Australasian Agribusiness Review - Vol.18 - 2010

Paper 8

ISSN 1442-6951

Old Model, New Problem: When Should You Update a Model and What Happens When You Do?

G.R. Griffith, L.R. Malcolm, S.W. Mounter and H. Slattery[1]

1. Introduction

A couple of months ago the phone rings:

> BM: G'day mate…(then follows light-hearted bagging of various cricket teams, football teams, state bureaucrats, university administrators, etc; catching up on mates and family; red wine finds; etc)…(then a bit on AAR editorial issues)…(then) listen mate I've got this final year student Henry looking for a project and I thought we might be able to do something extra with Amy's survey on that pig stuff.
> GG: do you mean the willingness to pay for low cholesterol pork?
> BM: yeah.
> GG: well, we could use her results as inputs into that pig edm model we published in the journal a few years back – Stuart Mounter's model - and look at the industry wide benefits.
> BM: sounds good, what do we have to do?
> GG: that's a tricky one. I'd better come down and meet Henry and see what he wants to do.
> BM: good, how about early May?
> GG: I'm available then. Dinner at Jimmy's?
> BM: all clear.

So a "quick" phone call generates a good idea, which at first blush seems a simple thing to do – apply an existing model to a new problem and then write it up. But the question "What do we have to do?" is a good one, and at second blush things are not so simple. In this short piece we

[1] Garry Griffith is a Principal Research Scientist with Industry and Investment NSW, Armidale and an Adjunct Professor in the School of Business, Economics and Public Policy, University of New England, Armidale; Stuart Mounter is a Lecturer in the School of Business, Economics and Public Policy, University of New England, Armidale; Bill Malcolm is a Principal Advisor with the Department of Primary Industries, Victoria, Parkville, and an Associate Professor in the School of Land and Environment, University of Melbourne, Parkville; and Henry Slattery is an undergraduate student in the School of Land and Environment, University of Melbourne, Parkville.
Author contact: garry.griffith@industry.nsw.gov.au

The authors acknowledge the helpful comments of Emeritus Professor Roley Piggott on an earlier draft.

talk about some of the considerations involved in applying an existing model to a new problem, in particular in deciding whether to update or not, and some of the issues involved in interpreting the output from the new application.

2. The Old Model

The old model we are talking about is the equilibrium displacement model (EDM) of the Australian pig industry, as reported in Mounter *et al.* (2004, 2005a, 2005b). The two purposes for developing this model were (a) to have available an economic framework of the Australian pig industry that reflected the industry structure in its then present form (including a separate sector representative of the expanding export industry and an allowance for substitution between the rapidly increasing imports of pig meat and domestically produced carcasses in the manufacturing of processed pig meat); and (b) to provide a relatively disaggregated framework, both vertically and horizontally, to enable returns among various industry sectors and markets from other types of changes, such as new technologies, or new advertising campaigns, to be estimated. These returns are calculated as producer and consumer surplus changes. This is the same type of model developed for examining R&D and advertising scenarios in the Australian beef (Zhao, Griffith and Mullen 2001) and sheep (Mounter *et al*. 2008) industries.

The structure of the model depicting the Australian pig meat industry is shown in Figure 1. Each rectangle represents a production function and each arrowed line represents the supply and demand for a product, with the non-arrowed end indicating the supply of the product and the arrowed end indicating the demand for the product. The supply and demand schedules, where an exogenous shift may occur, are represented by the ovals. The model defines equilibrium in 12 product markets comprising a possible 24 endogenous price and quantity variables. A detailed description of the model is given in Mounter *et al*. (2004, 2005a). Definitions of the variables and parameters in this model are replicated in Appendix 1.

To implement this model, data are required on the prices and quantities in the 12 product markets and on any exogenous variables, on the various elasticities that represent economic behaviour by producers, intermediaries and consumers, and on the various shift variables that reflect assumed or actual displacements from the specified initial equilibrium. In the old model, the specified equilibrium was a representative year measured by average prices and quantities over the period 2000-2002 (see the left hand side of Table 1). These and other data inputs are described in detail in the publications mentioned above.

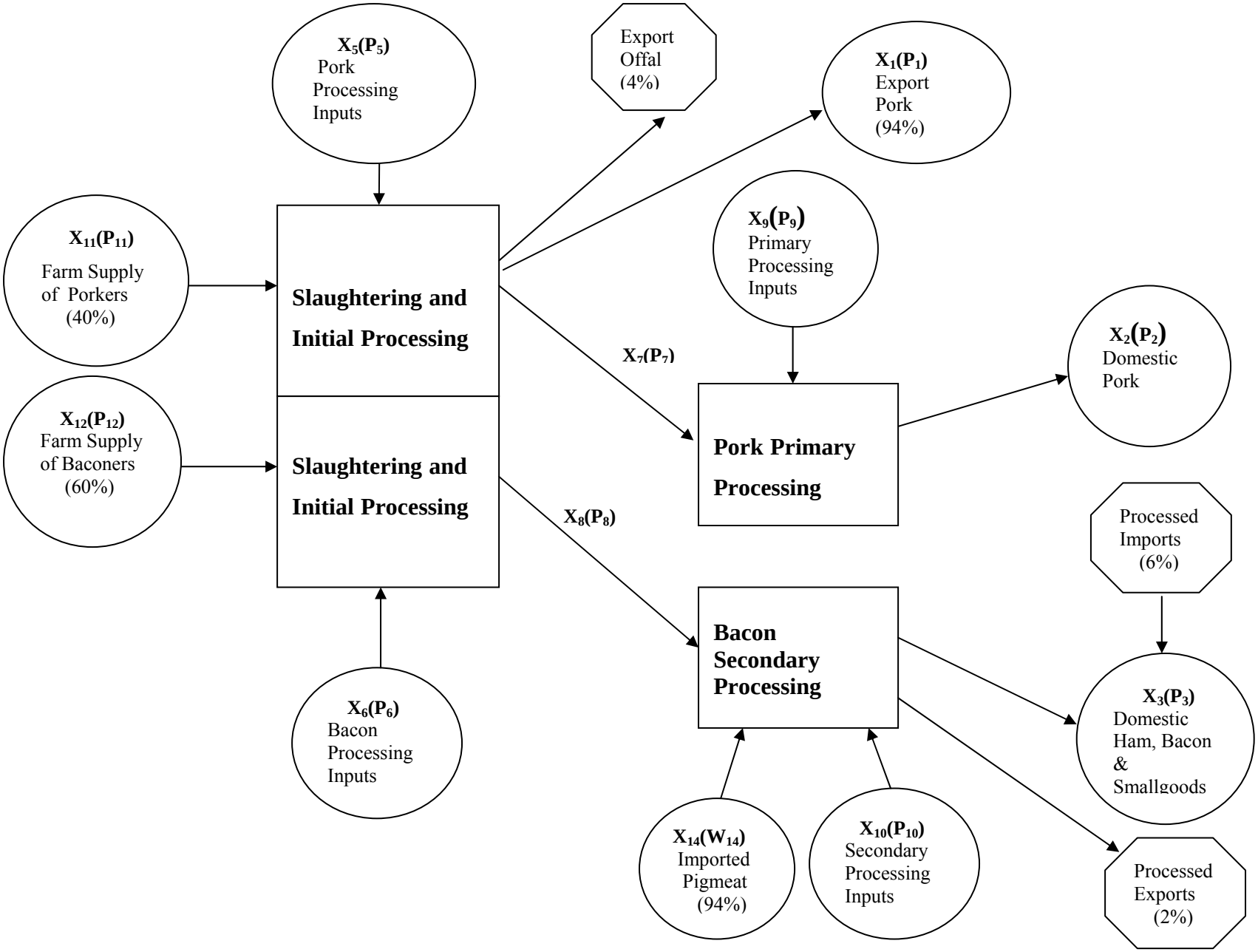


Figure 1: Model Structure

3. The New Problem

The new problem we are talking about relates to a consumer survey conducted by Amy Bellhouse (Bellhouse 2009, Bellhouse *et a*l. 2010). She surveyed 861 consumers around Australia during mid 2009 on their willingness to pay and willingness to purchase a hypothetical fresh pork product that had a significantly lower cholesterol level than existing pork. Individual consumers were found to be willing to purchase more and/or willing to pay more for pork that had lower cholesterol. However, no attempt was made in that study to investigate the industry wide implications of these results. Based on the discussion recorded above, a decision was made to try and use the old model described above to do this. Given that the old model is based around a representative year covering the period 2000-2002, and Amy's results are based on market conditions during mid 2009, the issue arises of whether to update the old model, and if so, in what way. Three broad areas have to be assessed.

3.1 The structure of the industry

Model specification is always a compromise between detailed reality and parsimonious practicality. We need just enough detail to capture the main decision making processes and the main avenues for adjustment to change. This is what is contained in the model structure, as detailed in Figure 1. The first consideration then is whether the current industry structure is similar enough to that observed during the period 2000-2002 so that the main structural elements captured in the model framework are still relevant to current research problems. This involves examination of aggregate supply and disappearance tables, investigation of whether there have been any domestic or trade policy changes that have influenced product flows or values, and investigation of whether there have been any merger or acquisition activity that might have consolidated the production, processing or distribution sectors.

It also involves checking that several specific simplifying assumptions made to limit the complexity of the model still hold. These are that the fresh pork market (export and domestic) comprises 40 per cent of total pig meat production and the processed pig meat market comprises 60 per cent of total pig meat production; that total exports of pig meat consist entirely of pork classified under tariff code sub-heading 0203; that 100 per cent of pig meat imports are used in secondary processing; that the export price is endogenous due to the disease free, niche positioning of Australian pork in export markets; and that the import price is exogenous, so that imported pork from all sources is assumed to be identical.

This meant looking through data series and graphs in the ABARE *Commodity Statistical Bulletin* (ABARE 2009), in Australian Pork Limited *Pig Annual* and *Supplements* (APL 2009a, 2010) (such as Figures 2-5 below) and in one-off reports such as Productivity Commission inquiries into the industry (PC 2005, 2008), and assessing market reviews in Australian Pork Limited *Annual Reports* (APL 2009b) and other publications.

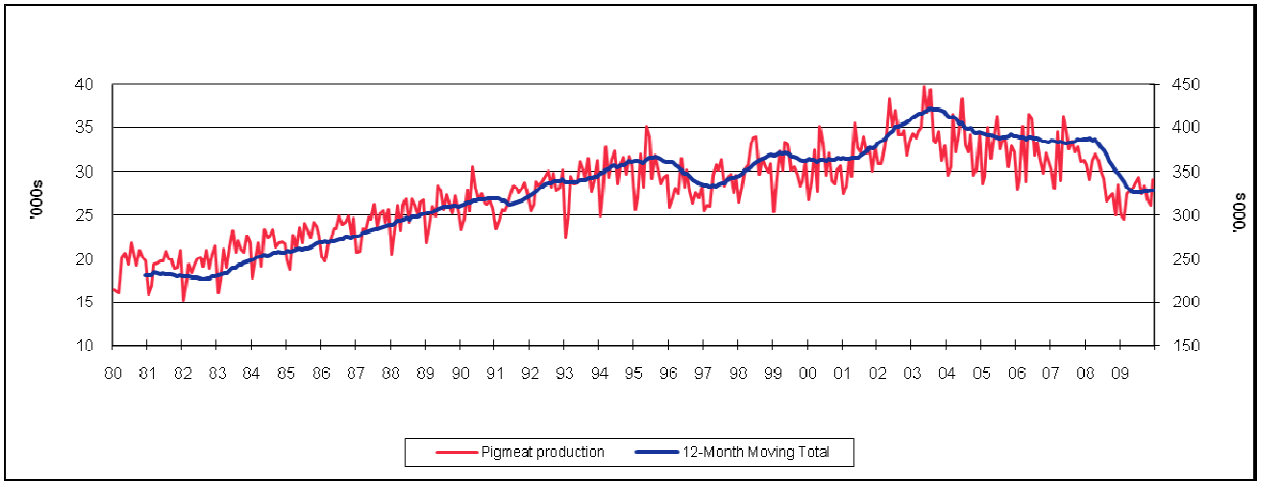
The conclusion was that the current industry structure is essentially the same as that specified in 2003, and therefore that the modelling framework described in Figure 1 does still adequately represent the current industry structure.

3.2 The base price and quantity data

In the EDM framework, changes in consumer and producer surplus values from market interventions are measured as displacements away from the assumed initial equilibrium points. Thus where you start from influences where you end up. The price and quantity values which define the initial equilibrium are selected to represent a "typical" year or set of years which would be likely to also hold in the medium term future, the period over which the industry adjusts to the displacement that is being modelled. It is assumed that prices are defined in real terms and thus the influence of general price inflation is removed. In the old model, average price and quantity values for the three years 2000-2002 were chosen as the representative year at the time the model was specified and implemented. So the second consideration is whether the current industry cost and revenue components are similar enough to that observed during the period 2000-2002 so that the initial equilibrium specified in the model framework is still relevant to current research problems. This involves examination of aggregate supply and disappearance tables, and prices paid and received at different levels of the market.

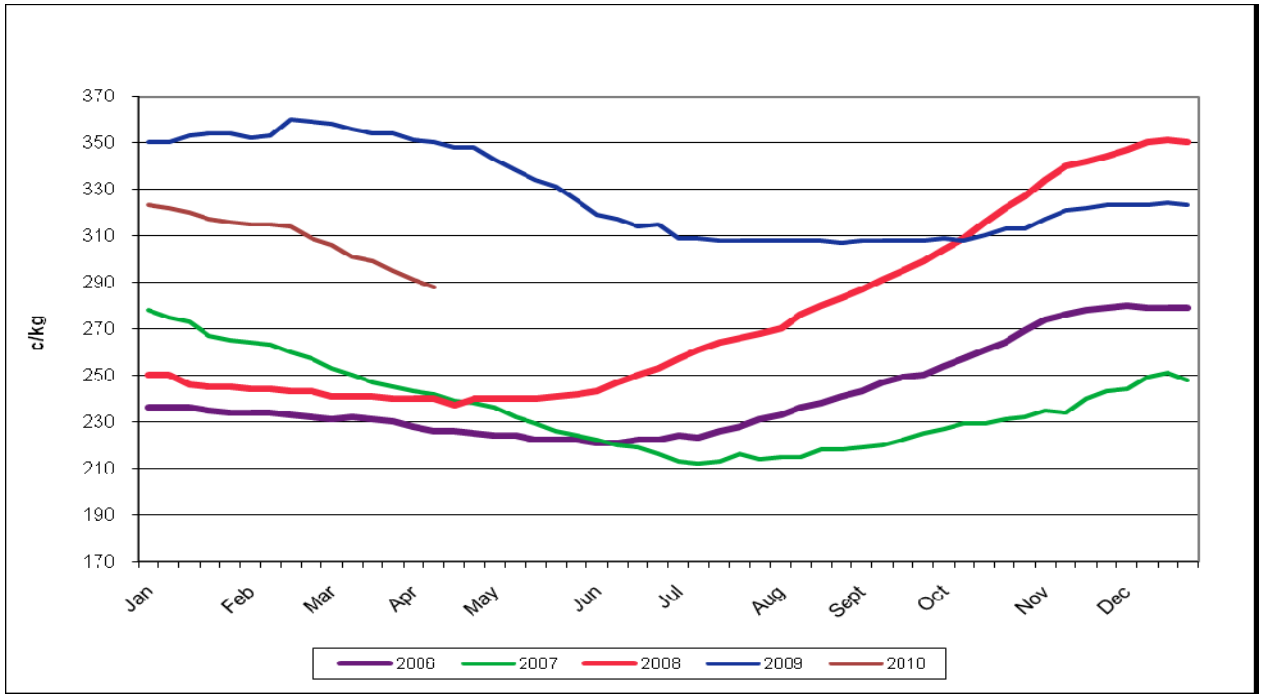
Initial examination of the industry reports detailed above suggested that this might be an area which would require updating, so a more detailed investigation was undertaken. In particular, examination of Figures 2 to 5, and related data in APL (2009a, 2010), indicates that pig meat production was somewhat lower in 2009 than in the early part of the decade; that most pig meat prices in 2009 were substantially higher than in previous years; that imports of pig meat into Australia have continued to grow significantly and in 2009 were some four times those of the 2000-2002 period; and that pig meat consumption in Australia was about 25 per cent higher in 2009 than in the early 2000s. These data suggest that some updating of price and quantity values is required.

Figure 2: Pig Meat Production, Australia, 1980-2009, '000 tonnes CW



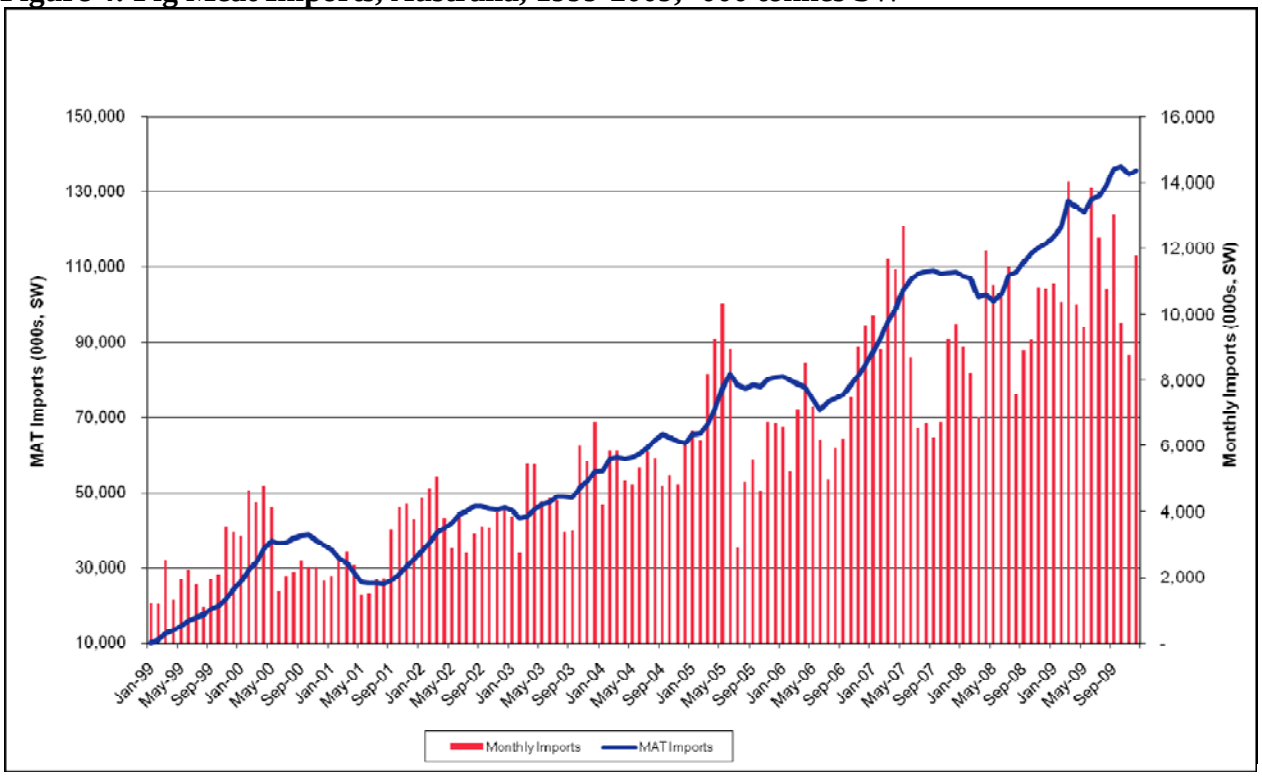
Source: APL (2010)

Figure 3: Baconer Price, Australia, 2006-2010, c/kg CWE



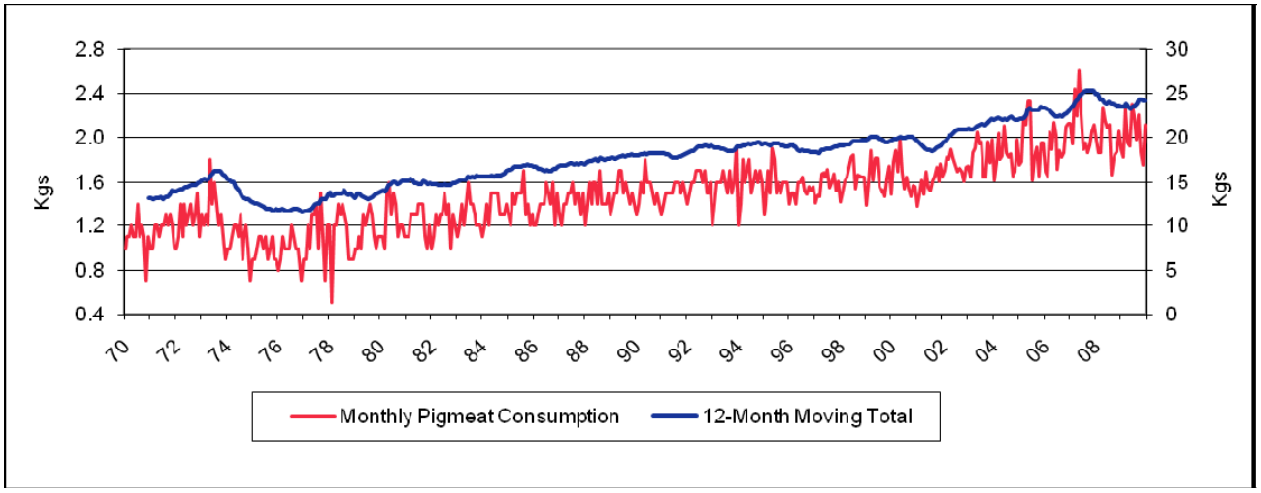
Source: APL (2010)

Figure 4: Pig Meat Imports, Australia, 1999-2009, '000 tonnes SW



Source: APL (2010)

Figure 5: Per Capita Consumption of Pig Meat, Australia, 1970-2009, kg/head



Source: APL (2010)

3.3 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. So the final consideration is whether current industry responses to price changes are similar enough to those assumed to hold during the period 2000-2002 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).

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 text 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, and no indication in any of the Australian Pork Limited reports, that elasticity values have changed since the early years of the decade.

The conclusion was that the elasticity values specified in the existing 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.

4. The New Price and Quantity Data

Based on these observations**,** the decision was taken to keep the existing model structure and set of elasticity values, but to update the base price and quantity data to better reflect the current size and value of the pig meat industry in Australia. Since the ultimate purpose of this update was to enable an extension of the Bellhouse (2009) willingness to pay results, 2009 was selected as the new equilibrium year.

The new price and quantity data, and the associated sector total values, cost shares and/or revenue shares, are reported in the right hand side of Table 1.

All quantity values are expressed in terms of carcass weight equivalent tonnes and all prices and quantities were obtained from APL (2010), except for the wholesale prices which were sourced from NLRS (2010). The cost and revenue shares required for the different sectors within the model are derived from the base price and quantity values. The cost shares for other inputs into the processing sectors are calculated as a residual from the specified equilibrium conditions for each sector.

The quantity of pig meat produced in Australia during 2009 was 329,055 tonnes. Under the assumption that pork comprises 40 per cent of total pig meat production, the quantity of pork produced was 131,622 tonnes and the quantity of pig meat produced for the manufacture of bacon/ham was 197,433 tonnes. APL recommend adjusting the shipped weight of exported pork (35,744 tonnes) to a carcass weight equivalent basis using a conversion factor of 0.8. Using this conversion factor, the quantity of exported pork was calculated as 44,680 tonnes on a carcass weight equivalent basis, leaving the quantity of pork consumed in the domestic retail market as 86,942 tonnes. Similarly, a conversion factor of 0.56 was used to derive a carcass weight equivalent of 242,095 tonnes for imported pig meat from the recorded shipped weight of 135,753 tonnes. The imported pig meat quantity was added to the quantity of domestically produced bacon/ham to yield total consumption of bacon/ham at the retail level equivalent to 439,528 tonnes.

Table 1: **Base Equilibrium Prices, Quantities and Revenue and Cost Shares, 2000-2002 Compared to 2009**

	2000-2002 typical year		**2009 typical year**	
	Quantity (X variables, CWE tonnes) **Price (P variables, $/kg)** **Sector revenue (TV variables, $m)**	**Revenue and Cost Shares**	**Quantity (X variables, CWE tonnes)** **Price (P variables, $/kg)** **Sector revenue (TV variables, $m)**	**Revenue and Cost Shares**
Final Pig Meat Products	Domestic Bacon/Ham $X_3 = 297,991$ $P_3 = 18.65$ $TV_3 = 5557.5$ Domestic Pork $X_2 = 88,101$ $P_2 = 11.97$ $TV_2 = 1054.6$		Domestic Bacon/Ham $X_3 = 439,528$ $P_3 = 19.52$ $TV_3 = 8579.6$ Domestic Pork $X_2 = 86,942$ $P_2 = 15.55$ $TV_2 = 1351.9$	
Wholesale Carcass	Domestic Bacon Carcass $X_8 = 230,033$ $P_8 = 3.57$ $TV_8 = 821.2$ Imported Carcass $X_{14} = 67,958$ $W_{14} = 2.36$ $TV_{14} = 160.4$ Domestic Pork Carcass $X_7 = 88,101$ $P_7 = 3.70$ $TV_7 = 326.0$ Export Pork Carcass $X_1 = 65,255$ $P_1 = 3.29$ $TV_1 = 214.7$ $TV_{(1+7)} = 540.7$	Bacon/Ham Secondary Processing Cost Shares $k_{X8} = 0.15$ $k_{X10} = 0.82$ $k_{X14} = 0.03$ Pork Primary Processing Cost Shares $k_{X7} = 0.31$ $k_{X9} = 0.69$ Pork Initial Processing Revenue Shares $\gamma_{X1} = 0.40$ $\gamma_{X7} = 0.60$	Domestic Bacon Carcass $X_8 = 197,433$ $P_8 = 4.48$ $TV_8 = 884.5$ Imported Carcass $X_{14} = 242,095$ $W_{14} = 2.06$ $TV_{14} = 498.7$ Domestic Pork Carcass $X_7 = 86,942$ $P_7 = 4.91$ $TV_7 = 426.9$ Export Pork Carcass $X_1 = 44,680$ $P_1 = 2.89$ $TV_1 = 129.1$ $TV_{(1+7)} = 555.9$	Bacon/Ham Secondary Processing Cost Shares $k_{X8} = 0.10$ $k_{X10} = 0.84$ $k_{X14} = 0.06$ Pork Primary Processing Cost Shares $k_{X7} = 0.32$ $k_{X9} = 0.68$ Pork Initial Processing Revenue Shares $\gamma_{X1} = 0.23$ $\gamma_{X7} = 0.77$
Live Pig	Baconers $X_{12} = 230,033$ $P_{12} = 2.47$ $TV_{12} = 568.2$ Porkers $X_{11} = 153,356$ $P_{11} = 2.80$ $TV_{11} = 429.4$	Bacon/Ham Initial Processing Cost Shares $k_{X6} = 0.31$ $k_{X12} = 0.69$ Pork Initial Processing Cost Shares $k_{X5} = 0.21$ $k_{X11} = 0.79$	Baconers $X_{12} = 197,433$ $P_{12} = 3.35$ $TV_{12} = 661.4$ Porkers $X_{11} = 131,622$ $P_{11} = 3.75$ $TV_{11} = 493.6$	Bacon/Ham Initial Processing Cost Shares $k_{X6} = 0.25$ $k_{X12} = 0.75$ Pork Initial Processing Cost Shares $k_{X5} = 0.11$ $k_{X11} = 0.89$

The farm prices for porkers and baconers of $3.75 and $3.35 per kilogram, respectively, are based on average national dressed carcass weight prices. The wholesale price was estimated to be $4.91 per kilogram for a pork carcass and $4.48 per kilogram for a bacon carcass, based on Sydney wholesale prices. Export and import prices were calculated as unit values by dividing the total dollar values of exports and imports by the respective carcass weight equivalent quantities. The export price for pork was $2.89 per kilogram and the price for imported pig meat was $2.06 per kilogram. Data were not readily available to enable the calculation of retail carcass weight equivalent prices for pork and bacon/ham. The average retail price for pork, $15.55 per kilogram, was taken to be the price of pork loin chops in state capitals, as collected by ABS. The average retail price of the bacon/ham composite good was taken to be the average retail price of bacon rashers in state capitals, $19.52 per kilogram, as price estimates for ham were unavailable[2].

Comparing the 2009 data with the 2000-2002 average data indicates the following:

- Prices for domestically produced pigs and pig meat have risen some 30 per cent over the period, well above the rate of inflation (ABARE 2009), while prices for both pork exports and processed pig meat imports have fallen;
- Production of pork at the farm level has fallen a little but this has been offset by a fall in pork exports, so that pork consumption at retail has been quite stable;
- Imports of pig meat for the processed market have risen more than three fold, so consumption of bacon and ham at retail has risen some 50 per cent – total pig meat consumption is up almost 25 per cent on the early 2000s;
- The price rises have more than offset the quantity declines in the domestic market so that gross values at the farm gate, wholesale and retail levels are all higher than in the early 2000s: 16 per cent at the farm level, 14 per cent at the wholesale level, and 28 per cent at the pork retail level;
- The huge rise in imported pig meat coupled with a slight price rise has increased the gross value of the retail bacon and ham sector by more than 50 per cent; and
- The different changes in prices and quantities at the different market levels have also resulted in some significant changes in the cost and revenue shares.

Therefore, the Australian pig meat industry in 2009 is significantly different in terms of price and quantity parameters than the industry of the early part of the decade.

5. What Does This Mean for Use of the Model and for Interpretation of the Output?

The input file for the pig equilibrium displacement model was updated with the new price, quantity, cost share and revenue share data, and several 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, using the same numbering system. The simulations were as follows:

[2] Note that because carcass weight equivalent retail prices for pork and bacon/ham have not been used, the revenues or total sector values specified in Table 1 for the pork and bacon/ham retail-sectors (TV_2 and TV_3) are over-estimated. As a result, the cost shares associated with the other processing inputs used in the pork primary processing and bacon/ham secondary processing sectors (k_{X9} and k_{X10}) are also over-estimated. In Mounter *et al.* (2005b) this issue was investigated, but that exercise is not repeated here.

- Scenario 1: a one per cent upward shift in the domestic demand for pork (N2 in Appendix 1);
- Scenario 2: a one per cent upward shift in the domestic demand for bacon and ham (N3);
- Scenario 4: a one per cent downward shift in the supply of porkers (T1); and
- Scenario 5: a one per cent downward shift in the supply of baconers (T2).

The results of this comparison are reported in Table 2[3].

The first thing to notice is that all of the values for change in total economic surplus calculated for the 2009-based scenarios are larger than the equivalent values for the scenarios based on 2000-2002 data, and that the proportional increases in total surpluses are very similar to the proportional increases in sector total values as shown in Table 1. Taking a closer look, it is obvious that the values for change in total surplus for the different scenarios (each of which are one per cent displacements) are almost exactly one per cent of the total value of the sector where the displacement occurs. Thus, for the 2009 data, a one per cent upward shift in the domestic demand for pork (scenario 1) results in a gross change in total surplus of $13.57m per annum, after the period of market adjustment that is embedded in the relevant elasticity values. This is about one per cent of the 2009 total value of the pork sector at retail, $1351.9m. Similarly, a one per cent downward shift in the supply of baconer pigs (scenario 5) results in a change in total surplus of $6.61m per annum. This is exactly one per cent of the 2009 gross value of the baconer production sector of $661.4m. Thus a simple rule of thumb is that expected change in total surplus will be well approximated by the total value of the sector under study times whatever percentage shift in demand or supply is assumed, if that shift is relatively small. Total surplus is solely determined by the size of the sector and the size of the displacement – elasticity values have no effect on total surplus.

The second thing to notice is that while the changes in pig producer and domestic consumer surpluses broadly increase with the increase in the change in total surplus when moving from 2000-2002 data to 2009 data, there are some differences between the two sets of initial data. Even though the elasticity values have not been changed, the cost and revenue shares have changed and this is reflected in different shares to producers and consumers. For example, for scenario 4, a one per cent improvement in the cost of producing porker pigs, the producer share of the total surplus change was 25.7 per cent using the 2000-2002 data but only 21.46 per cent using the 2009 data. This is because the porker production sector is a relatively smaller part of the industry in 2009 than in the early part of the decade and the benefits from technological change at the farm level are more dispersed across the rest of the industry.

[3] In these hypothetical one per cent scenarios, the surplus measures calculated by the model and reported in Table 2 are gross benefits. No allowances are made for either the proportion of producers or consumers who might take up the opportunity presented by the cost saving or increased willingness to pay, or for any additional costs required to implement these shifts in supply or demand curves. In a real world application, these issues would have to be addressed in detail.

Table 2: 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, 2000-2002 compared to 2009

	2000-2002 average								2009							
Change in economic surplus to	**Scenario 1 domestic pork advertising**		**Scenario 2 domestic bacon/ham advertising**		**Scenario 4 porker production R&D**		**Scenario 5 baconer production R&D**		**Scenario 1 domestic pork advertising**		**Scenario 2 domestic bacon/ham advertising**		**Scenario 4 porker production R&D**		**Scenario 5 baconer production R&D**	
	$m	**%**	**$m**	**%**	**$m**	**%**	**$m**	**%**	**$m**	**%**	**$m**	**%**	**$m**	**%**	**$m**	**%**
pig producers	1.52	14.40	2.63	4.72	1.11	25.70	0.43	7.51	1.93	14.22	3.13	3.63	1.06	21.46	0.50	7.56
domestic consumers	7.31	69.10	44.92	80.49	2.82	65.60	4.72	83.02	9.57	70.52	70.17	81.43	3.84	77.73	5.44	82.30
Total Surplus	10.58	100	55.81	100	4.30	100	5.69	100	13.57	100	86.17	100	4.94	100	6.61	100

Thus where you start from does influence where you end up. Both change in total surplus and to a lesser extent the distribution of this change in total surplus across sectors, depends on the price and quantity data which is used to define the initial equilibrium, even if elasticity values are the same. So careful consideration should be given to whether an existing model should be updated because updating a model does matter.

The final point to restate is that consumers of pig meat end up being the winners from either cost saving technology at the farm level or new product development or advertising campaigns at the retail level. Even for new technology implemented at the farm level, producers only receive about 20 per cent of the total benefits. These issues are discussed in detail in Mounter *et al*. (2005a, 2005b).

Therefore in relation to the new problem outlined above, we now have a modelling framework available for the task that has been tested in a number of different ways and that now reflects current industry structure and size. It should be a more appropriate framework than the original that was described in the papers by Mounter *et al*. (2004, 2005a, 2005b).

References

ABARE (2009), *Australian Commodity Statistics*, Australian Bureau of Agricultural and Resource Economics, Canberra.

APL (2009a), *Pig Annual 2009*, Australian Pork Limited, Canberra.

APL (2009b), *Annual Report 2008-2009*, Australian Pork Limited, Canberra.

APL (2010), *Supplement to Pig Annual 2010*, Australian Pork Limited, Canberra.

Bellhouse, A.E. (2009), *Effect of Cholesterol Reduction on Consumer Demand for Fresh Pork Products*, BAgSc(Hons) and BCom(Bus) dissertation, Melbourne School of Land and Environment, University of Melbourne, Parkville.

Bellhouse, A.E., Malcolm, L.R., Dunshea, F.R. and Griffith, G.R. (2010), "Consumer willingness to pay and willingness to purchase a hypothetical lower cholesterol pork product", paper being prepared for submission to *Australasian Agribusiness Review.*

Chung, K.C. and Griffith, G.R. (2009), "Another look at market power in the Australian fresh meat industries", *Australasian Agribusiness Review* Volume 17, Paper 12, pp. 218-234. Available at: http://www.agrifood.info/review/2009/Chung_Griffith.pdf.

Mounter, S., Griffith, G.R. and Piggott, R.R. (2004), "Generic advertising and the Australian pig industry: allowing for trade", paper presented at the 48th Annual Conference of the Australian Agricultural and Resource Economics Society, Melbourne, February.

Mounter, S.W., Griffith, G.R. and Piggott, R.R. (2005a), "The payoff from generic advertising by the Australian pig industry, in the presence of trade", *Australasian Agribusiness Review,* Volume 13, Paper 4 (listed February 22). Available at: http://www.agrifood.info/Publications_Review/Mounter_Griffith_Piggott.htm

Mounter, S.W., Griffith, G.R., Piggott, R.R. and Mullen, J.D. (2005b), "The payoff from generic advertising by the Australian pig industry: further results relative to the payoff from R&D", *Australasian Agribusiness Review,* Volume 13, Paper 19 (published September 23). Available at: http://www.agrifood.info/review/2005/Mounter_et_al.html

Mounter, S., Griffith, G., Piggott, R., Fleming, E. and Zhao, X. (2008), "Potential returns to the Australian sheep and wool industries from effective R&D and promotion investments and their sensitivities to assumed elasticity values", *Australasian Agribusiness Review* Volume 16, Paper 1. Available at: http://www.agrifood.info/review/2008/mounter_et_al.pdf

National Livestock Reporting Service (2010), http://www.mla.com.au/TopicHierarchy/MarketInformation/NLRS/default.htm

Productivity Commission (2005), *Australian Pigmeat Industry*, Productivity Commission Inquiry Report No. 35, Productivity Commission, Melbourne, 18 March.

Productivity Commission (2008), *Safeguards Inquiry into the Import of Pigmeat*, Productivity Commission Inquiry Report No. 44, Productivity Commission, Melbourne, 31 March.

Zhao, Xueyan, Griffith, Garry and Mullen, John (2001), "Farmer returns from new technologies in the Australian beef industry: on-farm research versus off-farm research", *Australian Agribusiness Review,* Volume 9, Paper 1. Available at: http://www.agribusiness.asn.au/review/2001v9/Griffith_Beef_Research/Zhao_Griffith_Mullen.htm

Appendix 1: Definition of Variables and Parameters

Endogenous Variables:

X_1: Quantity of exported pork

X_2: Quantity of domestic pork

X_3: Quantity of domestic bacon

X_5: Quantity of initial processing inputs in the pork industry

X_6: Quantity of initial processing inputs in the bacon industry

X_7: Quantity of wholesale pork carcass for primary processing in the domestic pork industry

X_8: Quantity of wholesale baconer carcass for secondary processing in the domestic bacon industry

X_9: Quantity of primary processing inputs in the domestic pork industry

X_{10}: Quantity of secondary processing inputs in the bacon industry

X_{11}: Quantity of porkers

X_{12}: Quantity of baconers

X_{14}: Quantity of imported pig meat for secondary processing in the bacon industry

P_1: Price of export pork

P_2: Price of pork at retail

P_3: Price of bacon at retail

P_5: Price of initial processing inputs in the pork industry

P_6: Price of initial processing inputs in the bacon industry

P_7: Price of wholesale pork carcass for primary processing in the domestic pork industry

P_8: Price of wholesale baconer carcass for secondary processing in the domestic bacon industry

P_9: Price of primary processing inputs in the domestic pork industry

P_{10}: Price of secondary processing inputs in the bacon industry

P_{11}: Price of porkers

P_{12}: Price of baconers

Z: Aggregated input index of initial processing sector

Y: Aggregated output index of initial processing sector

Exogenous Variables

W_{14}: Price of imported pig meat for secondary processing in the bacon industry

N_1: Demand shifter for export pork

N_2: Demand shifter for domestic pork consumption

N_3: Demand shifter for domestic bacon consumption

T_1: Supply shifter for porkers

T_2: Supply shifter for baconers

T_3: Supply shifter for initial processing inputs in the pork industry

T_5: Supply shifter for initial processing inputs in the bacon industry

T_6: Supply shifter for secondary processing inputs in the bacon industry

T_7: Supply shifter for primary processing inputs in the domestic pork industry