{(Xn2, wn2)}Ew_{n2} + EF_{n1}$

(7) $EX_{s1} = \tilde{\eta}_{(Xs1, w1)}Ew_{s1} + \tilde{\eta}_{(Xs1, ws2)}Ew_{s2} + EY_s$

(8) $EX_{s2} = \tilde{\eta}_{(Xs2, w1)}Ew_{s1} + \tilde{\eta}_{(Xs2, ws2)}Ew_{s2} + EY_s$

*Backgrounding and Grass-Finishing Sectors Equilibrium:*

(9) $\kappa_{Xn1}EX_{n1} + \kappa_{Xn2}EX_{n2} = \gamma_{Fn1e}EF_{n1e} + \gamma_{Fn1d}EF_{n1d}$

(10) $\kappa_{Xn1}Ew_1 + \kappa_{Xn2}Ew_{n2} = \gamma_{Fn1e}Es_{n1e} + \gamma_{Fn1d}Es_{n1d}$

(11) $\kappa_{Xs1}EX_{s1} + \kappa_{Xs2}EX_{s2} = \gamma_{Yse}EY_{se} + \gamma_{Ysd}EY_{sd}$

(12) $\kappa_{Xs1}Ew_1 + \kappa_{Xs2}Ew_{s2} = \gamma_{Yse}Ev_{se} + \gamma_{Ysd}Ev_{sd}$

*Input-Constrained Output Supply of Backgrounding and Grass-Finishing Sectors:*

(13) $EF_{n1e} = \tilde{\varepsilon}_{(Fn1e, sn1e)}Es_{n1e} + \tilde{\varepsilon}_{(Fn1e, sn1d)}Es_{n1d} + EX_n$

(14) $EF_{n1d} = \tilde{\varepsilon}_{(Fn1d, sn1e)}Es_{n1e} + \tilde{\varepsilon}_{(Fn1d, sn1d)}Es_{n1d} + EX_n$

(15) $EY_{se} = \tilde{\varepsilon}_{(Yse, vse)}Ev_{se} + \tilde{\varepsilon}_{(Yse, vsd)}Ev_{sd} + EX_s$

(16) $EY_{sd} = \tilde{\varepsilon}_{(Ysd, vse)}Ev_{se} + \tilde{\varepsilon}_{(Ysd, vsd)}Ev_{sd} + EX_s$

*Other Input Supply to Feedlot Sector*

(17) $EF_{n2} = \varepsilon_{(Fn2,\ sn2)}(Es_{n2} - t_{Fn2})$

(18) $EF_{n3} = \varepsilon_{(Fn3,\ sn3)}(Es_{n3} - t_{Fn3})$

*Output-Constrained Input Demand of Feedlot Sector:*

(19) $EF_{n1e} = \tilde{\eta}_{(Fn1e,\ sn1e)}Es_{n1e} + \tilde{\eta}_{(Fn1e,\ sn1d)})Es_{n1d} + \tilde{\eta}_{(Fn1e,\ sn2)})Es_{n2} + \tilde{\eta}_{(Fn1e,\ sn3)}Es_{n3} + EY_n$

(20) $EF_{n1d} = \tilde{\eta}_{(Fn1d,\ sn1e)}Es_{n1e} + \tilde{\eta}_{(Fn1d,\ sn1d)})Es_{n1d} + \tilde{\eta}_{(Fn1d,\ sn2)})Es_{n2} + \tilde{\eta}_{(Fn1d,\ sn3)}Es_{n3} + EY_n$

(21) $EF_{n2} = \tilde{\eta}_{(\ Fn2,\ sn1e)})Es_{n1e} + \tilde{\eta}_{(Fn2,\ sn1d)})Es_{n1d} + \tilde{\eta}_{(Fn2,\ sn2)})Es_{n2} + \tilde{\eta}_{(Fn2,\ sn3)}Es_{n3} + EY_n$

(22) $EF_{n3} = \tilde{\eta}_{(\ Fn3,\ sn1e)})Es_{n1e} + \tilde{\eta}_{(Fn3,\ sn1d)})Es_{n1d} + \tilde{\eta}_{(Fn3,\ sn2)})Es_{n2} + \tilde{\eta}_{(Fn3,\ sn3)}Es_{n3} + EY_n$

*Feedlot Sector Equilibrium:*

(23) $\kappa_{Fn1e}EF_{n1e} + \kappa_{Fn1d}EF_{n1d} + \kappa_{Fn2}EF_{n2} + \kappa_{Fn3}EF_{n3} = \gamma_{Yne}EY_{ne} + \gamma_{Ynd}EY_{nd}$

(24) $\kappa_{Fn1e}Es_{n1e} + \kappa_{Fn1d}Es_{n1d} + \kappa_{Fn2}Es_{n2} + \kappa_{Fn3}Es_{n3} = \gamma_{Yne}Ev_{ne} + \gamma_{Ynd}Ev_{nd}$

*Input-Constrained Output Supply of Feedlot Sector:*

(25) $EY_{ne} = \tilde{\varepsilon}_{(Yne,\ vne)}Ev_{ne} + \tilde{\varepsilon}_{(Yne,\ vnd)}Ev_{nd} + EF_n$

(26) $EY_{nd} = \tilde{\varepsilon}_{(Ynd,\ vne)}Ev_{ne} + \tilde{\varepsilon}_{(Ynd,\ vnd)}Ev_{nd} + EF_n$

*Other Input Supply to Processing Sector*

(27) $EY_p = \varepsilon_{(Yp,\ vp)}(Ev_p - t_{Yp})$

*Output-Constrained Input Demand of Processing Sector:*

(28) $EY_{se} = \tilde{\eta}_{(Yse,\ vse)})Ev_{se} + \tilde{\eta}_{(Yse,\ vsd)})Ev_{sd} + \tilde{\eta}_{(Yse,\ vne)})Ev_{ne} + \tilde{\eta}_{(Yse,\ vnd)})Ev_{nd} + \tilde{\eta}_{(Yse,\ vp)}Ev_p + EZ$

(29) $EY_{sd} = \tilde{\eta}_{(Ysd,\ vse)})Ev_{se} + \tilde{\eta}_{(Ysd,\ vsd)})Ev_{sd} + \tilde{\eta}_{(Ysd,\ vne)})Ev_{ne} + \tilde{\eta}_{(Ysd,\ vnd)})Ev_{nd} + \tilde{\eta}_{(Ysd,\ vp)}Ev_p + EZ$

(30) $EY_{ne} = \tilde{\eta}_{(Yne,\ vse)})Ev_{se} + \tilde{\eta}_{(Yne,\ vsd)})Ev_{sd} + \tilde{\eta}_{(Yne,\ vne)})Ev_{ne} + \tilde{\eta}_{(Yne,\ vnd)})Ev_{nd} + \tilde{\eta}_{(Yne,\ vp)}Ev_p + EZ$

(31) $EY_{nd} = \tilde{\eta}_{(Ynd,\ vse)})Ev_{se} + \tilde{\eta}_{(Ynd,\ vsd)})Ev_{sd} + \tilde{\eta}_{(Ynd,\ vne)})Ev_{ne} + \tilde{\eta}_{(Ynd,\ vnd)})Ev_{nd} + \tilde{\eta}_{(Ynd,\ vp)}Ev_p + EZ$

(32) $EY_p = \tilde{\eta}_{(Yp,\ vse)})Ev_{se} + \tilde{\eta}_{(Yp,\ vsd)})Ev_{sd} + \tilde{\eta}_{(Yp,\ vne)})Ev_{ne} + \tilde{\eta}_{(Yp,\ vnd)})Ev_{nd} + \tilde{\eta}_{(Yp,\ vp)}Ev_p + EZ$

*Processing Sector Equilibrium:*

(33) $\kappa_{Yse}EY_{se} + \kappa_{Ysd}EY_{sd} + \kappa_{Yne}EY_{ne} + \kappa_{Ynd}EY_{nd} + \kappa_{Yp}EY_p = \gamma_{Zse}EZ_{se} + \gamma_{Zsd}EZ_{sd} + \gamma_{Zne}EZ_{ne} + \gamma_{Znd}EZ_{nd}$

(34) $\kappa_{Yse}Ev_{se} + \kappa_{Ysd}Ev_{sd} + \kappa_{Yne}Ev_{ne} + \kappa_{Ynd}Ev_{nd} + \kappa_{Yp}Ev_p = \gamma_{Zse}Eu_{se} + \gamma_{Zsd}Eu_{sd} + \gamma_{Zne}Eu_{ne} + \gamma_{Znd}Eu_{nd}$

*Input-Constrained Output Supply of Processing Sector:*

(35) $EZ_{se} = \tilde{\varepsilon}_{(Zse,\ use)}Eu_{se} + \tilde{\varepsilon}_{(Zse,\ usd)}Eu_{sd} + \tilde{\varepsilon}_{(Zse,\ une)}Eu_{ne} + \tilde{\varepsilon}_{(Zse,\ und)}Eu_{nd} + EY$

(36) $EZ_{sd} = \tilde{\varepsilon}_{(Zsd,\ use)}Eu_{se} + \tilde{\varepsilon}_{(Zsd,\ usd)}Eu_{sd} + \tilde{\varepsilon}_{(Zsd,\ une)}Eu_{ne} + \tilde{\varepsilon}_{(Zsd,\ und)}Eu_{nd} + EY$

(37) $EZ_{ne} = \tilde{\varepsilon}_{(Zne,\ use)}Eu_{se} + \tilde{\varepsilon}_{(Zne,\ usd)}Eu_{sd} + \tilde{\varepsilon}_{(Zne,\ une)}Eu_{ne} + \tilde{\varepsilon}_{(Zne,\ und)}Eu_{nd} + EY$

(38) $EZ_{nd} = \tilde{\varepsilon}_{(Znd,\ use)}Eu_{se} + \tilde{\varepsilon}_{(Znd,\ usd)}Eu_{sd} + \tilde{\varepsilon}_{(Znd,\ une)}Eu_{ne} + \tilde{\varepsilon}_{(Znd,\ und)}Eu_{nd} + EY$

*Other Input Supply to Marketing Sectors:*

(39) $EZ_{md} = \varepsilon_{(Zmd,\ umd)}(Eu_{md} - t_{Zmd})$

(40) $EZ_{me} = \varepsilon_{(Zme,\ ume)}(Eu_{me} - t_{Zme})$

*Output-Constrained Input Demand of Marketing Sectors:*

(41) $EZ_{sd} = \tilde{\eta}_{(Zsd,\ usd)}Eu_{sd} + \tilde{\eta}_{(Zsd,\ und)}Eu_{nd} + \tilde{\eta}_{(Zsd,\ umd)}Eu_{md} + EQ_d$

(42) $EZ_{nd} = \tilde{\eta}_{(Znd,\ usd)}Eu_{sd} + \tilde{\eta}_{(Znd,\ und)}Eu_{nd} + \tilde{\eta}_{(Znd,\ umd)}Eu_{md} + EQ_d$

(43) $EZ_{md} = \tilde{\eta}_{(Zmd,\ usd)}Eu_{sd} + \tilde{\eta}_{(Zmd,\ und)}Eu_{nd} + \tilde{\eta}_{(Zmd,\ umd)}Eu_{md} + EQ_d$

(44) $EZ_{se} = \tilde{\eta}_{(Zse,\ use)}Eu_{se} + \tilde{\eta}_{(Zse,\ une)}Eu_{ne} + \tilde{\eta}_{(Zse,\ ume)}Eu_{me} + EQ_e$

(45) $EZ_{ne} = \tilde{\eta}_{(Zne,\ use)}Eu_{se} + \tilde{\eta}_{(Zne,\ une)}Eu_{ne} + \tilde{\eta}_{(Zne,\ ume)}Eu_{me} + EQ_e$

(46) $EZ_{me} = \tilde{\eta}_{(Zme,\ use)}Eu_{se} + \tilde{\eta}_{(Zme,\ une)}Eu_{ne} + \tilde{\eta}_{(Zme,\ ume)}Eu_{me} + EQ_e$

*Domestic Marketing Sector Equilibrium:*

(47) $\kappa_{Zsd}EZ_{sd} + \kappa_{Znd}EZ_{nd} + \kappa_{Zmd}EZ_{md} = \gamma_{Qsd}EQ_{sd} + \gamma_{Qnd}EQ_{nd}$

(48) $\kappa_{Zsd}Eu_{sd} + \kappa_{Znd}Eu_{nd} + \kappa_{Zmd}Eu_{md} = \gamma_{Qsd}Ep_{sd} + \gamma_{Qnd}Ep_{nd}$

*Export Marketing Sector Equilibrium:*

(49) $\kappa_{Zse}EZ_{se} + \kappa_{Zne}EZ_{ne} + \kappa_{Zme}EZ_{me} = \gamma_{Qse}EQ_{se} + \gamma_{Qne}EQ_{ne}$

(50) $\kappa_{Zse}Eu_{se} + \kappa_{Zne}Eu_{ne} + \kappa_{Zme}Eu_{me} = \gamma_{Qse}Ep_{se} + \gamma_{Qne}Ep_{ne}$

*Input-Constrained Output Supply of Marketing Sectors:*

(51) $EQ_{sd} = \tilde{\varepsilon}_{(Qsd,\ psd)}Ep_{sd} + \tilde{\varepsilon}_{(Qsd,\ pnd)}Ep_{nd} + EZ_d$

(52) $EQ_{nd} = \tilde{\varepsilon}_{(Qnd,\ psd)}Ep_{sd} + \tilde{\varepsilon}_{(Qnd,\ pnd)}Ep_{nd} + EZ_d$

(53) $EQ_{se} = \tilde{\varepsilon}_{(Qse,\ pse)}Ep_{se} + \tilde{\varepsilon}_{(Qse,\ pne)}Ep_{ne} + EZ_e$

(54) $EQ_{ne} = \tilde{\varepsilon}_{(Qne,\ pse)}Ep_{se} + \tilde{\varepsilon}_{(Qne,\ pne)}Ep_{ne} + EZ_e$

*Domestic Retail Beef Demand:*

(55) $EQ_{sd} = \eta_{(Qsd,\ psd)}(Ep_{sd} - n_{Qsd}) + \eta_{(Qsd,\ pnd)}(Ep_{nd} - n_{Qnd})$

(56) $EQ_{nd} = \eta_{(Qnd,\ psd)}(Ep_{sd} - n_{Qsd}) + \eta_{(Qnd,\ pnd)}(Ep_{nd} - n_{Qnd})$

*Export Demand for Australian Beef:*

(57) $EQ_{se} = \eta_{(Qse,\ pse)}(Ep_{se} - n_{Qse})$

(58) $EQ_{ne} = \eta_{(Qne,\ pne)}(Ep_{ne} - n_{Qne})$

**Table 1. Definition of Variables and Parameters in the Model**

| | |
|---|---|
| *Endogenous Variables:* | |
| $X_{n1}$, $X_{n2}$: | Quantities of weaner cattle for lot-finishing and other inputs to the backgrounding sector, respectively. |
| $X_n$: | Aggregated input index for the feedlot finishing sector. |
| $w_{n2}$: | Price of other inputs to the backgrounding sector. |
| $F_{n1e}$, $F_{n1d}$, $F_{n2}$, $F_{n3}$: | Quantities of backgrounded cattle for export and domestic markets, feedgrain and other feedlot inputs, respectively. |
| $F_{n1}$: | Aggregated output index of the backgrounding sector. |
| $F_n$: | Aggregated input index of the feedlot sector. |
| $s_{n1e}$, $s_{n1d}$, $s_{n2}$, $s_{n3}$: | Prices of $F_{n1e}$, $F_{n1d}$, $F_{n2}$, $F_{n3}$. |
| $Y_{ne}$, $Y_{nd}$: | Quantities of feedlot-finished live cattle for export and domestic markets, respectively. |
| $Y_n$: | Aggregated output index of feedlot sector. |
| $v_{ne}$, $v_{nd}$: | Prices of grain-finished live cattle for export and domestic markets, respectively. |
| $X_{s1}$, $X_{s2}$: | Quantities of weaner cattle and other inputs to the grass finishing sector, respectively. |
| $X_s$: | Aggregated input index for the grass finishing sector. |
| $X_1$: | Quantity of total weaners, $X_1=X_{n1}+X_{s1}$ |
| $w_1$: | Price of weaners. |
| $w_{s2}$: | Price of other inputs to the grass finishing sector. |
| $Y_{se}$, $Y_{sd}$: | Quantities of grass-finished live cattle for export and domestic markets, respectively. |
| $Y_s$: | Aggregated output index for the grass finishing sector; |
| $v_{se}$, $v_{sd}$: | Prices of grass-finished live cattle for export and domestic markets, respectively. |
| $Y_p$: | Quantity of other inputs used in the processing sector. |
| $v_p$: | Price of other inputs used in the processing sector. |
| Y: | Aggregated input index for the processing sector. |
| Z: | Aggregated output index for the processing sector. |
| $Z_{ne}$, $Z_{nd}$: | Quantities of processed grain-fed beef carcass for export and domestic markets, respectively. |
| $u_{ne}$, $u_{nd}$: | Prices of processed grain-fed beef carcass for export and domestic markets, respectively. |
| $Z_{se}$, $Z_{sd}$: | Quantities of processed grass-fed beef carcass for export and domestic markets, respectively. |
| $u_{ne}$, $u_{nd}$: | Prices of processed grass-fed beef carcass for export and domestic markets, respectively. |
| $Z_{me}$, $Z_{md}$: | Quantities of other marketing inputs to export marketing and domestic marketing sectors, respectively. |
| $u_{me}$, $u_{md}$: | Prices of other marketing inputs to export marketing and domestic marketing sectors, respectively. |
| $Z_e$, $Z_d$: | Aggregated input indices to export marketing and domestic marketing sectors, respectively. |
| $Q_e$, $Q_d$: | Aggregated output indices for export marketing and domestic marketing sectors, respectively. |
| $Q_{ne}$, $Q_{se}$: | Quantities of export grain-fed and grass-fed beef, respectively. |
| $p_{ne}$, $p_{se}$: | Prices of export grain-fed and grass-fed beef, respectively. |
| $Q_{nd}$, $Q_{sd}$: | Quantities of domestic grain-fed and grass-fed retail beef cuts, respectively. |
| $p_{nd}$, $p_{sd}$: | Prices of domestic grain-fed and grass-fed retail beef cuts, respectively. |
| *Exogenous Variables:* | |
| $T_x$: | Supply shifter shifting down supply curve of x vertically due to cost reduction in production of x (x = $X_1$, $X_{n2}$, $X_{s2}$, $F_{n2}$, $F_{n3}$, $Y_p$, $Z_{md}$, $Z_{me}$). |
| $t_x$: | Amount of shift $T_x$ as a percentage of price of x (x =$X_1$, $X_{n2}$, $X_{s2}$, $F_{n2}$, $F_{n3}$, $Y_p$, $Z_{md}$, $Z_{me}$). |
| $N_x$: | Demand shifter shifting up demand curve of x vertically due to promotion or taste changes that increase the demand in x (x = $Q_{se}$, $Q_{ne}$, $Q_{sd}$, $Q_{nd}$). |
| $n_x$: | Amount of shift $N_x$ as a percentage of price of x (x = $Q_{sd}$, $Q_{se}$, $Q_{nd}$, $Q_{ne}$). |

**Table 1. Definition of Variables and Parameters in the Model (cont.)**

| | |
|---|---|
| <u>Parameters:</u> | |
| $\eta_{(x, y)}$ : | Demand elasticity of variable x with respect to change in price y. |
| $\varepsilon_{(x, y)}$ : | Supply elasticity of variable x with respect to change in price y. |
| $\widetilde{\eta}_{(x, y)}$: | Constant-output input demand elasticity of input x with respect to change in input price y. |
| $\widetilde{\varepsilon}_{(x, y)}$: | Constant-input output supply elasticity of output x with respect to change in output price y. |
| $\sigma_{(x, y)}$ : | Allen's elasticity of input substitution between input x and input y. |
| $\tau_{(x, y)}$ : | Allen's elasticity of product transformation between output x and output y. |
| $\kappa_x$: | Cost share of input x (x = $X_{n1}$, $X_{n2}$, $X_{s1}$, $X_{s2}$, $F_{n1e}$, $F_{n1d}$, $F_{n2}$, $F_{n3}$, $Y_{ne}$, $Y_{nd}$, $Y_{se}$, $Y_{sd}$, $Y_p$, $Z_{nd}$, $Z_{sd}$, $Z_{md}$, $Z_{ne}$, $Z_{se}$ and $Z_{me}$), where $\sum_{i=1}^{2}\kappa_{Xni}=1$, $\sum_{i=1}^{2}\kappa_{Xsi}=1$, $\sum_{i=1e,1d,2,3}\kappa_{Fni}=1$, $\sum_{i=ne,nd,se,sd,p}\kappa_{Yi}=1$, $\sum_{i=n,s,m}\kappa_{Zid}=1$, $\sum_{i=n,s,m}\kappa_{Zie}=1$. |
| $\gamma_y$: | Revenue share of output y (y = $F_{n1e}$, $F_{n1d}$, $Y_{ne}$, $Y_{nd}$ $Y_{se}$, $Y_{sd}$, $Z_{ne}$, $Z_{nd}$, $Z_{se}$, $Z_{sd}$, $Q_{ne}$, $Q_{se}$ $Q_{nd}$ and $Q_{sd}$), where $\sum_{i=e,d}\gamma_{Fni}=1$, $\sum_{i=e,d}\gamma_{Yni}=1$, $\sum_{i=e,d}\gamma_{Ysi}=1$, $\sum_{i=ne,nd,se,sd}\gamma_{Zi}=1$, $\sum_{i=n,s}\gamma_{Qie}=1$, $\sum_{i=n,s}\gamma_{Qid}=1$. |
| $\rho_{Xn1}$, $\rho_{Xs1}$: | Quantity shares of $X_{n1}$ and $X_{s1}$, ie. $\rho_{Xn1}= X_{n1}/( X_{n1}+ X_{s1})$, $\rho_{Xs1}= X_{s1}/( X_{n1}+ X_{s1})$. |

**Table 2. Selected Elasticity Values for the Equilibrium Displacement Model**

***Domestic Beef Demand Elasticities***

Grainfed beef, own-price = -1.6,
Grainfed beef, cross-price = 1.0,
Grassfed beef, cross-price = 0.3,
Grassfed beef, own-price = -1.1.

***Export Beef Demand Elasticities***

Grainfed beef, own-price = -2.5 ,
Grassfed beef, own-price = -5,

***Input Substitution Elasticities***

*a. Backgrounding Sector*
Weaner cattle for grainfeeding, other inputs = 0.1,
*b. Feedlot Sector*
Export backgrounded cattle, domestic backgrounded cattle = 0.05,
Export backgrounded cattle, feedgrains = 0.1,
Export backgrounded cattle, other inputs = 0.1,
Domestic backgrounded cattle, feedgrains = 0.1,
Domestic backgrounded cattle, other inputs = 0.1,
Feedgrains, other inputs = 0.1,
*c. Grass-Finishing Sector*
Weaner cattle for grass-finishing, other inputs = 0.1,
*d. Processing Sector*
Export grainfed cattle, domestic grainfed cattle = 0.05
Export grainfed cattle, export grassfed cattle = 0.05,
Export grainfed cattle, domestic grassfed cattle = 0.05,
Export grainfed cattle, other inputs = 0.1,
Domestic grainfed cattle, export grassfed cattle = 0.05,
Domestic grainfed cattle, domestic grassfed cattle=0.05,
Domestic grainfed cattle, other inputs = 0.1,
Export grassfed cattle, domestic grassfed cattle = 0.05,
Export grassfed cattle, other inputs = 0.1,
Domestic grassfed cattle, other inputs = 0.1,
*e. Export Marketing Sector*
Export grassfed beef, export grainfed beef = 0.05,
Export grainfed beef, other inputs = 0.1
Export grassfed beef, other inputs = 0.1
*f. Domestic Marketing Sector*
Domestic grassfed beef, domestic grainfed beef = 0.05,
Domestic grassfed beef, other inputs = 0.1,
Domestic grainfed beef, other inputs = 0.1,

***Weaner Supply Elasticity***

All weaners, own-price = 0.9,

***Feedgrain Supply Elasticity***

Feedgrain, own-price = 0.8,

***Other Factor Supply Elasticities***

Other inputs into grassfeeding, own-price=5
Other inputs into backgrounding, own-price=5
Other inputs into feedlotting, own-price=5
Other inputs into processing, own-price=5
Other inputs into domestic marketing, own-price=5
Other inputs into export marketing, own-price=5

***Product Transformation Elasticities***

*a. Backgrounding Sector*
Export backgrounded cattle, domestic backgrounded cattle = -2,
*b. Feedlot Sector*
Export grainfed cattle, domestic grainfed cattle=-0.05,
*c. Grass-Finishing Sector*
Export grassfed cattle, domestic grassfed cattle = -2
*d. Processing Sector*
Export grainfed beef, export grassfed beef = -0.05,
Export grainfed beef, domestic grainfed beef = -0.05,
Export grainfed beef, domestic grassfed beef = -0.05,
Export grassfed beef, domestic grainfed beef = -0.05,
Export grassfed beef, domestic grassfed beef = -0.05,
Domestic grainfed beef, domestic grassfed beef=-0.05,
*e. Export Marketing Sector*
Export grainfed beef, export grassfed beef = -0.05,
*f. Domestic Marketing Sector*
Domestic grainfed beef, domestic grassfed beef=-0.05.

**Table 3. Economic Surplus Changes (in $million) and Percentage Shares of Total Surplus Changes (in %) to Various Industry Groups from Alternative Research Investment Scenarios**

| Industry Group | Scenario 1 weaner production research | | Scenario 2 grass-finishing research | | Scenario 3 back-grounding research | | Scenario 4 feedgrain production research | | Scenario 5 feedlot research | | Scenario 6 processing research | | Scenario 7 domestic marketing research | | Scenario 8 export marketing research | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $m | % | $m | % | $m | % | $m | % | $m | % | $m | % | $m | % | $m | % |
| Weaner producers | 6.00 | 30.6 | 2.98 | 22.3 | 0.41 | 23.3 | 0.30 | 21.1 | 0.26 | 23.3 | 1.05 | 22.5 | 4.10 | 17.2 | 0.49 | 26.2 |
| Grass-finishers | 0.54 | 2.7 | 0.65 | 4.9 | 0.06 | 3.3 | 0.04 | 3.0 | 0.04 | 3.3 | 0.14 | 3.0 | 0.55 | 2.3 | 0.07 | 3.5 |
| Backgrounders | 0.07 | 0.4 | 0.06 | 0.4 | 0.04 | 2.2 | 0.003 | 0.2 | 0.002 | 0.2 | 0.02 | 0.4 | 0.07 | 0.3 | 0.01 | 0.5 |
| Farmers subtotal | 6.61 | 33.7 | 3.69 | 27.6 | 0.51 | 28.8 | 0.34 | 24.3 | 0.29 | 26.8 | 1.21 | 25.9 | 4.72 | 19.8 | 0.57 | 30.2 |
| Feedgrain growers | 0.34 | 1.8 | 0.27 | 2.0 | 0.02 | 1.0 | 0.17 | 12.0 | 0.01 | 1.1 | 0.09 | 1.8 | 0.34 | 1.4 | 0.04 | 2.1 |
| Feedlotters | 0.05 | 0.2 | 0.04 | 0.3 | 0.002 | 0.1 | 0.002 | 0.1 | 0.02 | 2.1 | 0.01 | 0.3 | 0.05 | 0.2 | 0.006 | 0.3 |
| Processors | 0.19 | 1.0 | 0.14 | 1.1 | 0.02 | 1.1 | 0.01 | 1.0 | 0.01 | 1.1 | 0.14 | 3.0 | 0.19 | 0.8 | 0.02 | 1.2 |
| Exporters | 0.09 | 0.5 | 0.07 | 0.5 | 0.01 | 0.5 | 0.006 | 0.4 | 0.006 | 0.5 | 0.02 | 0.5 | 0.07 | 0.3 | 0.05 | 2.6 |
| Domestic retailers | 0.74 | 3.8 | 0.55 | 4.1 | 0.07 | 4.1 | 0.05 | 3.7 | 0.05 | 4.1 | 0.19 | 4.1 | 1.63 | 6.8 | 0.07 | 3.6 |
| Overseas Consumers: grainfed beef | 0.61 | 3.1 | 0.45 | 3.4 | 0.06 | 3.4 | 0.04 | 2.7 | 0.04 | 3.6 | 0.16 | 3.4 | 0.46 | 1.9 | 0.08 | 4.3 |
| grassfed beef | 1.01 | 5.2 | 0.75 | 5.6 | 0.10 | 5.6 | 0.07 | 4.9 | 0.06 | 5.4 | 0.26 | 5.6 | 0.76 | 3.2 | 0.14 | 7.4 |
| Subtotal | 1.62 | 8.3 | 1.20 | 9.0 | 0.16 | 9.0 | 0.11 | 8.2 | 0.10 | 9.0 | 0.42 | 9.0 | 1.22 | 5.1 | 0.22 | 11.7 |
| Domestic consumers | 9.97 | 50.8 | 7.38 | 55.4 | 0.97 | 55.4 | 0.72 | 50.3 | 0.63 | 55.2 | 2.60 | 55.4 | 15.66 | 65.6 | 0.91 | 48.3 |
| Total Surplus | 19.60 | 100 | 13.32 | 100 | 1.74 | 100 | 1.44 | 100 | 1.13 | 100 | 4.69 | 100 | 23.88 | 100 | 1.88 | 100 |

**Table 4. Economic Surplus Changes (in $million) and Percentage Shares of Total Surplus Changes (in %) to Various Industry Groups from Alternative Promotion Investment Scenarios**

| Industry Group | Scenario 9<br><br>Grainfed export promotion | | Scenario 10<br><br>Grassfed export promotion | | Scenario 11<br><br>Grainfed domestic promotion | | Scenario 12<br><br>Grassfed domestic promotion | |
|---|---|---|---|---|---|---|---|---|
| | $m | % | $m | % | $m | % | $m | % |
| weaner producers | 1.69 | 27.2 | 5.60 | 27.4 | 1.91 | 20.1 | 6.40 | 20.3 |
| grass-finishers | 0.23 | 3.6 | 0.75 | 3.7 | 0.25 | 2.7 | 0.85 | 2.7 |
| backgrounders | 0.03 | 0.5 | 0.10 | 0.5 | 0.03 | 0.4 | 0.11 | 0.4 |
| farmers subtotal | 1.95 | 31.3 | 6.45 | 31.6 | 2.19 | 23.2 | 7.36 | 23.4 |
| feedgrain growers | 0.14 | 2.2 | 0.46 | 2.3 | 0.16 | 1.7 | 0.52 | 1.7 |
| feedlotters | 0.02 | 0.3 | 0.06 | 0.3 | 0.02 | 0.2 | 0.07 | 0.2 |
| processors | 0.08 | 1.3 | 0.26 | 1.3 | 0.09 | 0.9 | 0.30 | 1.0 |
| exporters | 0.04 | 0.7 | 0.14 | 0.7 | 0.03 | 0.3 | 0.11 | 0.3 |
| domestic retailers | 0.23 | 3.7 | 0.76 | 3.7 | 0.54 | 5.7 | 1.81 | 5.7 |
| Overseas Consumers: grainfed beef | 0.32 | 5.1 | 0.65 | 3.2 | 0.22 | 2.3 | 0.72 | 2.3 |
| grassfed beef | 0.33 | 5.3 | 1.28 | 6.3 | 0.36 | 3.7 | 1.19 | 3.8 |
| subtotal | 0.65 | 10.4 | 1.93 | 9.5 | 0.58 | 6.0 | 1.91 | 6.1 |
| domestic consumers | 3.12 | 50.1 | 10.32 | 50.6 | 5.87 | 61.9 | 19.45 | 61.7 |
| Total Surplus | 6.23 | 100 | 20.38 | 100 | 9.48 | 100 | 31.55 | 100 |

**Table 5. Rankings of Preferences to Farmers Among the Alternate Research and Promotion Investment Scenarios**

| Rank | in terms of % share of total benefits (%) | in terms of absolute benefits in dollars ($m) |
|---|---|---|
| 1 | Scenario 1 (33.7) | Scenario 12 (7.36) |
| 2 | Scenario 10 (31.6) | Scenario 1 (6.61) |
| 3 | Scenario 9 (31.3) | Scenario 10 (6.45) |
| 4 | Scenario 8 (30.2) | Scenario 7 (4.72) |
| 5 | Scenario 3 (28.8) | Scenario 2 (3.69) |
| 6 | Scenario 2 (27.6) | Scenario 11 (2.19) |
| 7 | Scenario 5 (26.8) | Scenario 9 (1.95) |
| 8 | Scenario 6 (25.9) | Scenario 6 (1.21) |
| 9 | Scenario 4 (24.3) | Scenario 8 (0.57) |
| 10 | Scenario 12 (23.4) | Scenario 3 (0.51) |
| 11 | Scenario 11 (23.2) | Scenario 4 (0.34) |
| 12 | Scenario 7 (19.8) | Scenario 5 (0.29) |

**Table 6. Required Percentage Shifts Necessary to Provide the Same Benefits to Farmers as from Scenario 1**

| | **Scenario 1** weaner production research | **Scenario 2** grass finishing research | **Scenario 3** back-grounding research | **Scenario 4** feedgrain research | **Scenario 5** feedlot research | **Scenario 6** processing research |
|---|---|---|---|---|---|---|
| **Returns to farmers ($million)** | 6.61 | 6.61 | 6.61 | 6.61 | 6.61 | 6.61 |
| **Initial % Shifts Required (%)** | 1.00 | 1.79 | 12.96 | 19.44 | 22.79 | 5.46 |
| **Initial Shifts(C/kg)*** | 1.12 | 1.52 | 11.28 | 3.36 | 6.84 | 6.90 |

| | **Scenario 7** domestic marketing research | **Scenario 8** export marketing research | **Scenario 9** export grainfed promotion | **Scenario 10** export grassfed promotion | **Scenario 11** domestic grainfed promotion | **Scenario 12** domestic grassfed promotion |
|---|---|---|---|---|---|---|
| **Returns to farmers ($million)** | 6.61 | 6.61 | 6.61 | 6.61 | 6.61 | 6.61 |
| **Initial % Shifts Required (%)** | 1.40 | 11.60 | 3.39 | 1.02 | 3.01 | 0.90 |
| **Initial Shifts (C/kg)*** | 3.25 | 1.86 | 19.18 | 3.12 | 31.03 | 7.03 |

* measured as cents per kilogram of cattle/beef inputs of the relevant sector.

**Table 7. Summary Statistics for Welfare Benefits (in $million) and Shares of the Total Benefits (in %) for Various Industry Groups[1]**

| Industry Group | Scenario 1 (weaner production research) $m | Scenario 1 % | Scenario 6 (processing research) $m | Scenario 6 % | Scenario 7 (domestic marketing research) $m | Scenario 7 % |
|---|---|---|---|---|---|---|
| Farmers total: | | | | | | |
| base | 6.61 | 33.7 | 1.21 | 25.9 | 4.72 | 18.7 |
| mean | 7.51 | 38.3 | 1.21 | 25.7 | 3.97 | 25.7 |
| std. dev. | 1.74 | 0.09 | 0.29 | 6.2 | 1.87 | 6.2 |
| 95% PI | (4.67, 11.53) | (23.8, 58.8) | (0.64, 1.78) | (13.6, 37.9) | (-0.2, 7.3) | (-0.9, 30.5) |
| Processors: | | | | | | |
| base | 0.19 | 1.0 | 0.14 | 3.0 | 0.19 | 0.8 |
| mean | 0.17 | 0.9 | 0.20 | 4.3 | 0.15 | 0.6 |
| std. dev. | 0.12 | 0.6 | 0.21 | 4.4 | 0.11 | 0.4 |
| 95% PI | (0.04,0.41) | (0.2, 2.1) | (0.04, 0.73) | (0.8, 15.6) | (-0.009, 0.37) | (-0.04, 1.5) |
| Domestic Retailers: | | | | | | |
| base | 0.74 | 3.8 | 0.19 | 4.1 | 1.63 | 6.8 |
| mean | 0.55 | 2.8 | 0.14 | 3.1 | 1.71 | 7.1 |
| std. dev. | 0.39 | 2.0 | 0.10 | 2.1 | 1.15 | 4.8 |
| 95% PI | (-0.02, 1.45) | (-0.1, 7.4) | (-0.007, 0.37) | (-0.1, 7.9) | (0.46, 4.30) | (1.9, 18.0) |
| Domestic Consumers: | | | | | | |
| base | 9.97 | 50.8 | 2.60 | 55.4 | 15.66 | 65.6 |
| mean | 9.06 | 46.2 | 2.49 | 53.2 | 16.7 | 69.8 |
| std. dev. | 1.75 | 8.9 | 0.37 | 7.9 | 2.6 | 10.9 |
| 95% PI | (5.50, 12.38) | (28.1, 63.2) | (1.82, 3.21) | (38.8, 68.5) | (11.9, 22.5) | (50.0, 93.9) |
| Total benefits: | | | | | | |
| base | 19.6 | 100 | 4.69 | 100 | 23.88 | 100 |
| mean | 19.6 | | 4.69 | | 23.88 | |
| std. dev. | 0.004 | | 0.001 | | 0.01 | |
| 95% PI | (19.60, 19.61) | | (4.686, 4.688) | | (23.87, 23.91) | |

1. Figures on the left of each cell are the monetary benefits and figures on the right are the percentage shares of total benefits, for individual groups.

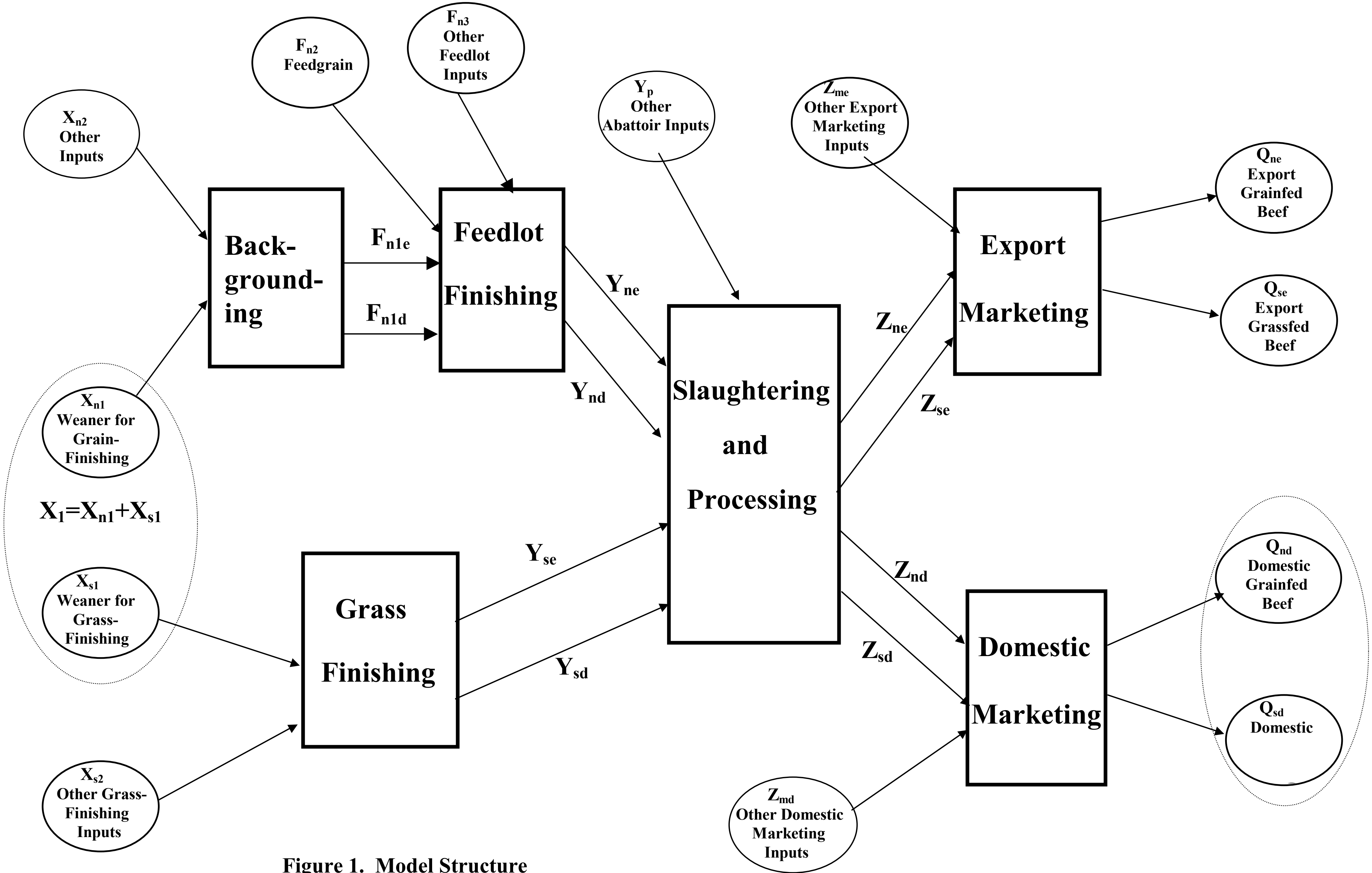


**Figure 1. Model Structure**