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# **Returns to New Technologies in the Australian Beef Industry: On-farm Research versus Off-farm Research**

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## **Background**

The cattle and beef industry is a major component of the Australian agricultural sector. Farm-gate earnings are at about \$4 billion per annum. About two-thirds of its output is exported, earning almost \$3 billion per annum, or about one-third of all farm export revenue (ABARE 1998). 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 1998). Overseas, liberalisation of some Asian markets has provided more opportunities for the industry, but the recent Asian economic crisis has also imposed challenges. While the beef import quota in the United States has been terminated, some South American exporters have achieved foot-and-mouth free status and are seeking a greater share of the United States market. 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.

Total annual expenditure on R&D and promotion for the beef and sheep meat industries has reached \$100 million in recent years (MRC 1996/97, AMLC 1996/97, MLA 1998/99). In the early 1990's, the majority of the R&D and promotion funds were spent on promotion. For example, only 34% of the total funds were invested in R&D in 1990/91. This percentage was increased to 40% in 1996/97 and to 49% in 1998/99 (MLA 1998/99). The splits of R&D expenditure among different types of R&D investments were not available before 1997/98. In 1998/99, of the 49% of the MLA expenditure spent on R&D, 21.4% was spent on producer R&D in the farm and feedlot sectors, 8.7% was spent on processor R&D in the processing sector under contract, and the remaining 18.9% was spent on joint R&D programs which address issues affecting all sectors of the industry.

Like most agricultural industries in Australia, in the cattle and beef industry, producers, feedlotters, processors and exporters pay levies to fund R&D programs, advisory and extension programs, and promotion and market development programs. Producer funds for R&D are also matched by government contributions on a dollar-for-dollar basis up to 0.5% of the gross industry value. In March 1997, the Federal Government announced a historic restructure of the Australian red meat industry's statutory organization, which came into effect on 1 July 1998. The new structure has seen the formation of a primarily producer-funded body, Meat and Livestock Australia (MLA), which replaces the former Australian Meat and Livestock Corporation (AMLC) and the Meat Research Corporation (MRC). It has also seen the emergence of meat processors and exporters' and live exporters' own companies, the

Australian Meat Processor Corporation (AMPC) and the Australian Livestock Exporter Corporation (Livecorp), respectively.

The restructure has resulted in new arrangements in the funding and management of R&D and promotion activities (MLA 1998). Before the restructuring, the AMLC was responsible for red meat promotion and the MRC was responsible for R&D programs. These funds came from various statutory levies and export charges from producers, feedlotters, processors and exporters, as well as government matching funds. Since July 1998, both the R&D and promotional programs have been managed by the same organization, MLA. There are also significant changes in the funding of MLA. Now the majority of MLA funds are from compulsory producer and feedlot levies and government matching grants, but processors and live exporters no longer pay compulsory levies. AMPC and Livecorp collect non-statutory levies from their own members and contract MLA to deliver on research and promotion. Consequently, the contributions from processors and live exporters are significantly reduced. For 1997/98, processors and live exporters were estimated to have contributed \$51 million under the statutory levy arrangement. For 1998/99 these two sectors' contributions to MLA, through contracted projects, are \$12.9 million for AMPC and \$0.9 million for Livecorp.

Primary producers contributed about 60% of the total MLA funds in 1998/99 (MLA 1998). As the industry faces tougher market situations, producer groups have been concerned that the R&D and promotion investment dollars are allocated most efficiently to ensure the highest returns. The pay-off of the investments is also a public policy issue since the coercive powers of governments are used to underpin the levy system. Governments should also be concerned about the returns to the expenditure of public funds. The Commonwealth Government has paid 50% of the total R&D expenditure in recent years (MRC 1996/97; MLA 1998/99).

A successful investment in agricultural R&D leads to the production of knowledge and the creation of technology. Adoption of new technology increases productivity in the sense that more output can be produced for a given cost of inputs, or less input cost is needed to produce a given quantity of output. In the context of the Australian beef industry, R&D investments can be aimed at different sectors along the beef production and marketing chain. They can be on-farm investments targeting farm productivity, or they can be off-farm R&D investments improving the efficiency in feedlotting, processing, or domestic or export marketing sectors.

Knowledge about the total returns from alternative investments across different sectors is useful in that it facilitates efficient allocation of funds. Other important information is the distribution of gross returns across various industry groups -- producers, feedlotters, processors, exporters, retailers, and domestic and export consumers -- so that better decisions can be made about who should fund these investments. This is particularly relevant in today's economic climate where research resources are limited. The relevant questions are: How should the dollars be invested, particularly in relation to the balance of expenditures between 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 feedlot, processing and marketing? Who will benefit? Who should pay?

In this paper, the returns from on-farm research versus off-farm research and the distributions of returns among industry groups are examined using a multi-sectoral equilibrium displacement model of the Australian beef industry. How should R&D funds be allocated between traditional farm research and R&D beyond the farm gate? Should farmers be indifferent towards paying for pasture research and for processing research? As observed in Scobie, Mullen and Alston (1991), there seemed to be a perception that agricultural R&D funds should be diverted from traditional on-farm research to off-farm research. They pointed out that this perception maybe based on the fact that the value added to a farm product in processing is often larger than the value of the farm product, and thus the same productivity gain in processing will give higher total returns than in farm production. There is also a proposition that there maybe less potential in traditional farm R&D than in processing R&D.

There have been some studies comparing returns from farm-oriented research and processing and marketing research. Under the assumption of zero input substitution between the farm input and other inputs, Freebairn, Davis and Edwards (1982) concluded that the distribution of the total benefits among producers and consumers is the same whether the cost reduction occurs in the farm sector or in the marketing sector. Alston and Scobie (1983) showed that, once input substitution is allowed, producers will gain a greater proportion of total returns from research at the farm level than from research at the marketing level. In fact, producers can even lose welfare from non-farm research. This finding was also emphasized by Mullen, Alston and Wohlgenant (1989). Holloway (1989) further investigated the issue by separating the marketing sector into two sequential stages, i.e. processing and distribution. He pointed out that, when the elasticities of substitution between farm and non-farm inputs are different in the two marketing sectors, the farmers' benefits depend crucially on the stage in marketing system where the research occurs.

The objective of this paper is to re-examine the issue of farm research versus off-farm research in the context of the Australian beef industry when the industry is disaggregated both vertically into more production and marketing stages and horizontally into grain- and grass-finishing streams and domestic and export markets.

## **A Disaggregated Model of the Industry**

A disaggregated equilibrium displacement model of the Australian beef industry developed in Zhao (1999) is used in this paper to examine the returns from different types of on-farm and off-farm R&D investments. The approach involves a partial equilibrium displacement framework and the measures of economic surplus changes. With this approach, the equilibrium of the industry is represented with a system of demand and supply relationships among variables of all sectors. Comparative static analysis is applied to the model system, which is then used to linearly approximate the relationship among small finite changes of all prices and quantities (see Zhao, Mullen and Griffith 1997) . Impacts of exogenous changes, such as new technologies, promotional campaigns and government policies, are modelled as shifts in demand or supply curves in the relevant markets. When the equilibrium is displaced due to these

exogenous shifts, changes in prices and quantities in all markets are solved, and the consequent changes in producer and consumer surpluses are then estimated as welfare changes to various industry groups. A review of the equilibrium displacement modeling approach can be found in Alston, Norton and Pardey (1995).

The Australian beef industry involves multiple markets horizontally and multiple production and marketing stages vertically. In order to study the returns of various types of on-farm and off-farm research investments and the benefit distribution among different industry sectors, a model disaggregated along both vertical and horizontal directions is required. Based on information from various sources (ABARE 1998, MRC 1995, K. Wade, AFFA, per comm. 1998), the horizontal market segments of the industry, the associated product specifications and the average percentage shares of the various segments for 1992-1997 are summarized in Table 1. As shown in Table 1, during 1992-97, 62% of Australian-produced beef was sold overseas. On average, 14% of exported beef and 18% of domestic consumed beef are grain finished in commercial feedlots. Vertically, production of final consumable beef products involves breeding, backgrounding, grain or grass finishing, processing, and domestic or export marketing.

The structure of the model is specified in Figure 1, where each rectangle represents a production function, each arrowed straight line represents a market of a product, with the non-arrowed end being the supply of the product and the arrowed end being the demand of the product, and each oval represents a supply or demand schedule where an exogenous shift occurs. The industry was disaggregated into sectors covering breeding, backgrounding, grass- or grain-finishing, processing, marketing and final consumption. The model include four end products with segregation being made on the basis of grain versus grass finishing and domestic versus export consumption. These four components have different market specifications at all production and marketing stages and each comprises significant volume share of the industry. The model is more disaggregated than existing studies of the Australian beef industry. The 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.

Assume that (1) all sectors in the model are profit maximizers; (2) all multi-output production functions are separable in inputs and outputs; and (3) all production functions are characterised by constant returns to scale. Under these assumptions, the production transformation functions for the six industry sectors in the model can be written in general functional form as

$$(1) \quad F_{n1}(F_{n1e}, F_{n1d}) = X_n(X_{n1}, X_{n2}) \quad \textit{backgrounding}$$

$$(2) \quad Y_n(Y_{ne}, Y_{nd}) = F_n(F_{n1e}, F_{n1d}, F_{n2}, F_{n3}) \quad \textit{feedlot finishing}$$

$$(3) \quad Y_s(Y_{se}, Y_{sd}) = X_s(X_{s1}, X_{s2}) \quad \textit{grass-finishing}$$

$$(4) \quad Z(Z_{se}, Z_{sd}, Z_{ne}, Z_{nd}) = Y(Y_{se}, Y_{sd}, Y_{ne}, Y_{nd}, Y_p) \quad \textit{processing}$$

$$(5) \quad Q_d(Q_{nd}, Q_{sd}) = Z_d(Z_{nd}, Z_{sd}, Z_{md}) \quad \textit{domestic marketing}$$

$$(6) \quad Q_e(Q_{ne}, Q_{se}) = Z_e(Z_{ne}, Z_{se}, Z_{me}) \quad \text{export marketing}$$

Definition of all variables is given in Table 2. Under the three assumptions, the total cost functions relating to these production functions are also separable for given output levels and can be written as

$$(7) \quad C_{Fn1} = F_{n1} * c_{Fn1}(w_1, w_{n2}) \quad \text{backgrounding}$$

$$(8) \quad C_{Yn} = Y_n * c_{Yn}(s_{n1e}, s_{n1d}, s_{n2}, s_{n3}) \quad \text{feedlot-finishing}$$

$$(9) \quad C_{Ys} = Y_s * c_{Ys}(w_1, w_{s2}) \quad \text{grass-finishing}$$

$$(10) \quad C_Z = Z * c_Z(v_{se}, v_{sd}, v_{ne}, v_{nd}, v_p) \quad \text{processing}$$

$$(11) \quad C_{Qd} = Q_d * c_{Qd}(u_{nd}, u_{sd}, u_{md}) \quad \text{domestic marketing}$$

$$(12) \quad C_{Qe} = Q_e * c_{Qe}(u_{ne}, u_{se}, u_{me}) \quad \text{export marketing}$$

where  $C_y$  represents total cost for producing indexed output level  $y$  and  $c_y(\cdot)$  represents the unit cost function ( $y = F_{n1}, Y_n, Y_s, Z, Q_d$  and  $Q_e$ ). Similarly, the revenue functions subject to given input levels can be represented as

$$(13) \quad R_{Xn} = X_n * r_{Xn}(s_{n1e}, s_{n1d}) \quad \text{backgrounding}$$

$$(14) \quad R_{Fn} = F_n * r_{Fn}(v_{ne}, v_{nd}) \quad \text{feedlot-finishing}$$

$$(15) \quad R_{Xs} = X_s * r_{Xs}(v_{se}, v_{sd}) \quad \text{grass-finishing}$$

$$(16) \quad R_Y = Y * r_Y(u_{nd}, u_{sd}, u_{ne}, u_{se}) \quad \text{processing}$$

$$(17) \quad R_{Zd} = Z_d * r_{Zd}(p_{nd}, p_{sd}) \quad \text{domestic marketing}$$

$$(18) \quad R_{Ze} = Z_e * r_{Ze}(p_{ne}, p_{se}) \quad \text{export marketing}$$

where  $R_x$  represents total revenue produced from the fixed input index level  $x$  and  $r_x(\cdot)$  represents the unit revenue function associated with one unit of input index  $x$  ( $x = X_n, F_{n1}, X_s, Y, Z_d$  and  $Z_e$ ).

Using Shephard's lemma and Samuelson-McFadden lemma (Chambers 1991 p262, p264), output-constrained input demand and input-constrained output supply functions can be derived as partial derivatives of the above cost and revenue functions. Adding the exogenously determined supply schedules for factors and demand schedules for final products, and incorporating the exogenous shifters representing impacts of various new technologies and promotions, the model system that describes the equilibrium of the Australian beef industry can be derived in general functional form. All exogenous shifts are assumed parallel along the price direction. When a new technology or promotion disturbs the system through the exogenous shifters and results in a displacement of the

equilibrium, the linear relationships among relative changes of all endogenous prices and quantities and the exogenous shifters can be derived through totally differentiating the system of equations at the initial equilibrium. These linear relationships have market elasticities as parameters.

As can be seen from Figure 1, there are 23 factor or product markets that involve 46 price and quantity variables. There are also 12 aggregated input and output index variables for the six multi-output sectors. This amounts to 58 endogenous variables for the 58 equations in the system. The exogenous variables are the 12 shifters representing impacts of new technologies in individual sectors and promotion in domestic and overseas markets. The ultimate objective is to estimate the resulting changes in all prices and quantities in order to estimate the welfare implications of these exogenous shifts. The complete equilibrium displacement model is given in Zhao (1999).

## **Data**

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

The base equilibrium values are specified as the average prices and quantities for 1992-97. Significant effort has been invested in Zhao (1999) to compile a set of consistent equilibrium prices and quantities for all sectors and product types. These include 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. There are no published data that are disaggregated to the required level. In a spreadsheet established for the data derivation (Zhao and Griffith 1999), published data are taken from various government and industry agencies and other available sources, assumptions are made regarding the relationship of cattle prices and quantities at different levels, and the unavailable prices and quantities are derived based on these assumptions. The average prices and quantities for 1992-97 and the resulting cost and revenue shares for all sectors are summarised in Table 3. 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 (1999; Appendix 3).

Market elasticities are 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 are specified based on economic theory, existing empirical estimates and subjective judgement. They relate to a medium-run time frame, which is assumed as the required time frame for the industry to reach a new equilibrium after an initial exogenous shock. Integrability constraints among the elasticities are also ensured in the parameter specification. Details of the specification of market elasticities are given in Zhao (1999). Where published estimates are limited,

substantial subjective judgement is required in order to choose a set of ‘most likely’ elasticity values. A stochastic approach to sensitivity analysis will be used below to systematically study the robustness of results to uncertainty in market elasticities.

There are 12 exogenous shifter variables in the model that shift the relevant demand or supply curves. They are used to model alternative scenarios of research and promotion investments. Equal 1% shifts in the relevant supply or demand curves are assumed for all scenarios. This allows for the simulation of the impacts of 1% cost reductions in various sectors and 1% increases in consumer’s ‘willingness to pay’ in various markets. All 12 scenarios are examined in Zhao (1999). As the focus in this paper is on comparison of returns from different types of research investments, only the seven research scenarios are discussed. These seven scenarios are defined in Table 4 and the exogenous variables are specified accordingly.

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

As shown in Table 4, seven scenarios of research investments are defined that represent cost reductions in the seven production sectors. Typically, research into new technologies in weaner production (Scenario 1), cattle grass-finishing (Scenario 2) and cattle backgrounding (Scenario 3) are 'traditional' on-farm research. Examples include genetic research increasing calving percentage, pasture research increasing grazing efficiency or education initiatives improving producers’ farm management. Off-farm research is R&D beyond the farm gate. In the model, cost reductions in feedlots (Scenario 5), abattoirs (Scenario 6) and domestic (Scenario 7) and export (Scenario 8) marketing sectors relate to off-farm R&D investments.

As mentioned earlier, existing studies on the returns of research investments were based on more aggregated models of an agricultural industry, consisting of a farm sector and a marketing sector. In this study, as shown in Figure 1, the farm sector is separated into breeding, backgrounding, feedlot and grass-finishing sectors. The marketing sector is also disaggregated into a processing sector and separate domestic and export marketing sectors. The disaggregation allows for welfare gains from different types of on-farm and off-farm research to be estimated. It also enables the identification of benefits to individual sectors. Based on the results shown in Alston and Scobie (1983) and Holloway (1989), as non-zero (0.05 and 0.1) 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.

Using the specified base prices and quantities and market elasticities, the equilibrium displacement model can be solved to obtain the percentage changes of all prices and quantities for each research or promotion scenario. Welfare implication in terms of producer and consumer surplus changes can be estimated using the price and quantity changes. Results of the total economic surplus changes and their distribution among industry groups for the seven research scenarios are given in Table 5. For each scenario, total economic surplus gain and its distribution among producers, feedlotters, processors, exporters, retailers and domestic and overseas consumers are presented. Valuable insights can be gained by comparing the results of different scenarios.



Some qualification of the results should be noted before any comparison is undertaken. First, the results in Table 5 relate to equal 1% exogenous shifts in the relevant supply curves. The question of how much money is required to bring about the 1% shifts (i.e. 1% cost reductions in relevant sectors) is not discussed in the study. Information on the investment costs necessary to bring about the 1% shifts requires the knowledge of investment efficiency in individual sectors. For example, Lemieux and Wohlgenant (1989) used experimental data from research into a particular biotechnology to quantify the shift in the supply curve from a particular technology. Alternatively, attempts have been made to estimate the increase in productivity due to R&D expenditure using observed data. For example, Scobie, Mullen and Alston (1991) examined the shape of a research production function for the wool industry, which relates farm R&D expenditures to productivity growth and, consequently, the magnitudes of research-induced supply shifts. Mullen and Cox (1995) and Cox, Mullen and Hu (1997) also studied the relationship of research expenditure and productivity of Australian Broadacre Agriculture. However, accurate estimation of the average relationships between R&D expenditures and supply shifts requires considerable observed data and analysis, which is beyond the scope of the present study. Thus, the monetary returns from alternative scenarios in Table 5 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<sup>1</sup>. For example, the farmers' percentage share of the total benefits from processing technology (i.e. 25.9% for Scenario 6 in Table 5) 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.

Consider first the total welfare gains from alternative scenarios. 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 Table 5, for equal 1% shifts in the relevant markets, domestic beef marketing technology (Scenario 7) and weaner production research (Scenario 1) result in the largest total returns: \$23.88 million and \$19.60 million, respectively. These are followed by grass-finishing research (Scenario 2, \$13.32 million). The total benefits from unit percentage cost reduction in the backgrounding, feedlot, processing and export marketing sectors are much smaller (less than \$4.69 million) due to the small value added to the cattle/beef products in these sectors.

For all seven research scenarios, majority of the total benefits accrue to domestic consumers and cattle producers. Domestic consumers gain the largest share of total

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<sup>1</sup> This is shown in Zhao (1999, p160).

benefits (48.3% to 65.6%) in all seven cases. This is because domestic retail beef comprises the bulk of total industry value at retail and because domestic beef demand is assumed far from perfectly elastic. Farmers, including weaner producers, grass-finishers and backgrounders, receive between 19.8% to 33.7% of total benefits for the seven scenarios.

Overseas consumers and domestic retailers are the other two groups who gain significant shares of total returns. Although more than half of Australian beef goes overseas, the total value of export beef (valued at f.o.b.) is much smaller than the value of domestic beef at retail. More importantly, 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 than domestic consumers in all cases. The shares of the total surplus gains to overseas consumers range from 5.1% to 11.7%. Domestic retailers share 3.6% to 6.8% of total benefits in all scenarios. Beef value is more than doubled through the domestic marketing sector, which makes the value of the retail sector substantial. However, the assumption of a highly elastic supply of marketing inputs (with an elasticity of 5) means that the welfare gain to the retail sector is still rather small.

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 (with an elasticity value of 5).

Now concentrate on the farmers' shares of total benefits from on-farm research versus off-farm research. As can be seen from Table 5, farmers will 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 some types of on-farm research such as R&D in cattle backgrounding and grass-finishing.

The reason that cost reduction in export marketing gives farmers a much larger share of benefits than domestic marketing is that, in comparison to domestic marketing, the export marketing sector is much smaller in value and overseas consumers have a much more elastic demand. Since export consumers and marketers (due to a large elasticity value of 5 for the marketing input supply) are consequently unable to collect benefits, the benefit flows naturally back to producers rather than to the domestic marketers and consumers.

In summary, the results from the present model are consistent with the literature in concluding that, in terms of the shares of total benefits, farmers should prefer on-farm R&D than R&D in feedlots, processing and domestic marketing sectors. However, they should also be interested in export marketing research, which may provide them a even larger share than some post-weaning farm research.

As for Australian consumers, the preference between farm research and off-farm research is inconclusive. While they gain an overwhelmingly larger proportion of the benefits from domestic marketing research (65.6%) and relatively lower shares for weaner production research (50.8%) and export marketing research (48.3%), their shares for the other on-farm and post-farm research scenarios are very similar (55.2% to 55.4%).

Feedlotters, processors and marketers each receive a significantly larger share for research occurring in their own sector. Otherwise, these groups are mostly indifferent among other types of on-farm and off-farm research investments.

### **More Insights about the Results**

The comparison among alternative research investments in the literature and in this study has focused on the percentage shares of the total benefits to individual groups, irrespective of the total dollar benefits of different scenarios. As the information on the costs involved in bringing about the same 1% shifts in the various markets is unavailable, the conclusions that can be drawn from comparing the actual dollar returns from alternative investment scenarios are limited.

Complete insights into the issues can only be gained from information on (1) the cost involved in bringing about the initial research-induced supply shifts, (2) the total welfare gains in dollars resulting from these initial shifts, and (3) the percentage shares of the total benefits to individual industry groups. Without information on the costs or efficiency of research investments in (1), comparison of welfare gains in dollars can only be made under some assumptions such as *equally efficient* investments in all sectors. For example, *if* the investments in marketing research *were* equally efficient in the two marketing sectors in that the R&D investments of bringing about the 1% cost reduction in the two marketing sectors are the same, producers would prefer domestic marketing research (\$4.72 million) to export marketing research (\$0.57 million), even though the shares of total benefits give the opposite preference (19.8% for domestic and 30.2% for export). Or, from a different perspective, investment in export marketing research needs to be eight times as efficient ( $4.72/0.57$  is 8.28) as investment in domestic marketing in order for the farmers to be indifferent about investing in the two marketing sectors.

The rankings of preferences to farmers among the seven 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 6. 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 seven scenarios; that is, the costs of bringing about the equal 1% shifts in all scenarios are the same. Obviously, the ranking of preferences in the two columns is rather different.

More insights may also be gained from the information given in Table 7. In Table 7, the initial percentage shifts required in all scenarios that are necessary to achieve the same dollar benefits as that from Scenario 1 are listed. 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), cost in cattle processing needs to be reduced by 5.46% (Scenario 6), or cost in feedlot inputs needs to be reduced by 22.79% (Scenario 5). Similarly, in order for *farmers* to be indifferent about investing in grass-finishing research (Scenario 2) and in export marketing research (Scenario 8), the cost of creating a technology that reduces the grass-finishing cost by 1.79% needs to be the same as the necessary R&D investment that reduces the export marketing cost by 11.60%. Thus, it is dependent upon the investment costs in bringing about the 1.79% and 11.60% shifts in the two sectors as to which of the two investment scenarios is preferable to producers.

## **Sensitivity of Results to Market Elasticities**

The results presented above are based on the particular set of market-related elasticities. They are the 'best bet' values chosen based on the published estimates, economic theory and the author's 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 some others, very little empirical evidence is available. In particular, given the level of disaggregation in this study, few empirical models are disaggregated to the required level to provide information on some of the parameters. Specification of these parameter values in the base model has had to rely substantially on subjective judgement. Thus, it is essential to study the sensitivity of model results and their policy-related conclusions to changes in values of parameters. Given the large number of parameters involved, it is difficult to obtain a complete picture of the sensitivity issue using discrete sensitivity analysis.

A stochastic approach to sensitivity analysis proposed in Zhao, *et al.* (2000) (see also Davis and Espinoza 1998; Griffiths and Zhao 2000) is used to study the sensitivity issue. Subjective probability distributions are specified to characterize the uncertainty in parameter values and the correlations among different parameters. The implied probability distributions for the welfare measures are then obtained through Monte Carlo simulation. From these distributions, mean values, standard deviations and 95% probability intervals can be calculated for the results in Tables 5 and 7. Details are reported in Zhao (1999).

For example, given the uncertainty in elasticities specified in the subjective distributions, we can be 95% confident that the farmers will gain \$4.67 million to \$11.53 million from weaner research (Scenario 1); the 'best bet' estimate in the base run is \$6.61 million. Also, 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 producers will lose surplus from research dollars invested in the domestic marketing sector. This arises because of some large values allowed in the distributions of input substitution elasticities. The conclusions about the 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.

The impacts of individual parameters on the estimated welfare measures are also studied using the simulation data. Information on the comparative importance of better knowledge about individual parameters is valuable in empirical applications. A response surface is estimated that approximates the relationship between a welfare measure and the market parameters. A sensitivity elasticity (SE) is defined and calculated for each parameter which represents the average percentage change in a welfare measure due to a 1% change in a single parameter. The mean error (ME) in a welfare measure attributable to uncertainty in an individual parameter is also defined and calculated. These measures reflect the relative importance of different parameters taking into account the fact that our level of knowledge about different parameters is different. Although the SEs for input substitution and output transformation elasticities ( $\sigma$ 's and  $\tau$ 's) are much smaller than those for beef demand elasticities and some factor supply elasticities ( $\eta$ 's and  $\varepsilon$ 's), the MEs for  $\sigma$ 's and  $\tau$ 's are just as large as, or even larger than, those for some  $\eta$ 's and  $\varepsilon$ 's. This is because that, in empirical applications, much less is known about the values of  $\sigma$ 's and  $\tau$ 's and there is a much bigger chance of making significant errors in the choice of  $\sigma$ 's and  $\tau$ 's than in  $\eta$ 's and  $\varepsilon$ 's. Details are in Zhao (1999). These SEs and MEs are useful in indicating the relative importance of finding more information about individual parameters.

## 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 from levies paid by producer 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 on-farm R&D and off-farm R&D. In this paper, the issue of on-farm research versus off-farm research is examined using a multi-sectoral equilibrium displacement model of the Australian beef industry.

In particular, 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) are estimated. The results is consistent with existing studies in showing that producers will receive higher shares of total benefits from all types of farm research than research in the feedlotting, processing and *domestic* marketing sectors. However, when the marketing sector is separated into domestic and export sectors, research into *export* marketing is shown to be more preferable to producers, in terms of their shares of the total returns, than on-farm investments such as those in the cattle backgrounding and post-weaner grass-finishing.

Complete cost-benefit analysis 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 provides information about the benefits of alternative investment scenarios, but the costs involved in bringing about the 1% shifts are not examined. Without the cost information, only the percentage shares of the total benefits are comparable among alternative investment scenarios. Further research about the R&D investment efficiency in different industry sectors is necessary. However, the model in this study 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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**Table 1. Australian Beef Industry Disaggregation and Product Specifications**

Market Segments			Product Specifications			
<b>Export (62%)</b>	<b>Grainfed (14%)</b>		Carcass weight(kg)	Age (mths)	Sex	Days on Feed (days)
		JP B3 (18%)	380-420	24-28	steers	230-300
		JP B2 (37%)	340-380	24-28	steers	150
		JP B1 (34%)	330-360	26-30	steers	100
	JP Grainfed Yearling (11%)	240-260	16-18	steers	100	
	Korea: (7%)	K1	220-320	30-36	steers & heifers	100
		Fullset	280-350	24-36	mainly steers	100
	Others: (1%)	Taiwan, EU, US, Canada, etc.				
	<b>Grassfed (86%)</b>	US (37%) Japan (28%) Korea (9%) Canada (7%) Taiwan (5%) Others (14%)	Mainly lower quality manufacturing beef for the US market and high quality fullset and yearlings for the Japanese market. Quality to other countries are mixed.			
<b>Domestic (38%)</b>	<b>Grainfed (18%)</b>	Commercial feedlot finished	Carcass weight(kg)	Age (mths)	Sex	Days on Feed (days)
		(18%)	200-260	16-20	steers & heifers	70
	<b>Grassfed (82%)</b>	Grain supplemented pasture or fed in opportunis feedlots	Mostly yearling beef.			

Sources: ABARE (1998), MRC (1995) and K. Wade, AFFA (per. Comm., 1998)



**Table 2. Definition of Variables and Parameters in the Model**

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$X_{n1}, X_{n2}$ :	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.
$u_{se}, u_{sd}$ :	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.
$t_x$ :	Amount of x supply shift as a percentage of price of x ( $x = X_1, X_{n2}, X_{s2}, F_{n2}, F_{n3}, Y_p, Z_{md}, Z_{me}$ ).

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**Table 3 Base Equilibrium Prices, Quantities and Cost and Revenue Shares (averages of 1992-1997)**

	<b>Quantity and Price</b>	<b>Cost and Revenue Shares</b>
<b>Final Beef Products</b>	<p><b>Export</b> (in <i>kt</i> and <i>\$/kg</i>, shipped weight):</p> $Q_{ne} = 110, p_{ne} = 5.66,$ $Q_{se} = 665, p_{se} = 3.06. TV_{Qe} = 2658$	<p><b>Export Marketing Revenue Shares:</b></p> $\gamma_{Qne} = 0.23, \gamma_{Qse} = 0.77$
	<p><b>Domestic</b> (in <i>kt</i> and <i>\$/kg</i>, retail cuts):</p> $Q_{nd} = 92, p_{nd} = 10.31$ $Q_{sd} = 404, p_{sd} = 7.81. TV_{Qd} = 4104$	<p><b>Domestic Marketing Revenue shares:</b></p> $\gamma_{Qnd} = 0.23, \gamma_{Qsd} = 0.77$
	$TV_Q = 6762$	
<b>Wholesale Carcass</b>	<p>(in <i>kt</i> and <i>\$/kg</i>, carcass weight)</p> $Z_{ne} = 161, u_{ne} = 2.45,$ $Z_{se} = 974, u_{se} = 2.13. TV_{Ze} = 2469$	<p><b>Export Marketing Cost Shares:</b></p> $\kappa_{Zne} = 0.15, \kappa_{Zse} = 0.78$ $\kappa_{Zme} = 0.07$
	$Z_{nd} = 128, u_{nd} = 2.70,$ $Z_{sd} = 561, u_{sd} = 2.45. TV_{Zd} = 1720$	<p><b>Domestic Marketing Cost Shares:</b></p> $\kappa_{Znd} = 0.08, \kappa_{Zsd} = 0.34$ $\kappa_{Zmd} = 0.58$
	$TV_Z = 4189$	<p><b>Processing Sector Revenue Shares:</b></p> $\gamma_{Zne} = 0.09, \gamma_{Zse} = 0.50,$ $\gamma_{Znd} = 0.08, \gamma_{Zsd} = 0.33.$
<b>Finished Live Cattle</b>	<p>(in <i>kt</i> and <i>\$/kg</i>, live weight)</p> $Y_{ne} = 293, v_{ne} = 1.20,$ $Y_{nd} = 232, v_{nd} = 1.34. TV_{Yn} = 662$	<p><b>Processing Sector Cost Shares:</b></p> $\kappa_{Yne} = 0.08, \kappa_{Yse} = 0.43,$ $\kappa_{Ynd} = 0.07, \kappa_{Ysd} = 0.29,$ $\kappa_{Yp} = 0.12.$
	$Y_{se} = 1772, v_{se} = 1.03,$ $Y_{sd} = 1019, v_{sd} = 1.21. TV_{Ys} = 3058$	<p><b>Feedlot Sector Revenue Shares:</b></p> $\gamma_{Yne} = 0.53, \gamma_{Ynd} = 0.47$
	$TV_Y = 3720$	<p><b>Grass Finishing Sector Revenue Shares:</b></p> $\gamma_{Yse} = 0.60, \gamma_{Ysd} = 0.40$
<b>Feeder Cattle and Feedgrain</b>	<p><b>Feeders</b> (in <i>kt</i> and <i>\$/kg</i>, live weight):</p> $F_{n1e} = 205, s_{n1e} = 1.12,$ $F_{n1d} = 172, s_{n1d} = 1.02. TV_{F1} = 405$	<p><b>Feedlot Sector Cost Shares:</b></p> $\kappa_{Fn1e} = 0.35, \kappa_{Fn1d} = 0.26,$ $\kappa_{Fn2} = 0.22, \kappa_{Fn3} = 0.17.$
	<p><b>Feedgrain</b> (in <i>kt</i> and <i>\$/kg</i>):</p> $F_{n2} = 819, s_{n2} = 0.176$	<p><b>Backgrounding Sector Revenue Shares:</b></p> $\gamma_{Fn1e} = 0.57, \gamma_{Fn1d} = 0.43.$
<b>Weaner Cattle</b>	<p>(in <i>kt</i> and <i>\$/kg</i>, live weight)</p> $X_{n1} = 206, X_{s1} = 1542,$ $X_1 = 1748, w_1 = 1.12. TV_{X1} = 1958$	<p><b>Backgrounding Sector Cost Shares:</b></p> $\kappa_{Xn1} = 0.57, \kappa_{Xn2} = 0.43.$
		<p><b>Grass Finishing Sector Cost Shares:</b></p> $\kappa_{Xs1} = 0.56, \kappa_{Xs2} = 0.44.$

**Table 4. Exogenous Shift Variables for Various Investment Scenarios**

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**Scenario 1: Weaner Production Research:**

$t_{x1} = -0.01$ , rest  $t_{( )} = 0$  and  $n_{( )} = 0$ .

Cost reduction in weaner production resulting from any breeding or farm technologies that reduce the cost of producing weaners.

**Scenario 2: Grass-Finishing Research**

$t_{xs2} = -0.01$ , rest  $t_{( )} = 0$  and  $n_{( )} = 0$ .

Other cost reductions in the grass-finishing sector resulting from any farm technologies or new management strategies that increase the productivity of 'other inputs'. This also includes nutritional technologies in grain supplementing cattle, because cattle topped up on pasture are modelled as part of the grass-finishing sector.

**Scenario 3: Backgrounding Research**

$t_{xn2} = -0.01$ , rest  $t_{( )} = 0$  and  $n_{( )} = 0$ .

Other cost reductions in the backgrounding sector resulting from new backgrounding technologies.

**Scenario 5: Feedlot Research**

$t_{fn3} = -0.01$ , rest  $t_{( )} = 0$  and  $n_{( )} = 0$ .

Other cost reductions in the feedlot sector due to research into areas such as feedlot nutrition and management.

**Scenario 6: Processing Research**

$t_{yp} = -0.01$ , rest  $t_{( )} = 0$  and  $n_{( )} = 0$ .

Other cost reductions in the beef processing due to new technologies or management strategies in the processing sector.

**Scenario 7: Domestic Marketing Research**

$t_{zmd} = -0.01$ , rest  $t_{( )} = 0$  and  $n_{( )} = 0$ .

Other cost reductions in the domestic marketing and retailing sector resulting from research-induced technologies and improved management.

**Scenario 8: Export Marketing Research**

$t_{zme} = -0.01$ , rest  $t_{( )} = 0$  and  $n_{( )} = 0$ .

Other cost reductions in export marketing due to research investments that increase export marketing efficiency.

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**Table 5. Economic Surplus Changes (in \$million) and Percentage Shares of Total Surplus Changes (in %) to Various Industry Groups from Alternative Research Investment Scenarios**

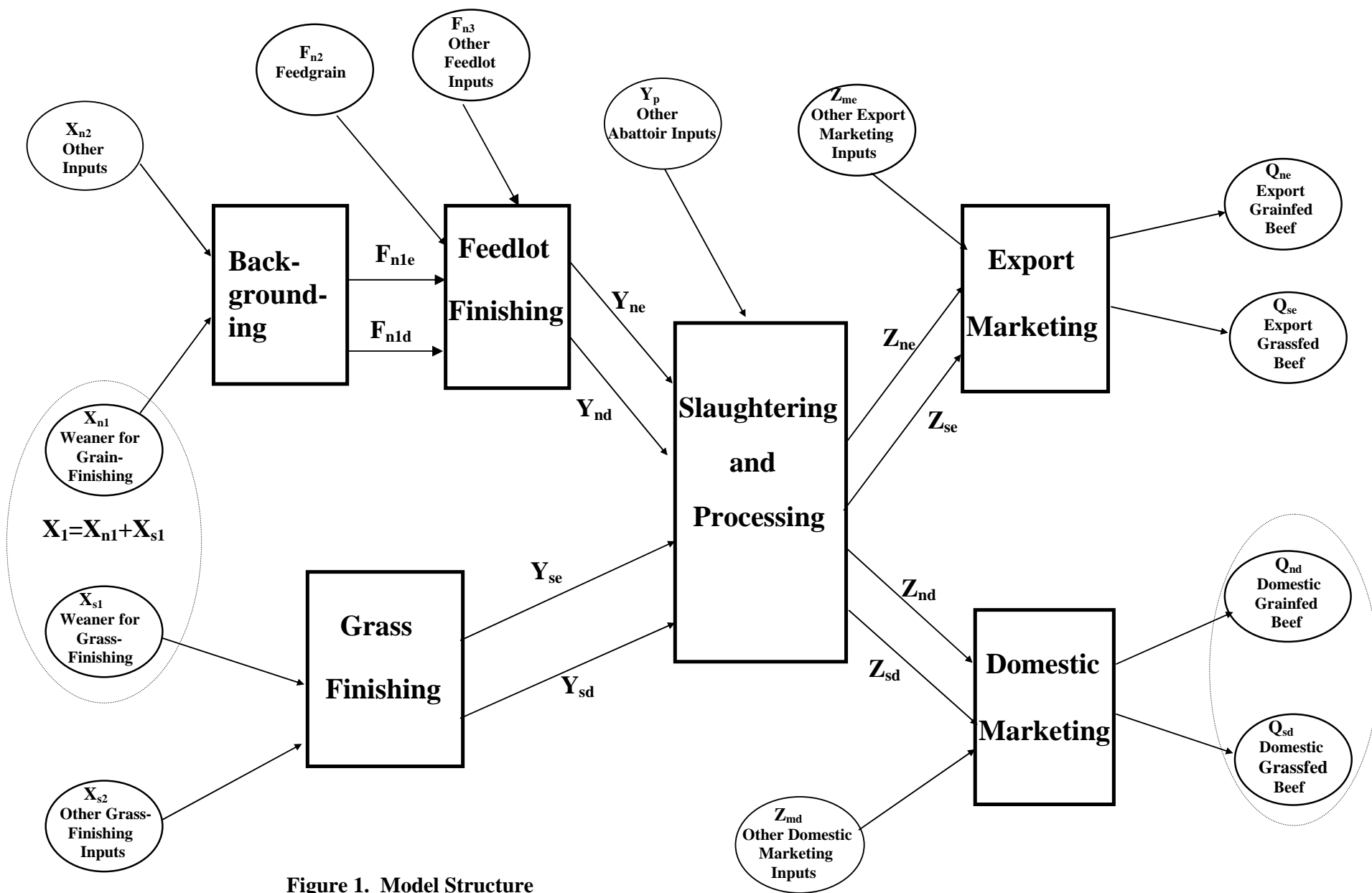
	Scenario 1 ( $t_{X1}=-1\%$ ) weaner research		Scenario 2 ( $t_{Xs2}=-1\%$ ) grass-finish- ing research		Scenario 3 ( $t_{Xn2}=-1\%$ ) background- ing research		Scenario 5 ( $t_{Fn3}=-1\%$ ) feedlot research		Scenario 6 ( $t_{Yp}=-1\%$ ) processing research		Scenario 7 ( $t_{Zmd}=-1\%$ ) domestic marketing research		Scenario 8 ( $t_{Zme}=-1\%$ ) export marketing research	
	\$m	%	\$m	%	\$m	%	\$m	%	\$m	%	\$m	%	\$m	%
$\Delta PS_{X1}$ weaner producers	6.00	30.6	2.98	22.3	0.41	23.3	0.26	23.3	1.05	22.5	4.10	17.2	0.49	26.2
$\Delta PS_{Xs2}$ grass-finishers	0.54	2.7	0.65	4.9	0.06	3.3	0.04	3.3	0.14	3.0	0.55	2.3	0.07	3.5
$\Delta PS_{Xn2}$ backgrounders	0.07	0.4	0.06	0.4	0.04	2.2	0.002	0.2	0.02	0.4	0.07	0.3	0.01	0.5
$\Delta PS_{X1} +$ $\Delta PS_{Xs2} + \Delta PS_{Xn2}$ <b>farmers subtotal</b>	<b>6.61</b>	<b>33.7</b>	<b>3.69</b>	<b>27.6</b>	<b>0.51</b>	<b>28.8</b>	<b>0.29</b>	<b>26.8</b>	<b>1.21</b>	<b>25.9</b>	<b>4.72</b>	<b>19.8</b>	<b>0.57</b>	<b>30.2</b>
$\Delta PS_{Fn2}$ <b>feedgrain growers</b>	0.34	1.8	0.27	2.0	0.02	1.0	0.01	1.1	0.09	1.8	0.34	1.4	0.04	2.1
$\Delta PS_{Fn3}$ <b>feedlotters</b>	0.05	0.2	0.04	0.3	0.002	0.1	0.02	2.1	0.01	0.3	0.05	0.2	0.006	0.3
$\Delta PS_{Yp}$ <b>processors</b>	0.19	1.0	0.14	1.1	0.02	1.1	0.01	1.1	0.14	3.0	0.19	0.8	0.02	1.2
$\Delta PS_{Zme}$ <b>exporters</b>	0.09	0.5	0.07	0.5	0.01	0.5	0.006	0.5	0.02	0.5	0.07	0.3	0.05	2.6
$\Delta PS_{Zmd}$ <b>domestic retailers</b>	<b>0.74</b>	<b>3.8</b>	<b>0.55</b>	<b>4.1</b>	<b>0.07</b>	<b>4.1</b>	<b>0.05</b>	<b>4.1</b>	<b>0.19</b>	<b>4.1</b>	<b>1.63</b>	<b>6.8</b>	<b>0.07</b>	<b>3.6</b>
<b>Overseas Consumers:</b>														
$\Delta CS_{Qne}$ grainfed beef	0.61	3.1	0.45	3.4	0.06	3.4	0.04	3.6	0.16	3.4	0.46	1.9	0.08	4.3
$\Delta CS_{Qse}$ grassfed beef	1.01	5.2	0.75	5.6	0.10	5.6	0.06	5.4	0.26	5.6	0.76	3.2	0.14	7.4
$\Delta CS_{Qne} + \Delta CS_{Qse}$ <b>subtotal</b>	<b>1.62</b>	<b>8.3</b>	<b>1.20</b>	<b>9.0</b>	<b>0.16</b>	<b>9.0</b>	<b>0.10</b>	<b>9.0</b>	<b>0.42</b>	<b>9.0</b>	<b>1.22</b>	<b>5.1</b>	<b>0.22</b>	<b>11.7</b>
$\Delta CS_{Qne}$ <b>domestic consumer</b>	<b>9.97</b>	<b>50.8</b>	<b>7.38</b>	<b>55.4</b>	<b>0.97</b>	<b>55.4</b>	<b>0.63</b>	<b>55.2</b>	<b>2.60</b>	<b>55.4</b>	<b>15.66</b>	<b>65.6</b>	<b>0.91</b>	<b>48.3</b>
<b>Total Surplus</b>	<b>19.60</b>	<b>100</b>	<b>13.32</b>	<b>100</b>	<b>1.74</b>	<b>100</b>	<b>1.13</b>	<b>100</b>	<b>4.69</b>	<b>100</b>	<b>23.88</b>	<b>100</b>	<b>1.88</b>	<b>100</b>

**Table 6. Rankings of Preferences to Farmers among the Seven Research Investment Scenarios**

<i>Rank</i>	<i>in terms of % share of total benefits (%)</i>	<i>in terms of absolute benefits in dollars (\$m)</i>
1	S. 1 (33.7)	S. 1 (6.61)
2	S. 8 (30.2)	S. 7 (4.72)
3	S. 3 (28.8)	S. 2 (3.69)
4	S. 2 (27.6)	S. 6 (1.21)
5	S. 5 (26.8)	S. 8 (0.57)
6	S. 6 (25.9)	S. 3 (0.51)
7	S. 7 (19.8)	S. 5 (0.29)

**Table 7. Required Percentage Shifts Necessary to Provide the Same Benefits to Farmers as from Scenario 1**

	<b>Scenario 1</b> weaner prod. research	<b>Scenario 2</b> grass-finishing research	<b>Scenario 3</b> backgrounding research	<b>Scenario 5</b> feedlot research	<b>Scenario 6</b> processing research	<b>Scenario 7</b> dom. marketing research	<b>Scenario 8</b> exp. marketing research
<b>Returns to farmers (\$million)</b>	6.61	6.61	6.61	6.61	6.61	6.61	6.61
<b>Initial % Shifts Required (%)</b>	1.00	1.79	12.96	22.79	5.46	1.40	11.60



**Figure 1. Model Structure**