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Updating and Recalibrating Equilibrium Displacement Models of the Australian Livestock Industries: Pig Meat[1,2]

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Abstract

In this paper, we report on a recent update of an equilibrium displacement model of the Australian pig meat industry. New price and quantity data for the period 2012-2016 are described and compared to values used in two previous versions of the model. Elasticity parameters are kept the same. Then two hypothetical simulations are run, one for a farm productivity improvement and one for a consumer demand expansion, and the results of these simulations are reported and compared with identical simulations previously reported for the earlier versions of the model.

Key words: pig meat, EDM, update, simulation

Background

Almost 15 years ago, an equilibrium displacement model (EDM) of the Australian pig industry was constructed and used to examine a range of research and development (R&D) and marketing issues relevant to this industry at the time. A detailed description of this model, and the results of those initial analyses, can be found in Mounter et al. (2004, 2005a, 2005b). A feature of this model is that it provides a detailed disaggregation across the value chain. This is important information since many 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.

As outlined in Zhang et al., 2018), the broad EDM approach employs comparative static analysis in a partial equilibrium framework. The framework is partial in the sense that prices in markets not

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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 broad structure of the model is shown in Figure 1. Given this defined structure of the model, three sets of data are required to implement the model: first, average price and quantity values in the 12 product markets for a representative year to provide the initial equilibrium points from which any simulations are measured against; second, measures of producer and consumer responsiveness (price elasticities) to changes in those equilibrium prices; and third, measures of whichever specified initial shifts in the market (the disequilibrium events) that are of current interest. Such shifts may be in any of the demand or supply curves embedded in the model structure. Definitions of the variables and parameters in this model are replicated in Appendix 1. The model was initially developed in 2003 and calibrated on data averaged over the period 2000-2002. The percentage values shown in Figure 1 represent the 2000-2002 situation. The model was updated in 2010 based on 2009 data, as reported in Griffith et al. (2010). As part of the updating process, the model structure was examined to see if it needed modifying and the results of the updating were compared to the original model results for an equivalent range of simulated disequilibria.

A new use for the model has been suggested recently, so again the model updating process is required. Initially, to confirm the main structural elements captured in the model framework are still current, it is necessary to test whether the current industry structure is similar enough to that observed earlier.

The Structure of the Industry

Although the relative volumes flowing through the various market channels have changed over the years, the current structure of the Australian pig meat industry remains similar to what was defined in the early 2000s. That is, total pig meat production is made up of carcases destined for the fresh pork market and carcases destined for the processed pig meat market. Some pork carcases are exported, while there is also a substantial import trade of pig meat destined for processing. The majority of processed pig meat products, such as ham and bacon, are made from imported pig meat. Exports of other than fresh pork, and imports of other than carcases/cuts destined for processing, remain at minor levels.

Figure 1. Pig meat EDM structure
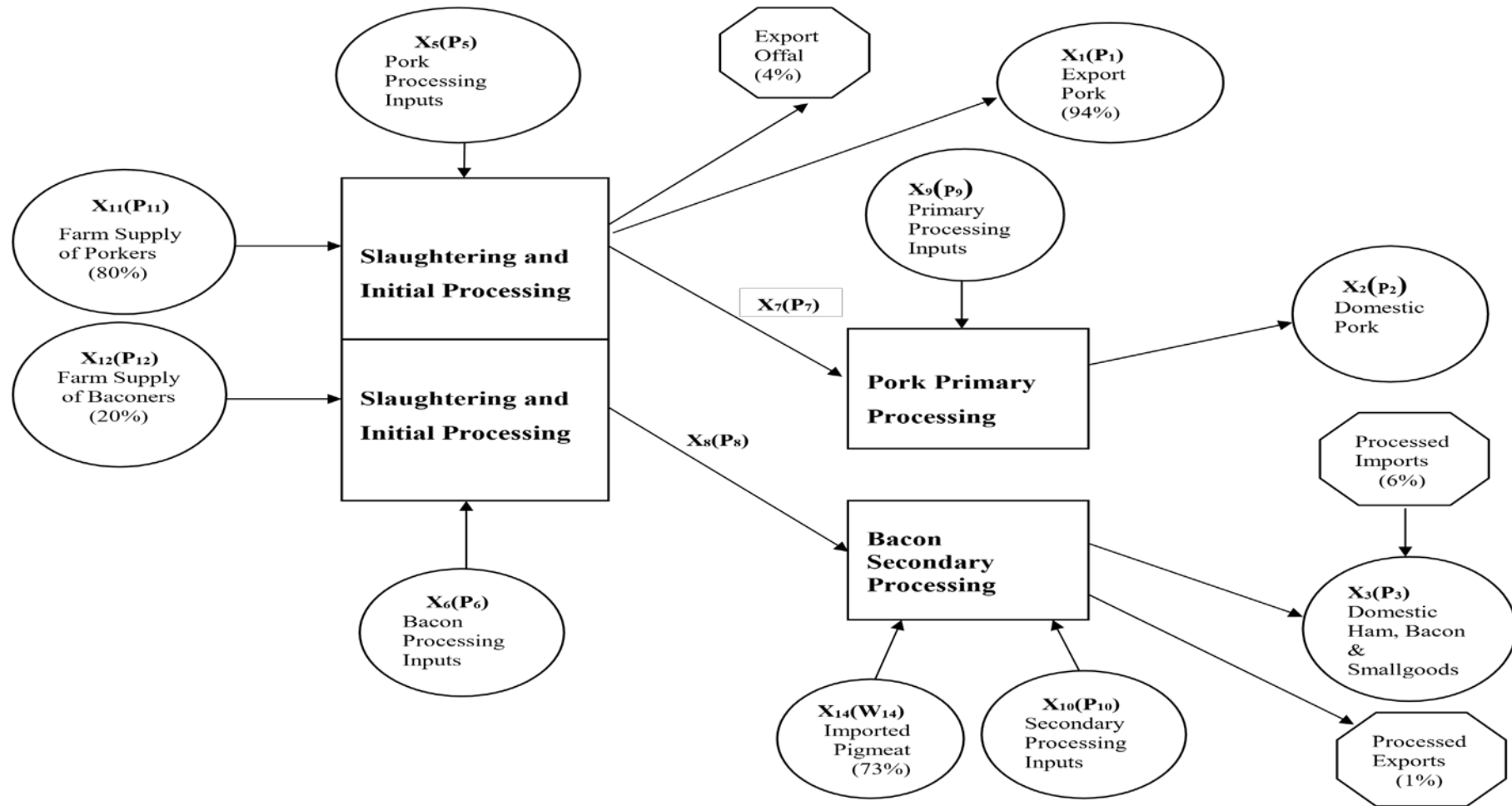
The Price and Quantity Data

Figure 2, and related data in APL (2015, 2017a), indicates that total Australian pig meat production has gradually recovered to levels of a decade earlier, following the substantial decline in 2008 and 2009. Production in 2009 was the lowest over the previous 20 years. Aggregate average production of all pig meat during 2012-2016 was 365,000 tonnes cw, which is about the long term average volume. However the composition of production has changed dramatically over time, with fresh pork production doubling and processed pig meat production falling from around 200,000 tonnes cw to just 68,000 tonnes cw in the 2012-2016 period. Production has continued to increase during 2016/2017 with output some 5 per cent higher than a year earlier (APL, 2018).

Figure 2. Pig meat production, Australia, 2006-2016, '000 tonnes CW
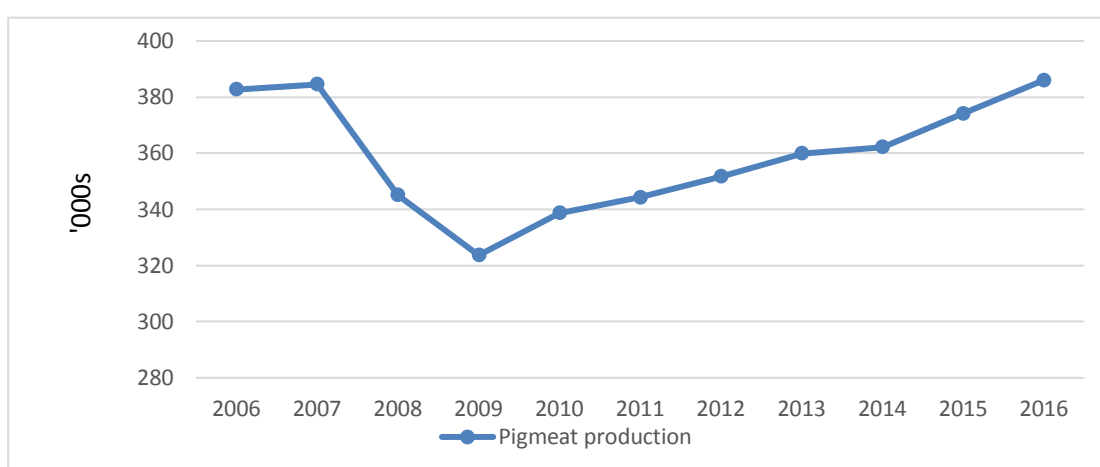

Source: Australian Bureau of Statistics (2017)

As shown in Figure 3, pig prices in 2009 were relatively high but then slumped in 2010 by more then $0.50/kg. Prices recovered through the period 2012-2016 to average $3.68/kg. However during 2016/17 prices fell dramatically again by some 25 per cent, back to levels last seen in 2012 (APL, 2018). While the representative year concept employed here (the average over 2012-2016) smooths out these large swings in prices, any single year of data could be used to calibrate the model. Thus the structure of the model is amenable to being used for a "high price" year and a "low price" year, as well as the average 2012-2106 year.

The other major driver of the Australian pig meat industry, the volume of imports, has also been relatively stable on a moving annual trend basis, although there has been substantial month by month variability (Figure 4).

Based on the information shown, it is evident that the base price and quantity data requires updating. The new base equilibrium values are specified as the average prices and quantities for 2012-2016. Input cost shares and output revenue shares are derived accordingly. The new price and quantity data, and the associated sector total values, are reported in Table 1, while the derived cost shares and/or revenue shares are shown in Table 2. All quantity values are expressed
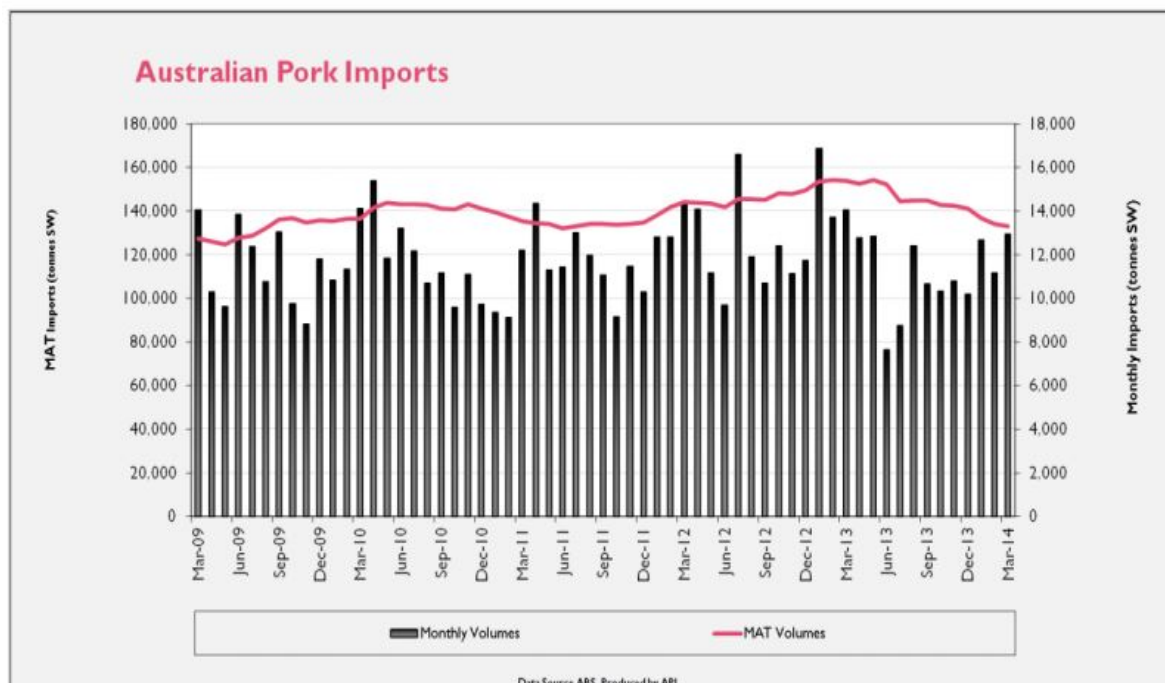
in terms of carcass weight equivalent tonnes*.*

Figure 3. Baconer price, Australia, 2000-2014, c/kg CWE
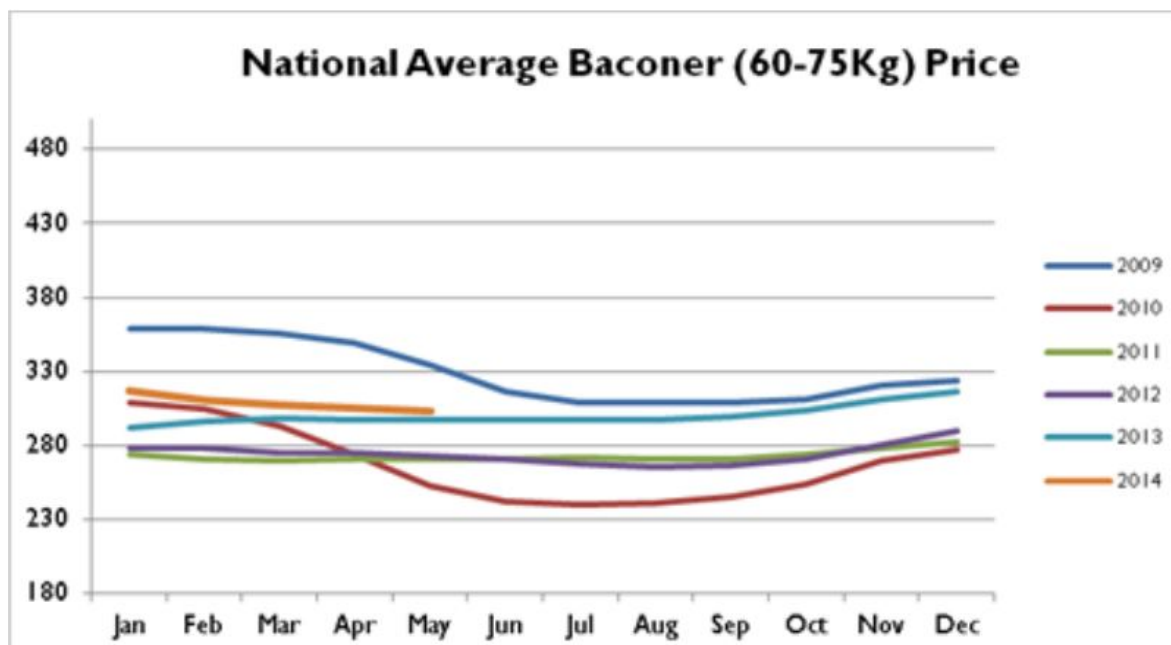
Source: APL (2015)

Figure 4. Pig meat imports, Australia, 2009-2014, tonnes SW

Source: APL (2015)

Details of the sources and the assumptions made for all inputs and outputs of all sectors for each year of 2012-2016 are described below.

Quantities

ABARES (2016a, Table 143) reports aggregate supply and disappearance data for pig meat, that is, total production, total imports, total exports and total apparent disappearance. This is all in carcase weight equivalents. Raw export and import data are converted from shipped weight to carcase weight by the use of standard conversion factors. These data were supplemented with similar data from ABARES (2016b) on the outlook for pig meat. The resulting average (rounded off) values for 2012-2016 were total production 365,000, total imports 308,000, total exports 46,000, and total consumption 627,000, all in tonnes carcase weight.

Step 1 X_{2+3} split into X_2 and X_3

APL (n.d.) reports that each year Australians consume around 24.2 kg of pig meat per person – this is made up of 9.2 kg of fresh pork and 15 kg of processed products such as ham, bacon and smallgoods (based on information supplied September 2014). No updated values are available. Based on these data we have assumed that on average, 40 per cent of consumption is fresh pork, and 60 per cent is processed pig meat. Thus X_2 is 251,000 tonnes, and X_3 is 376,000 tonnes on average each year.

Step 2 X_8

If apparent disappearance of processed pig meat is 376,000 tonnes annually, and all imported pig meat (308,000 tonnes) has to be processed by law, then domestically produced pig meat for processing (X_8) has to be 68,000 tonnes.

Step 3 X_7

Similarly, if apparent disappearance of fresh pork is 251,000 tonnes annually, and all exports of pig meat (46,000 tonnes) is unprocessed, then domestically produced pig meat for the fresh market (X_7) has to be 297,000 tonnes.

Step 4 $X_{11+12} \rightarrow X_{11}, X_{12}$

The quantity of pig meat from "baconer" pigs produced in Australia destined for the processed market is therefore the same as the volume at wholesale (68,000 tonnes), since there are no exports of processed pig meat, and the quantity of pig meat from "porker" pigs produced in Australia destined for the fresh market (297,000 tonnes) is the quantity exported plus the quantity sent to retail for domestic consumption.

Prices

P1, W14

APL (2015, 2017) reports monthly and annual pig meat export values and pig meat import values

Table 1. Base equilibrium prices and quantities, average of 2012-2016 compared to 2009 and to 2000-2002
(Quantity, CWE tonnes, Price,$/kg, TV=$m)

	2000-2002 typical year		2009 typical year		2012-2016 typical year	
Final pig meat products	Domestic Bacon/Ham		Domestic bacon/ham		Domestic bacon/ham	
	$X_3 = 297,991$	$P_3 = 18.65$	$X_3=439,528$	$P_3=19.52$	$X_3=376,000$	$P_3=10.14$
	$TV_3 = 5557.5$		$TV_3=8,579.6$		$TV_3=3,812.64$	
	Domestic Pork		Domestic pork		Domestic pork	
	$X_2 = 88,101$	$P_2 = 11.97$	$X_2=86,942$	$P_2=15.55$	$X_2=251,000$	$P_2=11.53$
	$TV_2 = 1054.6$		$TV_2=1,351.9$		$TV_2=2,894.03$	
Wholesale carcass	Domestic Bacon Carcass		Domestic bacon carcass		Domestic bacon carcass	
	$X_8 = 230,033$	$P_8 = 3.57$	$X_8=197,433$	$P_8=4.48$	$X_8=68,000$	$P_8=5.01$
	$TV_8 = 821.2$		$TV_8=884.5$		$TV_8=340.68$	
	Imported Carcass		Imported carcass		Imported carcass	
	$X_{14} = 67,958$	$W_{14} = 2.36$	$X_{14}=242,095$	$W_{14}=2.06$	$X_{14}=308,000$	$W_{14}=2.99$
	$TV_{14} = 160.4$		$TV_{14}=498.7$		$TV_{14}=920.92$	
	Domestic Pork Carcass		Domestic pork carcass		Domestic pork carcass	
	$X_7 = 88,101$	$P_7 = 3.70$	$X_7=86,942$	$P_7=4.91$	$X_7=251,000$	$P_7=5.24$
	$TV_7 = 326.0$		$TV_7=426.9$		$TV_7=1,315.24$	
	Export Pork Carcass		Export Pork Carcass		Export Pork Carcass	
	$X_1 = 65,255$	$P_1 = 3.29$	$X_1=44,680$	$P_1=2.89$	$X_1=46,000$	$P_1=2.52$
	$TV_1 = 214.7$		$TV_1=129.1$		$TV_1=115.92$	
	$TV_{(1+7)} = 540.7$		$TV_{(1+7)}=555.9$		$TV_{(1+7)}= 1,431.16$	
Live pig	Baconers		Baconers		Baconers	
	$X_{12} = 230,033$	$P_{12} = 2.47$	$X_{12}=197,433$	$P_{12}=3.35$	$X_{12}=68,000$	$P_{12}=3.68$
	$TV_{12} = 568.2$		$TV_{12}=661.4$		$TV_{12}=250.24$	
	Porkers		Porkers		Porkers	
	$X_{11} = 153,356$	$P_{11} = 2.80$	$X_{11}=131,622$	$P_{11}=3.75$	$X_{11}=297,000$	$P_{11}=4.03$
	$TV_{11} = 429.4$		$TV_{11}=493.6$		$TV_{11}=1,196.91$	

Table 2. Base equilibrium revenue and cost shares, average of 2012-2016 compared to 2009 and to 2000-2002

	2000-2002 typical year	2009 typical year	2012-2016 typical year
Wholesale carcass	Bacon/ham secondary processing cost shares $k_{X8}=0.15$ $k_{x10}=0.82$ $k_{x14}=0.03$	Bacon/ham secondary processing cost shares $k_{X8}=0.10$ $k_{x10}=0.84$ $k_{x14}=0.06$	Bacon/ham secondary processing cost shares $k_{X8}=0.09$ $k_{x10}=0.67$ $k_{x14}=0.24$
	Pork primary processing cost shares $k_{X7}=0.31$ $k_{x9}=0.69$	Pork primary processing cost shares $k_{X7}=0.32$ $k_{x9}=0.68$	Pork primary processing cost shares $k_{X7}=0.45$ $k_{x9}=0.55$
	Pork initial processing revenue shares $\gamma_{X1}=0.40$ $\gamma_{x7}=0.60$	Pork initial processing revenue shares $\gamma_{X1}=0.23$ $\gamma_{x7}=0.77$	Pork initial processing revenue shares $\gamma_{X1}=0.08$ $\gamma_{x7}=0.92$
Live pig	Bacon/ham initial processing cost shares $k_{X6}=0.31$ $k_{x12}=0.69$ Pork initial processing cost shares $k_{X5}=0.21$ $k_{x11}=0.79$	Bacon/ham initial processing cost shares $k_{X6}=0.25$ $k_{x12}=0.75$ Pork initial processing cost shares $k_{X5}=0.11$ $k_{x11}=0.89$	Bacon/ham initial processing cost shares $k_{X6}=0.27$ $k_{x12}=0.73$ Pork initial processing cost shares $k_{X5}=0.16$ $k_{x11}=0.84$

as well as relevant quantities. The price of exported pork and the price of imported pig meat were calculated as export unit values and import unit values respectively.

P2, P3

The price of fresh pork in domestic retail markets was taken from ABARES (2016a). There has been no retail price of bacon reported since 2011. The average price in 2010/2011 was used as the base sourcing from ABS (2011), and this was adjusted by the food and non-alcoholic beverage component of the CPI for later years.

P8

The wholesale prices for porker and baconer carcases were taken from APL (2017b).

P11, P12

APL (2017b) also reports weekly porker and baconer buyer and seller prices in four weight categories: 45kg-60kg, 60.1-75kg, 75.1-85kg, and 85kg above. It does not indicate the price for primary or secondary industry. The carcasses used for bacon/ham production are normally heavier than the carcasses used for fresh pork. Therefore, the seller price for weight category 45kg-60kg was considered as the porker price; the seller price for weight category 60.1-75kg was considered as the baconer price.

The Elasticity Values

The model requires values for 11 medium-term demand, supply, price transmission, input substitution and output transformation elasticities, which define the responsiveness of market participants to price changes. These are detailed for example in Table 2 of Mounter et al. (2005a) and justified in the accompanying text.

The final consideration in the model updating process is whether current industry responses to price changes are similar enough to those assumed to hold first during the period 2000-2002, and confirmed for 2009, so that the main adjustment processes captured in the model framework are still relevant to current research problems. This involves assessing whether there have been any changes in underlying consumer preferences in different pig meat markets, or in technologies in different pig meat production or processing activities, that would be sufficient to alter the nature of the assumed demand, supply, input substitution and product transformation relationships. Again, this meant examining the industry reports detailed above, plus any empirical evidence available on the changing nature of price responsiveness over time or on the nature of competition in these markets (Chung and Griffith, 2009).

Note that elasticities are defined as ratios of prices and quantities, so any change in the underlying prices and quantities might be expected to result in a change in the relevant elasticity value. This is what we see in standard textbook treatments of vertical market relationships where for example a

linear derived demand curve at a lower level in the market always has a lower elasticity than a parallel linear primary demand curve at a higher level, when both curves are anchored at the same quantity value. But this relationship does not necessarily hold when the assumptions of linearity and fixed margins are relaxed, or for the same demand or supply curve moving up or down, as the slopes of these curves are free to vary as well, keeping the "proportionate changes" in quantities and prices about the same.

There is no empirical evidence available (Mounter et al., 2012), and no indication in any of the Australian Pork Limited reports, that elasticity values have changed since the initial assumptions made in the early 2000s. Thus the conclusion was that the elasticity values specified in the original model still adequately represent the current adjustment processes in the industry. Sensitivity analyses can be done if new information comes to light casting doubt on this conclusion.

The Hypothetical Simulations

The input file for the pig meat EDM was updated with the new price, quantity, cost share and revenue share data, and two hypothetical simulations were run to test the impact of recalibrating the model to the new initial equilibrium. These simulations were done using the Time Series Processor 4.5 econometric package. The results were then compared to the same simulation results as reported in Mounter et al. (2005b, Table 3) based on the 2000-2002 data set, and in Griffith et al. (2010, Table 2) based on the 2009 data set, using the same numbering system. The simulations were as follows:

• Scenario 1: a one per cent upward shift in the domestic demand curve for pork (N2 in Appendix 1), due to a hypothesized successful consumer advertising campaign; and
• Scenario 4: a one per cent downward shift in the supply curve of porkers (T1), due to a hypothesized successful R&D outcome which reduces the cost of production of porker pigs.

The results of this comparison are reported in Table 3.

Discussion and Conclusions

In each scenario, increases are seen in the value for total economic surplus. The value of total surplus for scenario 1 (demand increase) and scenario 4 (cost decrease) based on 2012-2016 data were $29.05m and $11.99m respectively, compared to the equivalent values for the 2009-based scenarios, $13.57m and $4.94m. These more than double total surplus estimates are due to the recent rapid growth in the Australian fresh pork sector, as shown in Table 1. The total value of the pork sector at the farm gate is estimated to be almost $1.2 billion per annum during the 2012-2016 period, but just $494 million per annum in 2009.

Also, the change in total surplus from these hypothetical one per cent shifts is approximately equal to one per cent of the total value of the displaced sector. For example, in scenario 1 (demand increase), the change of total surplus in 2012-16 was $29.05m resulting from a one per cent upward shift in the domestic demand for pork. This value is similar to $28.94m, one per cent

of the total value of the fresh pork sector at retail ($2,894m in Table 1). This result confirms that the total surplus is solely determined by the size of the sector and the size of the displacement (Griffith et al., 2010).

Table 3. Economic surplus changes ($ million) and percentage shares of total surplus changes (%) to pig producers and domestic pig meat consumers from selected advertising and R&D investment scenarios, 2012-2016 data compared to 2009 data and to 2000-2002 data

	2000-2002 average				2009				2012-2016 average			
Change in economic surplus to	Scenario 1 domestic pork advertising		Scenario 4 porker production R&D		Scenario 1 domestic pork advertising		Scenario 4 porker production R&D		Scenario 1 domestic pork advertising		Scenario 4 porker production R&D	
	$m	%	$m	%	$m	%	$m	%	$m	%	$m	%
pig producers	1.52	14.40	1.11	25.70	1.93	14.22	1.06	21.46	2.83	9.75	1.35	11.23
domestic consumers	7.31	69.10	2.82	65.60	9.57	70.52	3.84	77.73	23.09	79.5	9.52	79.36
Total Surplus	10.58	100	4.30	100	13.57	100	4.94	100	29.05	100	11.99	100

Another thing to notice is that the shares of the change in total surplus accruing to pig meat producers continues to fall, while the shares of the change in total surplus accruing to consumers continues to rise, in both selected scenarios. This is due to the increasingly smaller share of consumption filled by domestically produced pig meat. In the most recent period, domestic production accounted for just 51 per cent of consumption, while in the early 2000s that share was 82 per cent.

The updated model detailed in this paper provides a framework that reflects the current size and structure of the Australian pig meat industry, based on available information. However, as shown by the simulation results, 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 the fresh or processed pig meat market, or policy proposals that might place restrictions on price or quantity values at different points in the chain. Proper benefit cost analyses can then be done with assumptions about investment costs over time and the patterns of adoption of technology or consumer

responses to advertising campaigns, so as to provide evidence for the allocation of industry research and marketing funds.

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Appendix 1: Definition of Variables and Parameters

Endogenous Variables:
X1: Quantity of exported pork
X2: Quantity of domestic pork
X3: Quantity of domestic bacon
X5: Quantity of initial processing inputs in the pork industry
X6: Quantity of initial processing inputs in the bacon industry
X7: Quantity of wholesale pork carcass for primary processing in the domestic pork industry
X8: Quantity of wholesale baconer carcass for secondary processing in the domestic bacon industry
X9: Quantity of primary processing inputs in the domestic pork industry
X10: Quantity of secondary processing inputs in the bacon industry
X11: Quantity of porkers
X12: Quantity of baconers
X14: Quantity of imported pig meat for secondary processing in the bacon industry
P1: Price of export pork
P2: Price of pork at retail
P3: Price of bacon at retail
P5: Price of initial processing inputs in the pork industry
P6: Price of initial processing inputs in the bacon industry
P7: Price of wholesale pork carcass for primary processing in the domestic pork industry
P8: Price of wholesale baconer carcass for secondary processing in the domestic bacon industry
P9: Price of primary processing inputs in the domestic pork industry
P10: Price of secondary processing inputs in the bacon industry
P11: Price of porkers
P12: Price of baconers
Z: Aggregated input index of initial processing sector
Y: Aggregated output index of initial processing sector
Exogenous Variables
W14: Price of imported pig meat for secondary processing in the bacon industry
N1: Demand shifter for export pork
N2: Demand shifter for domestic pork consumption
N3: Demand shifter for domestic bacon consumption
T1: Supply shifter for porkers
T2: Supply shifter for baconers
T3: Supply shifter for initial processing inputs in the pork industry
T5: Supply shifter for initial processing inputs in the bacon industry
T6: Supply shifter for secondary processing inputs in the bacon industry
T7: Supply shifter for primary processing inputs in the domestic pork industry