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Updating and Recalibrating Equilibrium Displacement Models of the Australian Livestock Industries: Beef[1]

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Abstract

An existing equilibrium displacement model of the Australian beef industry was updated to enable the distribution of the total benefits from the adoption of new technology or promotion investments to be estimated across the beef value chain. Three hypothetical simulations were run to test the impact of recalibrating the model to the new initial equilibrium. The distribution of the gross benefits to the various industry sectors were found to be broadly similar to those reported in the original model. Cattle producers receive between 29 and 40 per cent of the potential gross benefits from the hypothetical investments, overseas consumers receive between 11 and 15 per cent, while domestic consumers receive between 37 and 47 per cent, depending on the scenario. Beef processors, feedlots and domestic retailers all receive much smaller shares of gross benefits, typically less than 5 per cent each. While the updated model provides a framework that reflects the current industry size and structure, the results are conditional on the specified price and quantity values, their underlying assumptions and calculations, and the parameter values used to represent industry responses to price changes.

Key words: beef, EDM, update, simulation

Background

Evaluation of research and promotion can be either *ex post*, as a means of determining the effectiveness of investments already undertaken, or *ex ante*, as a basis for priority setting (Alston et al., 1995). Knowing the potential size and distribution of returns from alternative research and promotion investments across different sectors of an industry enables more informed strategic-level decisions to be made about how to allocate limited resources among a number of investment options. Such evaluations are usually undertaken using economic models of the relevant markets or industries.

In the context of research and promotion investments in the Australian beef industry, two options exist for formal market level modelling. One option is the DREAM (Dynamic Research Evaluation for Management) model which is a freely-available software package (Wood et al., 2001). This model provides the total benefits from adoption of a new technology or promotion campaign and a disaggregation of the regional distribution of the impact, but only a simple vertical disaggregation

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between producers and consumers. This approach has been applied to the Australian beef industry by Griffith (2009a) and Griffith et al. (2013).

The second option is the Zhao beef equilibrium displacement model (EDM) (Zhao et al., 2000). It also estimates total benefits but complements the DREAM model by providing a detailed disaggregation across the value chain. This is important information since many beef industry innovations are adopted at other than the farm level and many of the investors are looking at returns to particular sectors of the value chain. The original Zhao et al. model was based on average 1992-1997 data and was completed in 1999. Since then the model has been reconfigured into Excel format (Griffith, 2009b; Hester and Griffith, 2009), and also updated using average values for 2006-2010 (Mounter et al., 2011).

A new application has been identified for the model, relating to estimating the benefits from the Advanced Livestock Measurement Technology project. Thus, the objectives of this paper are to review and update the Zhao et al. model of the Australian beef market. This will enable more time relevant estimation of the vertical disaggregation of the total potential benefits from new technologies that are adopted at either the farm level or other sectors of the value chain (as well as generic promotion and potentially other policy changes in the different sectors and markets). Both the base price and quantity data and the underlying structure of the model need to be reviewed given the ongoing changes in industry structure and ways of doing business.

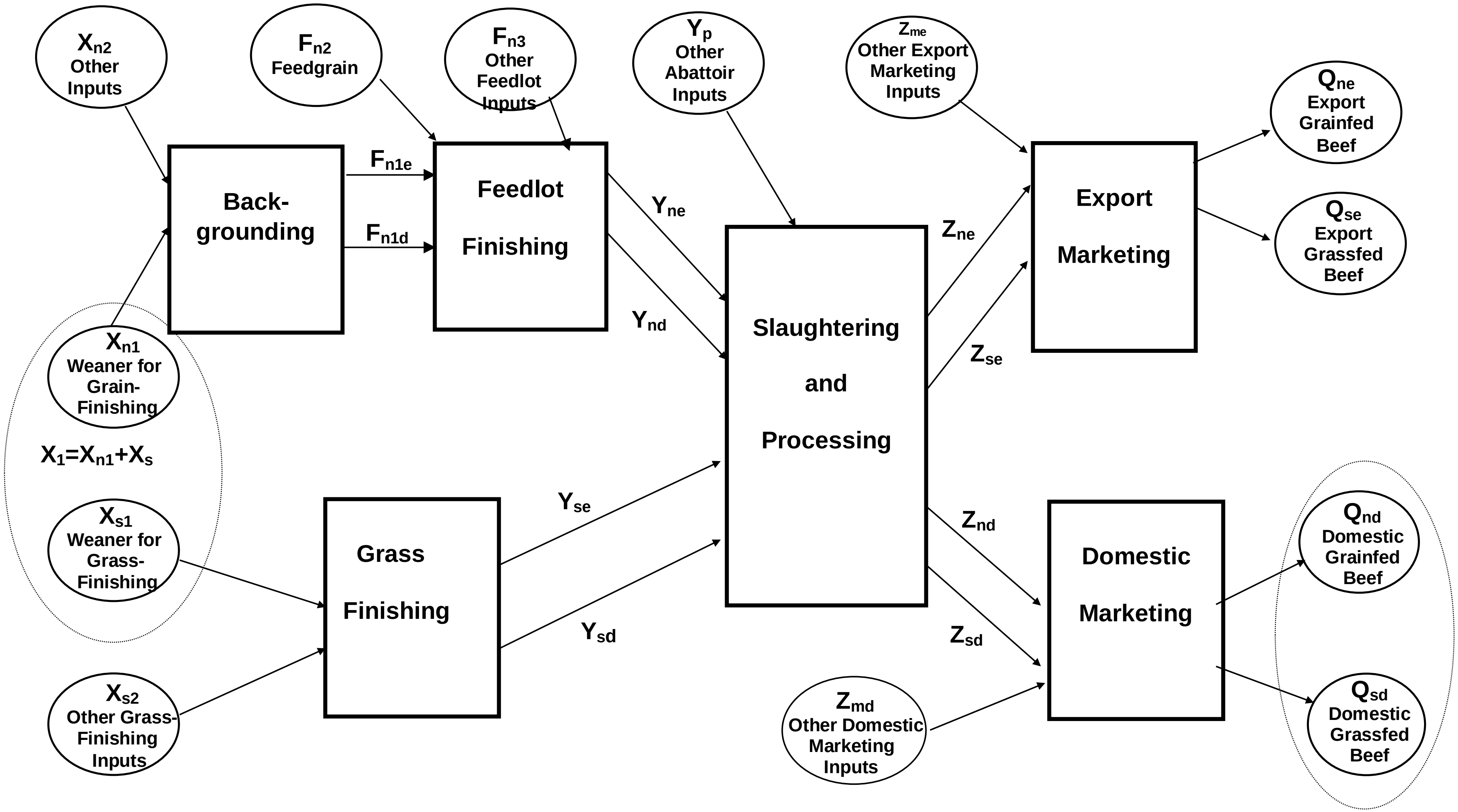
Methodology

The EDM approach employs comparative static analysis in a partial equilibrium framework. The framework is partial in the sense that prices in markets not included in the model are assumed constant. The approach offers a number of advantages over other modelling approaches in that it provides a consistent economic framework for examining various broad types of research and promotion, and is not overly data-intensive. Compared with the historical time series requirements of econometric modelling, EDM needs only one set of base equilibrium price and quantity data, and values for market parameters such as Marshallian demand and supply elasticities. Representation of an industry within an EDM consists of a system of demand and supply equations. The equations are expressed in terms of relative changes and elasticities by total differentiation of the general functional form equations and conversion into elasticity form. The impacts of exogenous changes, such as new technologies or promotions, are modelled as shifts in demand or supply in the relevant markets. From the resulting price and quantity changes in all markets, the welfare changes to the various industry participants are estimated as changes in producer and consumer surplus.

The structure of the industry

In updating the model there are three main areas that need to be considered. The first is to determine if the current industry structure is similar to the industry structure embedded in the original model (Figure 1). This involves checking data series to examine aggregate supply and disappearance figures and to check that the various market segments of the Australian beef industry are consistent with those observed during the period 1992-1997. A review of industry, and other relevant, publications led to the conclusion that the current industry structure is basically the same as it was in the mid-1990s. Hence, the original modelling framework is still representative of the current industry structure.

Figure 1. Model structure



It is also necessary to identify whether there have been any domestic or export policy changes that may have altered product flows or values, and to establish if there have been significant merger or acquisition activities that may have resulted in vertical industry sector consolidation. In recent times concerns have been expressed over the issue of market power in the Australian food marketing chain and increasing concentration in the retail food sector. However Chung and Griffith (2009) found no evidence that the marketing chains for the Australian fresh meat industries are non-competitive.

One change, however, has been made to the original model in which a separate sector was specified for export marketing of beef. As noted by Zhao et al. (2000) the domestic marketing sector comprises supermarkets and local butcher shops where retail cuts are prepared and packaged, whereas the export marketing sectors are most likely the boning and packing rooms in abattoirs. Hence, in this updated version of the model, export marketing is assumed to be a part of the slaughtering and processing (abattoir) sector.

Parameter values

The second consideration is to determine whether current industry responses to price changes are similar to the responses that represent the industry adjustment processes during the period 1992-1997. The EDM has six demand elasticities, seven supply elasticities, 21 input substitution elasticities and ten product transformation elasticities (Table 1). To assess whether any of the parameter values have altered significantly requires identifying whether there have been changes in consumer preferences in different markets or significant technological changes in production and processing activities that would have implications for the demand, supply, input substitution and product transformation relationships specified in the model.

Various industry reports and other publications were examined to ascertain if the specified relationships in the model may have changed. For example, recent empirical estimates of the own-price elasticity of domestic demand for beef were found to be similar in magnitude to the values specified in the EDM (Mounter et al., 2012).

Based on the available information it was concluded that no changes were needed to the elasticity values specified in the existing model as they were still a sufficiently accurate representation of adjustment responses in the beef industry.

The base price and quantity data

The third consideration is to establish if current aggregate industry-sector revenues and costs are comparable to those observed during the period specified in the original model. The base equilibrium data used in the model are reflective of an average situation in the Australian beef industry during the period 1992-1997. These values were selected as being representative of a "typical" year or set of years and reflective of conditions in the medium term future, the period of time assumed for industry adjustment to take place in response to a displacement of the initial equilibrium.

Examination of selected industry data indicates that average yearly beef production in the period 2014-2016 was approximately 13 per cent higher than in the mid-1990s; beef consumption was slightly lower; exports of beef were more than 50 per cent higher; and the average retail price of beef, in nominal terms, was about double the 1992-1997 average.

In relation to exports, according to MLA (2017), on average 72 per cent of Australian-produced beef was exported during 2014-2016 compared to 64 per cent during 2006-2010 and 62 per cent during 1992-1997. Approximately 20 per cent of exported beef during the 2014-2016 period was grain

Table 1. 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.

finished and 80 per cent was grass finished (compared with 24 per cent and 76 per cent, respectively during 2006-2010; and 14 per cent and 86 per cent, respectively during 1992-1997).

Japan accounted for over 51 per cent of Australia's export grain-finished beef during 2014-2016, followed by South Korea (17 per cent) and the newly emerging China market (7 per cent). The two largest markets for Australian grassfed beef during 2014-2016 were the United States and Japan (36 per cent and 16 per cent, respectively of total grassfed exports). Australian beef exports to the United States are still predominately lower quality manufacturing beef, while grassfed beef exports to Japan are mostly high quality. However the overall pattern of supplies and demands remains the same.

These differences indicate it is necessary to update the base price and quantity data, and hence the cost and revenue shares, used in the model to ensure a more accurate representation of both the size and value of the Australian beef industry, and it's components, in recent years.

Variable definitions are provided in Table 2. The average prices and quantities for 1992-1997, 2006-2010 and 2014-2016, and the cost and revenue shares of the specified industry sectors and markets, are listed in Tables 3-5 respectively. The specification of prices and quantities for all sectors are detailed in the Appendix.

Estimation and Results

The TSP input file for the EDM was updated with the new price, quantity, cost share and revenue share data shown in Table 5. Three of the original twelve hypothetical simulations in Zhao et al. (2000) were run to test the impact of recalibrating the model to the new initial equilibrium. The hypothetical simulations are listed in Table 6. They are Scenario 1: cost reduction in weaner production; Scenario 6: cost reduction in beef processing; and Scenario 11: domestic grain-fed beef promotion.

The results from the new hypothetical scenarios were compared to the Zhao et al. (2000) and the Mounter et al. (2011) simulation results. The comparisons are presented in Tables 7a and 7b.[2]

From Tables 7a and 7b it is apparent that, with one exception, the total economic surplus values (the total gross benefits from the hypothetical shift) derived from the 2014-2016 data are much larger than those calculated from the 1992-1997 data. The exception is the total surplus value for a one per cent cost reduction in processing inputs, which is lower than the earlier results. However in all cases the total surplus values are approximately one per cent of the total sector value in which the simulation occurs. For example the total value of weaner production is estimated as $4,095 million (TVX1 at the bottom of Table 5), and the total surplus from a one per cent cost reduction in weaner production (scenario 1) is $41 million (bottom of Table 7a). The same is true for an increase in grainfed beef willingness to pay (scenario 11 - $5,747 million and $57.45 million) and a cost reduction in beef processing (scenario 6 - $354 million (the difference between the total value of cattle inputs and the total value of carcase outputs) and $3.54 million). Therefore, as long as the percentage shift in demand or supply is relatively small, the change in total surplus can be approximated from the

[2] The changes in producer and consumer surplus measures reported in Tables 7a and 7b are essentially estimates of changes in aggregate willingness to pay by consumers, and aggregate profits to producers, respectively, due to the specified hypothetical shifts in supply or demand curves. Importantly, they are estimated gross benefits and do not consider the costs required to implement the demand or supply curve shifts or the rates of producer adoption of new technologies or of increased consumer willingness to pay.

Table 2. Definitions of price and quantity variables in the model

Xn1, Xn2: Quantities of weaner cattle for lot-finishing and other inputs to the backgrounding sector, respectively.
wn2: Price of other inputs to the backgrounding sector.
Fn1e, Fn1d, Fn2, Fn3: Quantities of backgrounded cattle for export and domestic markets, feedgrain and other feedlot inputs, respectively.
sn1e, sn1d, sn2, sn3: Prices of Fn1e, Fn1d, Fn2, Fn3.
Yne, Ynd: Quantities of feedlot-finished live cattle for export and domestic markets, respectively.
vne, vnd: Prices of grain-finished live cattle for export and domestic markets, respectively.
Xs1, Xs2: Quantities of weaner cattle and other inputs to the grass finishing sector, respectively.
X1: Quantity of total weaners, X1=Xn1+Xs1
w1: Price of weaners.
ws2: Price of other inputs to the grass finishing sector.
Yse, Ysd: Quantities of grass-finished live cattle for export and domestic markets, respectively.
vse, vsd: Prices of grass-finished live cattle for export and domestic markets, respectively.
Yp: Quantity of other inputs used in the processing sector.
vp: Price of other inputs used in the processing sector.
Zne, Zse: Quantities of export grain-fed and grass-fed beef, respectively.
une, use: Prices of export grain-fed and grass-fed beef, respectively.
Znd, Zsd: Quantities of processed grain-fed and grass-fed beef carcass for domestic market, respectively.
une, und: Prices of processed grain-fed and grass-fed beef carcass for domestic market, respectively.
Zmd: Quantity of other marketing inputs used in domestic marketing sector.
umd: Price of other marketing inputs used in domestic marketing sector.
Qnd, Qsd: Quantities of domestic grain-fed and grass-fed retail beef cuts, respectively.
pnd, psd: Prices of domestic grain-fed and grass-fed retail beef cuts, respectively.

Table 3: Base equilibrium prices, quantities and cost and revenue shares (average of 1992-1997)[3]

	Quantity and Price	Cost and Revenue Shares
Final Beef Products	**Export** (in *kt* and *$/kg*, shipped weight) Qne = 110, pne = 5.66, Qse = 665, pse = 3.06. *TVQe = 2658* **Domestic** (in *kt* and *$/kg*, retail cuts) Qnd = 92, pnd = 10.31 Qsd = 404, psd = 7.81. TVQd = 4104 TVQ = 6762	**Export Marketing Revenue Shares** γQne = 0.21, γQse = 0.69 **Domestic Marketing Revenue shares** γQnd = 0.85, γQsd = 0.15
Wholesale Carcass	(in *kt* and *$/kg*, carcass weight) Zne = 161, une = 2.45, Zse = 974, use = 2.13. TVZe = 2469 Znd = 128, und = 2.70, Zsd = 561, usd = 2.45 *TVZd =* 1720 TVZ = 4189	**Export Marketing Cost Shares** κZne = 0.15, κZse = 0.78 κZme = 0.07 **Domestic Marketing Cost Shares** κZnd = 0.08, κZsd = 0.34 κZmd = 0.58 **Processing Sector Revenue Shares** γZne = 0.09, γZse = 0.50, γZnd = 0.08, γZsd = 0.33.
Finished Live Cattle	(in *kt* and *$/kg*, live weight) Yne = 293, vne = 1.20, Ynd = 232, vnd = 1.34. TVYn = 662 Yse = 1772, vse = 1.03, Ysd = 1019, vsd = 1.21. TVYs = 3058 TVY = 3720	**Processing Sector Cost Shares** κYne = 0.08, κYse = 0.43, κYnd = 0.07, κYsd = 0.29, κYp = 0.12. **Feedlot Sector Revenue Shares** γYne = 0.53, γYnd = 0.47 **Grass Finishing Sector Revenue Shares** γYse = 0.60, γYsd = 0.40
Feeder Cattle and Feedgrain	**Feeders** (in *kt* and *$/kg*, live weight) Fn1e = 205, sn1e = 1.12, Fn1d = 172, sn1d = 1.02. TVF1 = 405 **Feedgrain** (in *kt* and *$/kg*) Fn2 = 819, sn2 = 0.176	**Feedlot Sector Cost Shares** κFn1e = 0.35, κFn1d = 0.26, κFn2 = 0.22, κFn3 = 0.17. **Backgrounding Sector Revenue Shares** γFn1e = 0.57, γFn1d = 0.43.
Weaner Cattle	(in *kt* and *$/kg*, live weight) Xn1 = 206, Xs1 = 1542, X1 = 1748, w1 = 1.12. TVX1 = 1958	**Backgrounding Sector Cost Shares** κXn1 = 0.57, κXn2 = 0.43. **Grass Finishing Sector Cost Shares** κXs1 = 0.56, κXs2 = 0.44.

[3] As detailed in Table 1, the variable naming conventions for quantities and prices respectively are X and w for weaner cattle, F and s for feeder cattle, Y and v for finished cattle, Z and u for wholesale carcases and Q and p for finished beef products; n for grain finished and s for grass finished; and e for export and d for domestic markets. So Yse is the quantity of finished grass fed cattle destined for the export market, and vse is the matching price.

Table 4. Base equilibrium prices, quantities and cost and revenue shares (average of 2006-2010)

	Quantity and Price	**Cost and Revenue Shares**
Final Domestic Beef Products	(in *kt* and *$/kg*, retail cuts) Qnd = 269, pnd = 17.05 Qsd = 286, psd = 14.55 TVQd = 8748	**Domestic Marketing Revenue shares** γQnd = 0.52, γQsd = 0.48
Export Beef Products	(in *kt* and *$/kg*, carcass weight) Zne = 224, une = 7.53, Zse =717, use = 4.03. TVZe = 4576	
Domestic Wholesale Carcass	(in *kt* and *$/kg*, carcass weight) Znd = 373, und = 5.06, Zsd = 397, usd = 3.31 TVZd = 3201 TVZ = 7778	**Domestic Marketing Cost Shares** κZnd = 0.22, κZsd = 0.15 κZmd = 0.63 **Processing Sector Revenue Shares** γZne = 0.22, γZse = 0.37, γZnd = 0.24, γZsd = 0.17.
Finished Live Cattle	(in *kt* and *$/kg*, live weight) Yne = 599, vne = 1.70, Ynd = 679, vnd = 1.88. TVYn = 2295 Yse = 1916, vse = 1.50, Ysd = 722, vsd = 1.69. TVYs = 4094 TVY = 6389	**Processing Sector Cost Shares** κYne = 0.13, κYse = 0.37, κYnd = 0.16, κYsd = 0.16, κYp = 0.18. **Feedlot Sector Revenue Shares** γYne = 0.44, γYnd = 0.56 **Grass Finishing Sector Revenue Shares** γYse = 0.70, γYsd = 0.30
Feeder Cattle and Feedgrain	**Feeders** (in *kt* and *$/kg*, live weight) Fn1e = 419, sn1e = 1.86, Fn1d = 481, sn1d = 1.78. TVF1 = 1636 **Feedgrain** (in *kt* and *$/kg*) Fn2 = 2084, sn2 = 0.271	**Feedlot Sector Cost Shares** κFn1e = 0.34, κFn1d = 0.37, κFn2 = 0.25, κFn3 = 0.04. **Backgrounding Sector Revenue Shares** γFn1e = 0.48, γFn1d = 0.52.
Weaner Cattle	(in *kt* and *$/kg*, live weight) Xn1 = 495, Xs1 = 1286, X1 = 1781, w1 = 1.85. TVX1 = 3295	**Backgrounding Sector Cost Shares** κXn1 = 0.56, κXn2 = 0.44. **Grass Finishing Sector Cost Shares** κXs1 = 0.58, κXs2 = 0.42.

Table 5. Base equilibrium prices, quantities and revenue and cost shares (average of 2014-2016)

	Quantity and Price	Cost and Revenue Shares
Final Beef Products	**Export** (in *kt* and *$/kg*, shipped weight) Qne = 263, pne = 10.04, Qse = 934, pse =6.05. TVQe = 8290.36 **Domestic** (in *kt* and *$/kg*, retail cuts) Qnd = 312, pnd = 18.42 Qsd = 167, psd = 16.90. TVQd = 8580.44 TVQ = 16870.80	**Export Marketing Revenue Shares** γQne = 0.32, γQse = 0.68 **Domestic Marketing Revenue shares** γQnd = 0.67, γQsd = 0.33
Wholesale Carcass	(in *kt* and *$/kg*, carcass weight) Zne = 387, une = 4.66 Zse = 1373, use = 4.45. TVZe = 7908.51 Znd = 433, und = 5.05, Zsd = 233, usd = 4.64 *TVZd* = 3268.96 TVZ = 11177.47	**Export Marketing Cost Shares** κZne = 0.22, κZse = 0.74 κZme =0.04 **Domestic Marketing Cost Shares** κZnd = 0.26, κZsd = 0.13 κZmd = 0.61 **Processing Sector Revenue Shares** γZne = 0.16, γZse = 0.55, γZnd = 0.19, γZsd = 0.10.
Finished Live Cattle	(in *kt* and *$/kg*, live weight) Yne = 704, vne = 2.48, Ynd = 788, vnd = 2.70. TVYn = 3872.32 Yse = 2496, vse = 2.37, Ysd = 423, vsd = 2.47, TVYs = 6950.59 TVY = 10822.92	**Processing Sector Cost Shares** κYne = 0.16, κYse = 0.19, κYnd = 0.53, κYsd = 0.09, κYp = 0.03 **Feedlot Sector Revenue Shares** γYne = 0.45, γYnd = 0.55 **Grass Finishing Sector Revenue Shares** γYse = 0.85, γYsd = 0.15
Feeder Cattle and Feedgrain	**Feeders** (in *kt* and *$/kg*, live weight) Fn1e = 350, sn1e = 2.81, Fn1d = 842, sn1d = 2.62. TVF1 =3191.01 **Feedgrain** (in *kt* and *$/kg*) Fn2 = 2366.04, sn2 = 0.244	**Feedlot Sector Cost Shares** κFn1e = 0.09, κFn1d = 0.21, κFn2 = 0.05, κFn3 = 0.65. **Backgrounding Sector Revenue Shares** γFn1e = 0.31, γFn1d = 0.69.
Weaner Cattle	(in *kt* and *$/kg*, live weight) Xn1 = 544, Xs1 = 1134, X1 = 1678, w1 = 2.44. TVX1 = 4095.11	**Backgrounding Sector Cost Shares** κXn1 = 0.42, κXn2 = 0.58. **Grass Finishing Sector Cost Shares** κXs1 = 0.40, κXs2 = 0.60.

Table 6. Three simulation scenarios

Scenario 1: Weaner Production Research **tX1 = -0.01**, remaining 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 6: Processing Research** **tYp = -0.01**, remaining t(.) = 0 and n(.) = 0. Other cost reductions in beef processing due to new technologies or management strategies in the processing sector. **Scenario 11: Domestic-Grainfed Beef Promotion** **nQnd = 0.01**, remaining t(.) = 0 and n(.) = 0. Increase in the willingness to pay by domestic-grainfed beef consumers due to beef promotion or changes in taste in the domestic market.

total value of the sector in which the displacement occurs. In other words the parameter (elasticity) values have no impact on total surplus (Griffith et al., 2010).

Also reported in Tables 7a and 7b are the distributions of the gross benefits to the various industry sectors associated with each hypothetical scenario. In all instances the proportions of total benefits accruing to beef producers are a little higher in magnitude to those obtained when using 1992-1997 data. For example for scenario 1 (cost reduction in weaner production), the share to producers was 33.7 per cent in 1992-1997 and 39.5 per cent in 2014-2016.

Feed grain growers receive a larger share of total benefits in all scenarios when using 2014-2016 data, reflecting a higher cost share of feed grain as an input into feedlot finishing in recent years. The same is true for domestic retailers. Conversely, the processing sector shares are much lower, reflecting the very small share of total costs (3 per cent) attributable to other inputs into processing. The feedlot sector is shown to be operating at a very small profit level given the assumptions made.

In all simulations the percentage shares of gross benefits received by domestic consumers were substantially lower than those derived using both the earlier data sets. For example, for scenario 1 (decreased cost of weaner production), the share accruing to domestic consumers was 36.5 per cent for 2014-2016, compared to 46.4 and 50.8 per cent for 2006-2010 and 1992-1997 respectively. The same pattern is evident for the other two scenarios. Conversely, overseas consumers are now the recipients of considerable higher shares, with consumers of grainfed beef the main beneficiaries. This is due to the substantially larger share of beef exported during the 2014-2016 period (72 per cent compared to 62 per cent during 1992-1997) and the increased share of grainfed beef in total exports (20 per cent compared to 14 per cent during 1992-1997).

Discussion and Conclusion

Quite a lot of data that was readily available to populate the original model are no longer available. This meant that it was necessary to maintain a number of assumptions and calculations from the original model.

There are no published estimates of grainfed and grassfed quantities for domestic consumption. Therefore the domestic grainfed and grassfed cattle splits are derived from the average live weights for finished (feedlot) cattle for domestic and export markets. The representative weights used by

Table 7a. Economic surplus changes (in $million) and percentage shares of total surplus changes (in %) to various industry groups from alternative scenarios

Industry Group	Scenario 1 (1992-1997)		Scenario 1 (2006-2010)		Scenario 1 (2014-2016)		Scenario 6 (1992-1997)		Scenario 6 (2006-2010)		Scenario 6 (2014-2016)	
	$m	%	$m	%	$m	%	$m	%	$m	%	$m	%
Weaner producers	6.00	30.6	10.03	30.4	13.70	33.4	1.05	22.5	3.09	22.3	0.89	25.5
Grass-finishers	0.54	2.7	0.68	2.0	1.92	4.7	0.14	3.0	0.32	2.3	0.18	5.1
Backgrounders	0.07	0.4	0.30	0.9	0.86	2.1	0.02	0.4	0.13	1.0	0.08	2.3
Farmers subtotal	**6.61**	**33.7**	**11.**	**33.3**	**16.48**	**40.2**	**1.21**	**25.9**	**3.54**	**25.6**	**1.15**	**32.9**
Feedgrain growers	0.34	1.8	1.31	4.0	1.52	3.7	0.09	1.8	0.59	4.3	0.14	4.0
Feedlotters	0.05	0.2	0.04	0.1	0.49	1.2	0.01	0.3	0.02	0.1	0.01	0.1
Processors	0.19	1.0	0.56	1.7	0.16	0.4	0.14	3.0	0.53	3.8	0.08	2.4
Exporters	0.09	0.5	-	-	-	-	0.02	0.5	-	-	-	-
Domestic retailers	**0.74**	**3.8**	**1.78**	**5.4**	**1.95**	**4.8**	**0.19**	**4.1**	**0.82**	**5.9**	**0.18**	**5.2**
Overseas Consumers:												
grainfed beef	0.61	3.1	1.61	4.9	2.73	6.7	0.16	3.4	0.74	5.3	0.25	7.2
grassfed beef	1.01	5.2	1.39	4.2	2.96	7.2	0.26	5.6	0.64	4.6	0.27	7.8
Subtotal	**1.62**	**8.3**	**3.00**	**9.1**	**5.69**	**13.9**	**0.42**	**9.0**	**1.38**	**9.9**	**0.52**	**14.8**
Domestic Consumers	**9.97**	**50.8**	**8.48**	**46.4**	**14.90**	**36.5**	**2.60**	**55.4**	**7.02**	**50.5**	**1.40**	**39.7**
Total Surplus	**19.60**	**100**	**32.99**	**100**	**41.00**	**100**	**4.69**	**100**	**13.9**	**100**	**3.47**	**100**

Zhao et al. (2000) were used in the domestic grainfed and grassfed quantity calculations in the updated model. The same live weight estimates as used by Zhao et al. to calculate feeder and weaner quantities for the export and domestic markets were also used to obtain these splits for the 2006-2010 data period. Considering the increased cattle weight and beef carcass yield, representative weights for grainfed and grassfed cattle and carcasses were updated for the 2014-2016 data period based on the various MLA (2017) reports (e.g. 'over the hook' (OTH), 'Store and weaner sales reports', 'Australia Saleyard Feeder Steer').

Feedgrain consumption is based on the "per kilogram liveweight gain feedgrain consumption" used by Zhao et al. and calculated from data in a feedlot case study of the Beef CRC (Meppem, 1995). This feedgrain consumption per kilogram liveweight is assumed to be 5.51 kilograms for 2006-2010 data. A new ratio of 7.9 was used for 2014-2016 data obtaining from CRC Beef (2012).

Table 7b. Economic surplus changes (in $million) and percentage shares of total surplus changes (in %) to various industry groups from alternative scenarios

Industry Group	Scenario 11 (1992-1997)		Scenario 11 (2006-2010)		Scenario 11 (2014-2016)	
	$m	**%**	**$m**	**%**	**$m**	**%**
Weaner producers	1.91	20.1	9.29	20.3	13.18	22.9
Grass-finishers	0.25	2.7	0.95	2.1	2.64	4.6
Backgrounders	0.03	0.4	0.40	0.9	1.18	2.1
Farmers subtotal	**2.19**	**23.2**	**10.64**	**23.3**	**17.00**	**29.6**
Feedgrain growers	0.16	1.7	1.77	3.9	2.07	3.6
Feedlotters	0.02	0.2	0.05	0.1	0.07	0.1
Processors	0.09	0.9	0.77	1.7	0.22	0.4
Exporters	0.03	0.3			-	-
Domestic retailers	**0.54**	**5.7**	**3.62**	**7.9**	**4.32**	**7.4**
Overseas Consumers:						
grainfed beef	0.22	2.3	1.70	3.7	3.05	5.3
grassfed beef	0.36	3.7	1.47	3.2	3.30	5.7
Subtotal	**0.58**	**6.0**	**3.17**	**6.9**	**6.35**	**11.0**
Domestic Consumers	**5.87**	**61.9**	**25.83**	**56.3**	**27.20**	**47.4**
Total Surplus	**9.48**	**100**	**45.85**	**100**	**57.45**	**100**

Regression analysis using 1998 OTH price observations was undertaken by Zhao et al. to calculate saleyard grainfed price premiums for the domestic and Japanese markets. The grainfed price premiums for the 2014-2016 period were estimated based on the latest OTH reports (MLA, 2017). In the absence of similar data the same price premiums were assumed in the calculations of export and domestic grainfed finished cattle prices in this updated version of the model.

National processed beef carcass prices are not collected. Therefore average Sydney wholesale beef carcass prices are assumed to be representative of national average prices. In addition, there are no published data on separate grainfed and grassfed carcass prices. Consequently, domestic wholesale and retail price premiums for grainfed beef are specified on the basis of industry advice.

The updated model detailed in this paper provides a framework that reflects the current industry size and structure, based on available information. However, it is important to note that the results from the model are conditional on the price and quantity values specified for each market, their underlying assumptions and calculations, and the parameter values used to represent industry responses to price changes. Hence, the accuracy of the results is very much dependent on having accurate estimates of prices, quantities and parameter values.

When researchers are confident of such values, the model can be used to estimate total annual benefits and their distribution among industry participants from defined disequilibrium scenarios. These scenarios might be successful new technologies at different levels of the industry or for different products, new or expanded successful advertising campaigns in domestic or export beef markets, or policy proposals that might place restrictions on price or quantity values at different points in the chain. With assumptions about investment costs over time and the patterns of adoption of technology or consumer responses to advertising campaigns, rigorous benefit cost analyses can then be done so as to provide evidence for the allocation of industry research and marketing funds, as outlined previously in Zhao et al. (2000) and Mounter et al. (2011).

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Appendix. Specification of Equilibrium Quantities and Prices

Quantities

Annual quantities of all four types of cattle/beef products at all production and marketing stages for the period 2014-2016 (inclusive) are specified below.

Step 1. Qe, Qne, Qse and Ze ⇒Zne, Zse, Yne, Yse, and Ye

Qe, Qne, Qse are the quantities of total export beef, grain-fed export beef and grass-fed export beef respectively, measured in kilotons shipped weight. The data for 2014 and 2015 were obtained from the Beef Market Snapshot (MLA, 2014-2016a). The quantity of total export beef in 2016 was not differentiated in this report. The percentages of exported grain-fed and grass-fed beef for 2016 were estimated based on the Australian beef exports to several of the main reported destinations. Then the quantities of grain-fed and grass-fed export beef for 2016 were obtained.

Ze, the total Australian export of beef in kilotons carcass weight 2014-2015 was taken from Table 133 in ABARES (2016). The data for 2016 was not available. The saleable yield for converting the export carcass weight to the export shipped weight was obtained as the ratio of Qe to Ze. The average of this ratio for 2012-2015 is about 68%. This same yield percentage was used to derive the carcass weight for the total Australian export of beef in 2016, the export grain-fed and export grass-fed; that is Zne=Qne/0.68, and Zse=Qse/0.68.

A commonly used conversion factor of 0.55 (Griffith, Green, & Duff, 1991) was applied to all four beef categories to convert the beef carcass weights to cattle live weights. In particular, Yne=Zne/0.55, Yse=Zse/0.55 and Ye=Yne+Yse

Step 2. Zd⇒Yd and Y

Zd, the total domestic beef consumption in kilotons carcass weight, was also obtained from Table 133 in ABARES (2016). Live weight total domestic beef quantity Yd was derived using the 0.55 conversion percentage, ie. Yd=Zd/0.55. The total cattle live weight was calculated as Y=Yd+Ye.

Step 3. Derivation of WPH(Yne) and WHP(Ynd)

The total domestic beef quantity is given in Step 2. However, there was no published information available on the separate quantities for grain-fed and grass-fed domestic consumption.

MLA (2017) reports OTH prices for grain-fed cattle for four grades (280-300kg steer, 300-320kg steer, MSA 280-300kg steer, and MSA 300-320kg steer). Meat Standard Australia (MSA), a meat quality grading scheme, currently is only used for grading beef for domestic markets. Zhao et al. (2000) indicates that the carcass weight of cattle for export markets ranges 220-420kg, and that for domestic markets ranges 200-260kg. Based on such specification and the trend of increased carcass weight in the recent two decades, 310 kg (the mid-point of the range of 300-320kg) was considered the carcass weight of export grain-fed cattle; 290 kg (the mid-point of the range of 280-300kg) was considered the carcass weight of domestic grain-fed cattle.

The ratio 0.55 was used to convert the carcass weight to live weight, that is WHP(Yne)=310/0.55, WHP(Ynd)=290/0.55.

Step 4. Yne and WPH(Yne) ⇒Nne;

The number of Australian export of grain-fed cattle was derived as Nne=Yne/WHP(Yne).

Step 5. Nn, Nne⇒Nnd; N, Nn⇒Ns,

The total grain-fed cattle turn-off numbers from the Lot Feeding Brief (MLA, 2014-2016b). The number of domestic grain-fed cattle was calculated as Nnd=Nn-Nne.

The number of cattle slaughtered, N, for each year of 2014-2016 was taken from ABS (2016). The total grass-fed cattle turn-off was then numbered as Ns=N-Nn.

Step 6. WHP(Ynd), Nnd⇒Ynd

The live weight of Australian domestic grain-fed cattle was derived as Ynd=Nnd*WHP (Ynd).

Step 7. Yd and Ynd⇒Ysd

The live weight of Australian domestic grass-fed cattle was obtained as Ysd=Yd-Ynd.

Step 8. Ysd and Ynd⇒ Zsd, Znd, Qsd and Qnd

Using the conversion factor of 0.55 as discussed in Step 1, the carcass weight for the two domestic products was calculated as Znd=0.55*Ynd and Zsd=0.55*Ysd respectively.

Based on a study by Griffith et al. (1991), a yield percentage R(Zd/Qd)=0.72 was specified. Then the domestic retail beef quantities were calculated as Qnd=0.72*Znd and Qsd=0.72*Zsd.

Step 9. Derivation of WPH(Fn1e), WPH(Fn1d), WPH(Xne) and WPH(Xnd)

Data on cattle quantities at feeder and weaner levels were not available from published sources. They were derived from information on average per head weights of export quality feeders (WPH(Fn1e)) and weaners (WPH(Xne)), and domestic quality feeders (WPH) and weaners (WPH(Xnd)).

MLA (2017) publishes the $/head of feeder steer and heifer for 0-320kg, 320-400kg and above 400kg in several saleyards. As discussed in Step 3, the grade over 400kg was considered as the cattle for export markets, the others were considered as the cattle for domestic markets. The report indicates that the quantities of steers and heifers were about same for domestic grades sold during 2014 and 2016.

Another report related to feeder cattle can be found in MLA Eastern States Paddock Feeder Cattle Indicators (MLA, 2017). It publishes the price of feeder cattle for domestic and export paddocks. In particular, 280-350kg steer and heifer feeder cattle were reported for domestic paddock; long-fed feeder steer (250-350kg), mid-fed feeder steer (360-460kg), EU short-fed feeder steer (380-500kg), and short-fed feeder (380-500kg) were reported for export paddock.

This report does not indicate the specific destination of each product group, except the EU short-fed feeder steer. MLA defines long-fed as "cattle that are fed for over 200 days (up to 550 days) for the top Japanese markets"; medium-fed was defined as "cattle that are fed for 150 to 200 days, generally for the Japanese or Korean market". Japan and Korea are two major Australian grain-fed beef export markets accounting to 68% of total Australian grain-fed beef exports (2014-2016). Based on these definitions, long-fed feeder steer was taken as the cattle for producing chilled grain-fed beef exporting to Japan; mid-fed feeder steer was taken as the cattle for producing frozen grain-fed beef exporting to

Japan and all grades of grain-fed beef to Korea; short-fed feeder steer was taken as the cattle for producing grain-fed beef for other countries. The percentages of grain-fed beef export to Japan, Korea, EU and other countries were obtained from the Beef Market Snapshot (MLA, 2014-2016a)

MLA (2013) indicates that the empty entry weight for long-fed, mid-fed, and short-fed are 400–600kg, 420–480kg, and 440–480kg respectively. The mid-point weight of each product group was taken from the specifications. The average weight of feeders for domestic and export markets are shown as Table A1.

MLA (2013) also indicates that the store weaner's live weight is 220kg, but it didn't differentiate between domestic and export markets. The "Store and weaner sales reports" of MLA reports weaner prices in the in terms of location, weight range, number of head, and price in $/head (MLA, 2017). The mid-point weights of each product group were taken to calculate the total weight of all weaners sold in 2015 and 2016. The average live weight of weaner was then derived from the total weight divided by the number of head. Thereby, WPH(Xn)=238.27 was derived. Zhao et al. (2000) summarized the average weight for domestic and export markets. The ratio of WPH(Xnd) /WPH(Xne) indicated in this research was used in the current study. Thus WPH(Xnd)=223 and WPH(Xne)=253 are specified.

Table A1. Derivation of Average Feeder Weights Per Head

	Export				Domestic	
	Shortfed Feeder Steer	**EU Shortfed Feeder Steer**	**Midfed Feeder Steer**	**Longfed Feeder Steer**	**Feeder Steer**	**Feeder Heifer**
Weight range (kg) mid-point	420-480kg 450	440-480kg 460	440-480kg 460	400-600kg 500	280-350kg 315	280-350kg 315
Sub-group weights	0.26	0.06	0.17(Japan frozen grainfed) + 0.17 (Korean grainfed)	0.34	0.5	0.5
Weighted Average	WPH(Fn1e) =471kg				WPH(Fn1d) =315kg	

Step 10. WPH(*Xne*), WPH(*Xnd*), *Nne*, *Nnd* and *Ns* ⇒ *Xn1* and *Xs1*

Total weaner quantities for feedlot finishing were derived as *Xn1*=WPH(*Xne*)(*Nne*)+WPH(*Xnd*)(*Nnd*). Zhao et al. (2000) assumed that the weaner cattle are not differentiated in quality regardless of whether they are for grain or grass finishing. The current study also keeps this assumption. Thus, the average weaner weight per animal for grass-finishing was assumed as the same as that for grain-finishing. The average weight for weaners for grain-finishing was calculated as WPH(*Xn1*)=*Xn1*/*Nn*, and the quantity for weaners for grass-finishing was derived as *Xs1*=WPH(*Xn1*)(*Ns*).

Step 11. Derivation of Fn2

Feed grain consumption *Fn2* was estimated from the "per kilogram live weight gain feed grain consumption" (Meppem, 1995). The feed grain consumption per kilogram live weight gain, i.e. feed conversion ratio (FCR), was calculated as 7.9 by averaging the efficient and inefficient FCRs from (CRC Beef, 2012). The annual feed grain consumption was calculated by multiplying this amount by the total live weight gain each year; that is, *Fn2*=7.9*(*Yne*+*Ynd-Fn1e-Fn1d*). Details of the derivation is in Zhao et al. (2000).

Prices

The data sources, assumptions and derivations of the prices for all four types of cattle/beef products at all production and marketing stages for the period 2006-2010 (inclusive) are specified below.

Step 1. *vd*, *ve*

Australia OTH cattle indicators prices for various cattle categories (MLA, 2017). But it did not differentiate between the domestic prices and export prices. Under the specifications of average weight of cattle for domestic and export markets by Zhao et al. (2000), the prices for non-MSA cattle over 300kg and all categories of cows were averaged as the price for export finished cattle (ve), the others were averaged as the price for domestic finished cattle (vd). And 0.55 was used to convert the carcass weight to live weight.

Step 2. Grainfed price premiums for domestic *rY(dom)* and eport *rY(exp)* markets

As mentioned in Step 3 of Quantities, MLA (2017) also reports OTH prices for grain-fed cattle for four grades. The prices for similar grades were taken from the OTH indicators comparing with the prices of domestic and export grain-fed cattle respectively. Then 9 per cent and 5 per cent was calculated and used as the domestic grain-fed cattle premium and export grain-fed cattle premium respectively.

Step 3. vd and rY(dom) ⇒ vnd and vsd; *ve* and *rY(exp)* ⇒ *vne* and *vse*

Using the grainfed price premium specified in Step 2, the domestic grassfed and grainfed prices for finished cattle were seperated from the aggregated domestic price *vd* as *vsd*=*vd*/(1+*rY(dom*)* ρ*(nd/d)*) and *vnd*=(1+ *rY(dom)*)*vsd*, where ρ*(nd/d)*)=*Ynd*/*Yd* is the proportion of feedlot finished cattle in the domestic market and *rY(dom*)=9 per cent is the domestic grainfed cattle premium.
The same method was used to calculate the prices for export markets.

Step 4. *ud*, *vd* and Δ*ud-vd* ⇒ *und* and *usd*

Suggested by Zhao et al. (2000), the domestic wholesale price for grain-fed carcass is *und*=*vnd*/0.55+Δ*ud-vd* and for grass-fed carcass is *usd*=*vsd*/0.55+Δ*ud-vd*. This implies that the two domestic categories have the same price mark-up as the observed aggregated price difference Δ*ud-vd*= *ud*- *vd*/0.55 where Δ*ud-vd* was measured as per kilogram carcass weight.

However, there was no data available on *vd* during 2014-2016. The lasted data which was reported in 2011 was obtained from Griffith and Thompson (2012). Then the price difference in 2001 Δ*ud-vd* $0.15 was used for the period of 2014-2016.

Step 5. *ve* and Δ*ud-vd* ⇒ *ue*, *une* and *use*

The export carcass prices were calculated as *une*=*vne*/0.55 +Δud-vd, *use*=*vse*/0.55+Δ*ud-vd* and *ue*=*ve*/0.55+Δ*ud-vd*. Details of the derivation is in Zhao et al. (2000).

Step 6. *pe* and Δ*pne-pse* ⇒ *pne* and *pse*

The prices for shipped weight export beef were obtained from the unit values of Australian export beef and veal in Table 133, ABARES (2016). The prices were reported in financial years. Information on separate grain-fed and grass-fed export shipped weight prices was not available. The calendar year prices for *pe* were estimated as the total value divided by total quantity of exports, i.e. \$6.85. The exported grass-fed exported accounts for about 80% of the total beef exports, then we have 0.80pse+0.20pne=6.85. The average price Following the path provided by Zhao et al. (2000), a price premium was estimated based on the prices in principal overseas markets reported in Table 133, ABARES (2016), i.e. Δ*pne-pse*= \$3.99/kg (shipped weight). pne and pse were derived from the two equations.

Step 7. pd and Δpnd-psd ⇒ pnd and psd

The average price of retail beef was taken from MLA (2017). As discussed in Step 2 of Prices, a 9% of grain-fed premium was applied to the retail stage. Then pnd and psd can be derived.

Step 8. *sn1d* and *sn1e*

As mentioned in Step 9 of Quantities, MLA (2017) reports the feeder cattle prices for domestic and export markets. The sub-group weights were also obtained in Step 9. The average of the two grades of domestic feeder prices was used as domestic feeder price *sn1d*, and the four grades of exports feeder prices were used to derive the export feeder price *sn1e***.**

Step 9. w1

The average weaner price in 2015-2016 was taken from the “Store and weaner sales reports” in MLA (2017). The price taken from the “Australia Saleyard Feeder Steer” saw a dramatic increase in 2015 (MLA, 2017). The percentage of prices increase was applied to adapt the price of weaners in 2014. Then weaner price was calculated by averaging the price in 2015-2016 and 2014.