Size and Distribution of Research Benefits in the Australian Dairy Industry

Esther Liu
Department of Primary Industries Victoria, Parkville

Katherine Tarrant
Department of Primary Industries Victoria, Ellinbank

Christie Ho
Department of Primary Industries Victoria, Parkville

Bill Malcolm
Department of Primary Industries Victoria, Parkville
School of Land and Environment, University of Melbourne, Parkville

Garry Griffith
School of Business, Economics and Public Policy, University of New England, Armidale

Contributed paper prepared for presentation at the 56th AARES annual conference, Fremantle, Western Australia, February 7-10, 2012

Size and Distribution of Research Benefits in the Australian Dairy Industry

E.K. Liu, K.A. Tarrant, C.K.M. Ho, B. Malcolm and G.R. Griffith[1]

Abstract

An equilibrium displacement model of the Australian dairy industry is being developed for estimating the net benefits from dairy research undertaken by DPI Victoria. In this initial version, the dairy industry is represented by a system of aggregate demand and supply relationships for two input sectors, raw milk and milk processing inputs, and three output sectors, export and domestic manufactured milk and domestic fluid milk. Quantities and prices are calibrated in terms of milk equivalents. The vertical and horizontal disaggregation of the industry in the model enables the distribution of benefits from farmers to consumers to be assessed. The results for a 1% hypothetical shift in the supply curve in the farm and processing sectors are presented. Sensitivity analysis is also conducted for the uncertain elasticity values specified in the model.

Keywords

Australian dairy industry, research evaluation, equilibrium displacement model

1 Introduction

The Department of Primary Industries (DPI) Victoria is the lead agency for Dairy Research, Development and Extension (RD&E) under the National RD&E Strategy. The DPI undertakes a range of projects to assist farm businesses to increase their productivity. Dairy Directions is one particular research project that has been using biophysical and economic modelling to analyse potential development options for dairy businesses. Although the primary focus of the research team is on the net benefits and risk at the farm level, the industry wide benefits of various on-farm R&D investments is also of interest. Hence, an equilibrium displacement model (EDM) of the Australian dairy industry is being developed to help understand flow-on effects from agricultural research investments.

The Australian dairy industry plays a significant role across many levels in the economy. In 2009/10, dairy production was valued at $3.4 billion at the farm-gate level and it provided direct employment for around 40,000 people on dairy farms and manufacturing plants (Dairy Australia 2010). The Australian dairy industry exported $2.4 billion worth of products and contributed 10% of world dairy trade in 2009/10 (Dairy Australia 2010). Victoria alone has

[1] *Affiliations: Esther Liu is a Technical Officer in the Department of Primary Industries (DPI) Victoria, Parkville; Katherine Tarrant and Christie Ho are Research Scientists in DPI Victoria, Ellinbank and Parkville respectively; Bill Malcolm is a Principal Scientist with DPI Victoria, Parkville and an Associate Professor in the School of Land and Environment, University of Melbourne, Parkville; and Garry Griffith is an Adjunct Professor in the School of Business, Economics and Public Policy, University of New England, Armidale.*

approximately 62% of the 1.6 million dairy cattle in Australia (Dairy Australia 2010) and contributed to 86% of the value of Australia's dairy export in 2010/11 (DPI 2012). Maintaining and enhancing the productivity of the dairy industry through R&D investment is important for export earnings and for the regional economies of Australia.

However, there are a number of challenges influencing the future of the Australian dairy industry. Some examples as outlined by Dairy Australia (2011) are:

- The dynamics of the global economy is changing as developing countries become the major source of world economic recovery and growing food demand. This will also be affected by the transition to a low carbon economy.
- Climate variability and extremes will continue to put pressure on the supply of farm inputs (water, fuel, feed, etc) and increase the cost of production.
- Costs to comply with new policies on resource access and greenhouse gas emissions will be incurred in the future.
- Consumer and community demands are changing with increasing concern for environmental impacts and greenhouse gas emissions from dairy farms.

These challenges are all adding to the uncertainty and volatility of the market and climatic environment in which dairy farmers operate. Investment in R&D will be important to help maintain and increase the competitiveness of this industry.

Allocating research funds is a complex task which raises many interesting and open-ended questions. For example, while investment in a set of R&D option may maximise the net benefits at the aggregate or industry level, the distribution of the benefits and costs may be uneven across geographic regions and industry groups. Alternatively, R&D investments and benefits may be spread equitably across all geographic regions but the net benefits may not be maximised at the industry level. Other questions are:

- How to overcome inequity between generations of farmers contributing levies for and receiving benefits from RD&E.
- How to account for positive externalities.

The treatment of these issues will depend on the perspective taken and the definition of benefits used by those responsible for the allocation of R&D funds.

Given the number of stakeholders and the value of the Australian dairy industry, the way research funds are allocated across expected R&D options has implications of interest. It matters to know not just the size of the monetary benefits from each research investment but also its distribution to the different industry groups. Equilibrium Displacement Models (EDMs) are often used for such research evaluation purposes (Alston *et al.* 1995; Zhao *et al.* 2001; Farquharson *et al.* 2003). This modelling technique firstly involves delineating all the economic sectors of interest and relevance to the research study and the industry that it seeks to represent. Then a system of aggregate demand and supply relationships are specified for all the key sectors to represent the industry. Benefits from research are measured by (i) specifying exogenous shifts to the supply or demand curves of a particular sector in the base equilibrium, (ii) tracing the subsequent price and quantity changes in all markets (new equilibrium), and (iii) estimating the changes in consumer and producer surplus amongst different industry groups. The development of an Australian Dairy EDM will be of value to those making decisions with regard to research investment as well as assist DPI managers and researchers to understand and estimate the industry wide benefits of their dairy research investment.

The objectives of this paper are: to present the current model structure of the Australian dairy industry; to estimate the size of benefits from two types of R&D investment scenarios in the dairy industry; and to quantify the share of research benefits to different industry groups. In the next section of this paper, the current structure of the Australian dairy industry is described. This is followed by a section containing information about the market elasticity values applied in the model, the data used to determine our base equilibrium condition and the R&D scenarios modelled for this paper. Preliminary results for the scenarios and sensitivity analysis are presented and discussed in section 4, and conclusion is provided in section 5.

2 Equilibrium Displacement Model of the Australian Dairy Industry

2.1 Background

EDMs have previously been built for the Australian dairy industry. Freebairn (1992) developed a simple model to compare the returns and distribution of research benefits in the dairy industry under free market and past government regulation. The model by Hill *et al.* (2001), on the other hand, was used to compare the returns from generic dairy promotion expenditures under free market and policy intervention. The focus on consumer demand in Hill *et al.*'s (2001) paper meant that their model had to account for cross commodity effects; prices of substitutes, such as fruit juice and soft drinks. While the model presented in this paper has similar industry structure as the model by Freebairn (1992), the price and quantity data used in the latter dates back to the year 1989-90. Therefore, an EDM using more recent data seems appropriate and timely.

2.2 Horizontal and vertical market segments

In 2009/10, Australia produced a total of 9.02 billion litres of raw milk. Around 45% of this was exported as manufactured milk products such as cheese, butter, milk powder and yoghurt, 30% was domestically consumed as manufactured milk products and 25% as fluid milk (fresh and UHT milk). A very small amount of fluid milk is exported from Australia, 1.7% of the exported dairy products.

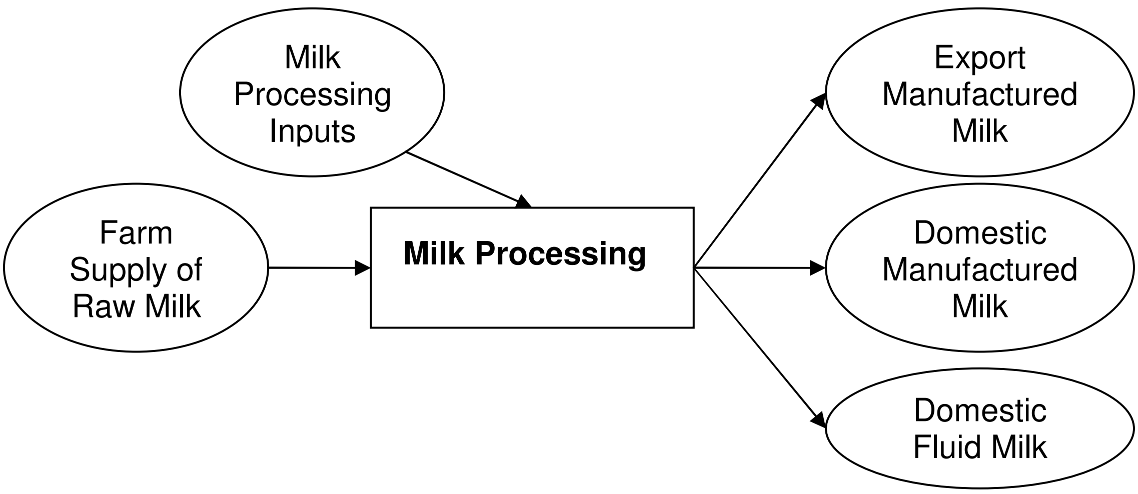

Figure 1. Model structure

Given the above information, the structure of the Australian dairy industry in the equilibrium displacement model is as shown in Figure 1. The industry is horizontally disaggregated by the production of three outputs: export manufactured milk products, domestic manufactured milk products, and domestic fluid milk. Vertically, the industry supply chain is disaggregated into the farm, milk processing and final consumption sectors. The processing sector is assumed to undertake all the necessary activities (transport, processing, manufacturing and distribution) to produce and supply to the export and domestic markets. In Figure 1, the rectangle in the middle is used to represent a multi-output production function for the processing sector of the dairy industry. The oval, on the other hand, represents the supply and demand schedule of a product where an exogenous shift may occur.

2.3 Model Specification

The equations for the model below closely follow the specification made by Mounter *et al.* (2004). The production function for the milk processing sector is written as follow:

(1) $$Y(X_1, X_2, X_3) = Z(X_5, X_{11})$$

where Y is the aggregated output index of the processing sector and Z is the aggregated input index. Table 1 on page 8 contains the definitions for all the model variables and parameters.

The total cost function for the same sector is:

(2) $$C_Y = Y * c_Y(P_5, P_{11})$$

where C_Y denotes the total cost of producing output index level Y and c_Y stands for the unit cost function.

The revenue function is:

(3) $$R_Z = Z * r_z(P_1, P_2, P_3)$$

where R_Z represents the total revenue derived from input level Z and r_z represents the unit revenue function associated with one unit of input index Z.

The following twelve equations, from (4) to (15), represent the EDM of the Australian dairy industry. It includes a pair of demand and supply function for each of the five sectors that are defined in the section 2.2. Hence, there are five price and five quantity variables. In addition, there is one aggregated input index variable and one aggregated output index variable, which results in a total of twelve endogenous variables. The five exogenous variables include the two supply shifters which represent the impact of new technologies in the farm and processing sector, and the three demand shifters that represent the impact of promotion in each of the three output markets. These equations in their general functional form are as follow:

Supply of raw milk

(4) $$X_{11} = X_t(P_{11}, T_1)$$

Here total supply of raw milk X_{11} is shown to be influenced by its price (P_{11}) and new technology that decreases the on-farm cost of milk production (T_1). The latter being an exogenous supply shifter.

Supply of other milk processing inputs

(5) $P_5 = a(X_5, T_3)$

Equation (5) states that the price of other milk processing inputs, P_5, is dependent on the level of supply of these other inputs, X_5, and an exogenous supply shifter, T_3, which represents the changes induced by the adoption of a new technology in the processing sector.

Output-constrained input demand of milk processing sector

(6) $X_{11} = Y * c'_{Y,X11}(P_5, P_{11})$ raw milk demand

(7) $X_5 = Y * c'_{Y,X5}(P_5, P_{11})$ other milk processing inputs demand

Equations (6) and (7) above show that the quantity of raw milk or processing inputs is equal to the output index, Y, times the partial derivatives of the unit cost function, $c'_{Y,X}(P_5, P_{11})$. Both have been derived from the cost function, equation (2), using Shephard's Lemma.

Input-constrained output supply of milk processing sector

(8) $X_1 = Z * r'_{Z,X1}(P_1, P_2, P_3)$ export manufactured milk supply

(9) $X_2 = Z * r'_{Z,X2}(P_1, P_2, P_3)$ domestic manufactured milk supply

(10) $X_3 = Z * r'_{Z,X3}(P_1, P_2, P_3)$ domestic fluid milk supply

Equations (8) to (10) are derived from the revenue function, equation (3) using the Samuelson-McFadden Lemma. They specify that the quantity of export manufactured milk (X_1), domestic manufactured milk (X_2) or domestic fluid milk (X_3) is equal to the input index Z times the partial derivatives of the revenue function $r'_{Z,X}(P_1, P_2, P_3)$.

Equilibrium condition

(11) $Z(X_{11}, X_5) = Y(X_1, X_2, X_3)$ quantity equilibrium

(12) $c_Y(P_{11}, P_5) = r_Z(P_1, P_2, P_3)$ value equilibrium

Equation (14) sets the aggregated input index Z equal to the aggregated output index Y, while equation (15) specifies that the unit cost (c_Y) of producing a unit of aggregated output Y equal the unit revenue r_z earned per unit of aggregated input Z.

Export demand for Australian manufactured milk product

(13) $X_1 = f(P_1, N_1)$

The export demand function states that the quantity of X_1 is determined by P_1, the price of export manufacture milk and N_1, an exogenous demand shifter that captures the demand changes for X_1 as a result of promotion or changes in taste. Here income is assumed to be constant. Price changes in milk products in overseas markets are also not included explicitly.

Domestic demand for Australian manufactured milk product

(14) $X_2 = n(P_2, P_3, N_2)$

The domestic demand equation for manufactured milk product shows that the amount of X_2 is a function of its price (P_2), price of its substitute - domestic fluid milk (P_3), and an exogenous demand shifter (N_2) which represents demand changes from promotion or taste changes. Constant income is also assumed and hence excluded from the equation.

Domestic demand for Australian fluid milk

(15) $X_3 = j(P_2, P_3, N_3)$

Similar to the previous two equations, domestic demand for fluid milk is affected by its price (P_3), price of its substitute – domestic manufactured milk (P_2), and an exogenous demand shifter (N_3).

2.4 The Model in Displacement Form

As previously mentioned, exogenous changes that can be examined in the EDM are impacts of new technologies in the farm sector (variable: T_1) and processing sector (T_3), and impacts of market research or promotions in the market for X_1, X_2 and X_3. The first two changes are modelled as parallel shifts in the supply curve for raw milk and processing inputs respectively, while the latter are modelled as parallel shifts in the demand curves for the three output products. These exogenous shifts will displace the base equilibrium that are specified and described in the next section.

In this section, the model components are presented in their displacement form. The equations below, (4a)-(15a), have been obtained by totally differentiating the system of equations, (4)-(15), at the initial equilibrium points. Please see Table 1 for the definitions of the variables and parameters. A small percentage change in variable (.) is denoted as E(.)=Δ(.)/(.).

Supply of raw milk

(4a) $\beta_{X11} EX_{11} = \varepsilon(EP_{11} - ET_1)$

Supply of other milk processing inputs

(5a) $EP_5 = s_{X5} EX_5 + ET_3$

Output-constrained input demand of milk processing sector

(6a) $EX_{11} = -k_{X5}\sigma_{(X5,X11)}EP_{11} + k_{X5}\sigma_{(X5,X11)}EP_5 + EY$

(7a) $EX_5 = k_{X11}\sigma_{(X5,X11)}EP_{11} - k_{X11}\sigma_{(X5,X11)}EP_5 + EY$

Input-constrained output supply of milk processing sector

(8a) $EX_1 = -(\gamma_{X2}\tau_{(X1,X2)} + \gamma_{X3}\tau_{(X1,X3)})EP_1 + \gamma_2\tau_{(X1,X2)}EP_2 + \gamma_{X3}\tau_{(X1,X3)}EP_3 + EZ$

(9a) $EX_2 = \gamma_{X1}\tau_{(X1,X2)}EP_1 + \gamma_3\tau_{(X2,X3)}EP_3 - (\gamma_{X1}\tau_{(X1,X2)} + \gamma_{X3}\tau_{(X2,X3)})EP_2 + EZ$

(10a) $EX_3 = \gamma_{X1}\tau_{(X1,X3)}EP_1 + \gamma_2\tau_{(X2,X3)}EP_2 - (\gamma_{X1}\tau_{(X1,X3)} + \gamma_{X2}\tau_{(X2,X3)})EP_3 + EZ$

Equilibrium condition

(11a) $k_{X5}EX_5 + k_{X11}EX_{11} = \gamma_{X1}EX_1 + \gamma_{X2}EX_2 + \gamma_{X3}EX_3$

(12a) $k_{X5}EP_5 + k_{X11}EP_{11} = \gamma_{X1}EP_1 + \gamma_{X2}EP_2 + \gamma_{X3}EP_3$

Export demand for Australian manufactured milk product

(13a) $EX_1 = \eta_{(X1,P1)}EP_1 + EN_1$

Domestic demand for Australian manufactured milk product

(14a) $EX_2 = \eta_{(X2,P2)}EP_2 + \eta_{(X2,P3)}EP_3 + EN_2$

Domestic demand for Australian fluid milk

(15a) $EX_3 = \eta_{(X3,P3)}EP_3 + \eta_{(X3,P2)}EP_2 + EN_3$

To be able to estimate the welfare changes in each industry sector, mathematical integrability conditions must be satisfied. Therefore, homogeneity and symmetry[2] conditions have been implicitly imposed on all the input demand and output supply functions in the EDM. Furthermore, the integrability conditions require that the input demand functions are specified as concave, while the output supply functions are convex.

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[2] The homogeneity condition implies that the input demand and output supply functions are homogeneous of degree zero in input and output prices respectively. That is, when all the variables in a function are scaled up by a constant, the resulting value of the function does not change. The symmetry condition means that the Hessian matrix of the Allen-Uzawa input substitution and product transformation elasticities are symmetric.

Table 1. Definition of variables and parameters

Endogenous variables	
X_1	Quantity of export manufactured milk product
X_2	Quantity of domestic manufactured milk product
X_3	Quantity of domestic fluid milk
X_5	Quantity of raw milk
X_{11}	Quantity of other milk processing inputs
P_1	Price of export manufactured milk product
P_2	Price of domestic manufactured milk product
P_3	Price of domestic fluid milk
P_5	Price of raw milk
P_{11}	Price of other milk processing inputs
Z	Aggregated input index
Y	Aggregated output index
Exogenous variables	
T_1	Supply shifter for raw milk
T_3	Supply shifter for other milk processing inputs
N_1	Demand shifter for export manufactured milk product
N_2	Demand shifter for domestic manufactured milk product
N_3	Demand shifter for domestic fluid milk
Parameters	
β_{X11}	Quantity share of other milk processing inputs in total milk production
ε	Own price elasticity of raw milk supply
s_{X5}	Supply elasticity of other milk processing inputs
k_{X5}	Processing cost share of raw milk
k_{X11}	Processing cost share of other milk processing inputs
$\sigma_{(X5,X11)}$	Elasticity of input substitution between raw milk and other processing inputs
γ_{X1}	Revenue share of output X_1
γ_{X2}	Revenue share of output X_2
γ_{X3}	Revenue share of output X_3
$\tau_{(X1,X2)}$	Elasticity of product transformation between X_1 and X_2
$\tau_{(X1,X3)}$	Elasticity of product transformation between X_1 and X_3
$\tau_{(X2,X3)}$	Elasticity of product transformation between X_2 and X_3
$\eta_{(X1,P1)}$	Own price elasticity of demand for X_1
$\eta_{(X2,P2)}$	Own price elasticity of demand for X_2
$\eta_{(X2,P3)}$	Demand elasticity for X_2 with respect to a change in P_3
$\eta_{(X3,P3)}$	Own price elasticity of demand for X_3
$\eta_{(X3,P2)}$	Demand elasticity for X_3 with respect to a change in P_2

3 Data

The table above shows that our model requires three types of input data. First, the initial equilibrium price and quantity values for all the sectors in our model are needed. The base equilibrium, see Table 2, has been estimated by using the average prices and quantities of all inputs and outputs for the period between 2007/08 and 2010/11. This has been done because this time period accounted for a range of climatic and economic conditions. For example, weather variation over the years, the global financial crisis and fluctuations in the exchange rates.

Table 2. Base equilibrium prices, quantities, cost shares and revenue shares

	Quantity (bn L)	Price ($/L)	Total Value ($bn)	Cost Shares	Revenue Shares^
Export Manufactured Milk	X_1=4.14	P_1=0.52	TV_1=2.15		γ_{X1}=0.308
Domestic Manufactured Milk	X_2=2.79	P_2=0.71	TV_2=1.98		γ_{X2}=0.283
Domestic Fluid Milk	X_3=2.25	P_3=1.27	TV_3=2.86		γ_{X3}=0.409
Raw Milk	X_{11}=9.18	P_{11}=0.44	TV_4=4.04	k_{X11}=0.42*	
Other Processing Inputs				k_{X5}=0.58**	

^ Calculated as: total value of one output divided by the sum of total value of all outputs

* Calculated as: total value of raw milk divided by the sum of total value of all outputs

** Calculated as follow: $k_{X5}=1- k_{X11}$

Figure 2 and 3 on the next page shows respectively the real prices and quantities of four commodities - export and domestic manufactured milk, domestic fluid milk and raw milk[3] - over a ten year period. Quantities and prices are calibrated in terms of milk equivalents. By definition, the data for the quantity of export manufactured milk should not include any fluid milk. Although this is true for our data[4], it should not be of great concern as the latter only accounts for a very small proportion of total dairy exports. All the price and quantity data have been directly provided by the staff members from Dairy Australia.

The second type of data required is the market elasticity values. Table 3 on page 11 are the selected elasticity values for: the supply of raw milk and other milk processing inputs, the demand of the three final products (both own price and cross-price elasticity), input substitution, and product transformation between the different outputs. These values are determined with consideration to economic theory, by a review of published estimates in the literature (Freebairn 1992; Hill *et al.* 2001; Bartos and Davey 2011; BDA Group 2011) and the authors' subjective judgment. In addition, the values used and presented are medium term elasticities since one of the assumptions is that it would take three to five years for a displacement to adjust back to equilibrium.

[3] Prices for export manufactured milk have been adjusted for inflation using ABS's Producer Price Index - final commodities for export. Real prices for domestic manufactured milk and fluid milk have been obtained by using ABS's Producer Price Index - final commodities for domestic consumption. The raw milk price data have been adjusted for inflation using ABARE's index of prices paid by farmers. The reference year is 2010/11.

[4] ABS does not distinguish between the two groups for their dairy export data.

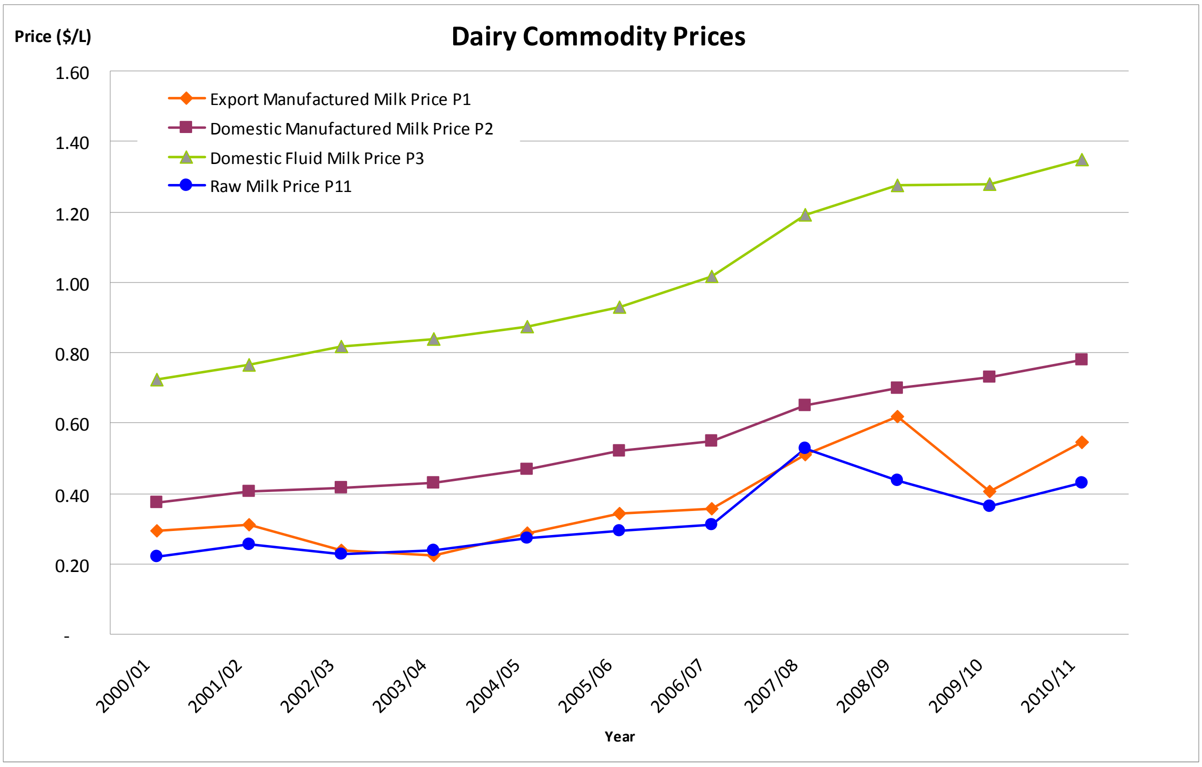

Figure 2. Dairy commodity prices, 2000/01 – 2010/11

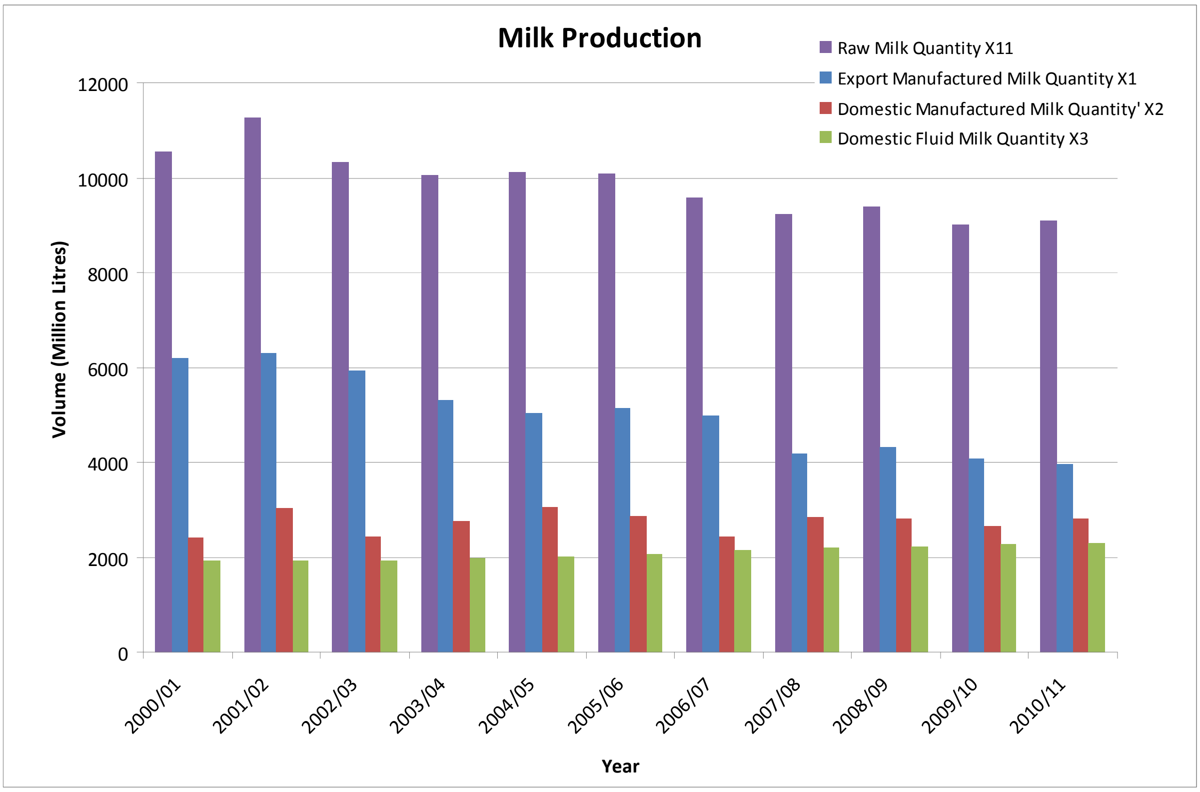

Figure 3. Milk production, 2000/01 – 2010/11

Table 3. Selected elasticity values and their subjective probability distributions#

	Elasticity	Probability Distribution
Own price elasticity of X_{11}	$\varepsilon = 1.1$	$N(1.1, 0.25^2 \mid >0)$
Supply elasticity of X_5	$s_{X5} = 5$	U(5,100)
Elasticity of input substitution bw X_5 and X_{11}	$\sigma_{(X5,X11)} = 0.1$	$N(0.1, 0.05^2 \mid >0)$
Elasticity of product transformation bw X_1 and X_2	$\tau_{(X1,X2)} = -0.5$	$N(-0.5, 0.1^2 \mid <0)$
Elasticity of product transformation bw X_1 and X_3	$\tau_{(X1,X3)} = -0.5$	$N(-0.5, 0.1^2 \mid <0)$
Elasticity of product transformation bw X_2 and X_3	$\tau_{(X2,X3)} = -0.5$	$N(-0.5, 0.1^2 \mid <0)$
Own price elasticity of demand for X_1	$\eta_{(X1,P1)} = -20$	$N(-20, 6.06^2 \mid <0)$
Own price elasticity of demand for X_2	$\eta_{(X2,P2)} = -0.4$	$N(-0.4, 0.18^2 \mid <0)$
Demand elasticity for X_2 wrt a change in P_3	$\eta_{(X2,P3)} =0.2$	U(0,0.39)
Own price elasticity of demand for X_3	$\eta_{(X3,P3)} = -0.12$	$N(-0.12, 0.05^2 \mid <0)$
Demand elasticity for X_3 wrt a change in P_2	$\eta_{(X3,P2)} = 0.05$	U(0, 0.11)

bw indicates between, wrt stands for with respect to

The uncertainty around the true market elasticity values means that it is useful to apply stochastic sensitivity analysis to the modelling results with respect to changes in these parameters. The third column in the table above shows the probability distributions that have been specified for each elasticity. Most of the parameters are assumed to have normal distribution (notation: $N(\mu,\sigma^2)$) and restricted to be either negative or positive value by truncation. A few parameters such as the elasticity of supply of other processing inputs have uniform distribution with the following notation: U(min, max). To satisfy the homogeneity and concavity conditions, the demand elasticities of the three final outputs have been chosen to meet the following criteria (Zhao *et al.* 2000, p.32):

$$\eta_{(Xi,Pi)} \leq 0, \quad \eta_{(Xi,Pj)} \geq 0 \quad \text{and} \quad |\eta_{(Xi,Pi)}| > |\eta_{(Xi,Pj)}| \quad (i, j = 1,2,3)$$

Monte Carlo random sampling has then been performed using these specifications with the @Risk computer program (Palisade 2007), allowing estimates of the probability distributions for the output variables, namely the estimated change in economic surpluses of each sector, to be obtained.

The third type of input data are the values specified for the exogenous shifter variables. There are two exogenous supply shift variables and three exogenous demand shift variables for the model here. In this paper, only the supply shift variables will be used to examine two hypothetical scenarios. The first scenario is the impact of on farm research and the second considers the impact of processing research. Both scenarios will model how new technologies or practices adopted from R&D may reduce the costs of production and induce a 1% downward supply shift in the farm and processing sector respectively.

4 Results and Discussion

4.1 Returns from R&D Investment Scenarios

Preliminary modelling results for the two R&D investment scenarios are shown in Table 4. They are presented by the size and share of benefits to various industry groups. Results for the on-farm research scenario will now be interpreted in detail; those found for the processing research scenario can be understood in a similar manner. To put the result numbers into context, Figure 4 below will be used to explain how the demand and supply curves in each sector have shifted and how the resulting economic surplus changes are linked to the numbers in the table.

Table 4. Benefit changes and percentage of total benefits to all industry groups

Industry Group	On-farm Research Scenario		Processing Research Scenario	
	$m	%	$m	%
Dairy Farmers	7.58	18.74	3.28	11.12
Processors	0.72	1.79	1.14	3.87
Overseas Consumers	0.42	1.04	0.33	1.12
Domestic Consumers				
Fluid Milk	19.84	49.07	15.50	52.49
Manufactured Milk	11.87	29.36	9.27	31.40
Subtotal	31.71	78.43	24.78	83.89
Total Benefits	40.43	100.00	29.53	100.00

Recall first that the on-farm research scenario examines a 1% downward shift in the supply of raw milk. The bottom right hand corner of Figure 4 shows this with S_0 moving to S_1, which leads to a fall in the commodity's farm gate price (-0.8% change from the initial equilibrium price) and an increase quantity of raw milk supplied (0.21% change from base quantity). The economic surplus gained by farmers, ΔPSx_{11}, is displayed as the shaded area in the diagram. Table 4 shows that this is measured to be $7.58 million relative to the base equilibrium or 18.7% of the total benefits for the specified expected elasticity values.

Consider now the market for other processing inputs, the diagram on the bottom left of Figure 4. The demand for other milk processing inputs is expected to increase as the quantity of raw milk supply increases. Hence, the demand curve is shifted from D_0 to D_1, with the resulting producer surplus area, ΔPSx_5, shown as shaded. The point estimate of the returns from on-farm R&D to processors is relatively small, $0.7m or 1.8% of the total benefits. The demand for other processing inputs does not increase as much as it would under an assumption of fixed input proportion since a non-zero input substitution elasticity of 0.1 is assumed between raw milk and other processing inputs (Zhao *et al.* 2000). In other words, milk processors are able to substitute for other inputs with the use more raw milk that is relatively cheaper.

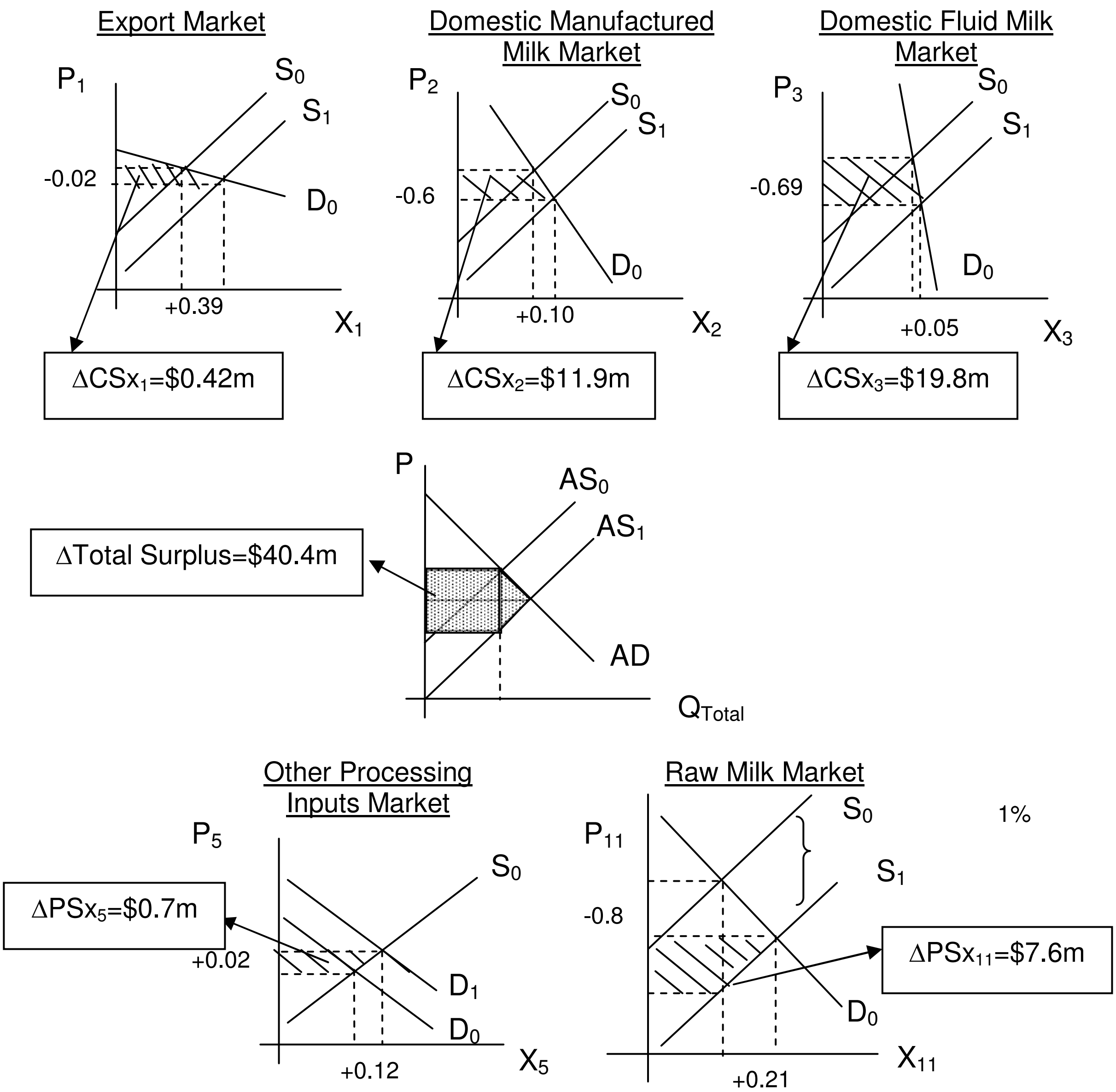

Figure 4. Market displacement and economic surplus changes in scenario 1 (T_1=1%)

Note: Numbers along the horizontal and vertical axes are the % change in quantity and price relative to the base equilibrium.

The top three diagrams in the figure show that the supply curves for each end product shift to the right as the on-farm research reduce the cost of production and increase the supply of raw milk. The demand curves for all three final products, however, do not change. Consequently, the prices of each product decrease and their consumption is increased. The shaded area in each diagram shows the consumer surplus gained in export market and the two domestic markets. Overseas consumers gain a low 1.04% of total benefits from on-farm research, while the combined consumer surplus in domestic manufactured milk and fluid milk is estimated to be $31.7m or 78% of total benefits. Most of the benefits accrue to domestic consumers because the gross revenue of the domestic fluid milk sector is relatively higher and the demand for the two domestic products are inelastic, -0.4 for manufactured milk and -0.12 for fluid milk.

Overall, the combined consumer and producer surplus from on-farm research is $40.4 million. For the processing research scenario, the total return is $29.5m and all industry groups are found to gain from the R&D investments. Please note that these results do not account for the cost required to induce a 1% shift. The efficiency of research investments are likely to vary from one to another. Hence the results for the two scenarios are not comparable unless equal investment efficiency is assumed (Zhao *et al.* 2000).

The size and distribution of benefits presented here differs from past results for a similar on-farm research scenario. Freebairn (1992) shows that for a 1% cost reduction in farm milk production, 100% of the benefits are gained by farmers under free market. The reason for these differences lies with the assumption made with regard the elasticity of substitution between raw milk and other milk processing inputs. For simplification Freebairn (1992) assumed fixed input proportion by using a value of zero. In contrast, this restrictive assumption is slightly relaxed for the model in this paper; some input substitution is allowed with the elasticity value specified at 0.1. Hence, there is more variation to the distribution of benefits to the different industry groups.

4.2 Sensitivity to Market Elasticity Values

The mean and variability of the economic surpluses under the two scenarios are presented in Table 5 on page 17. These preliminary results from the stochastic sensitivity analysis show that although total industry benefits are quite stable for both scenarios, there are different levels of confidence with regard to the distribution of benefits to each industry group. For example, the mean return of on-farm R&D to dairy farmers is $7.79 million or 19.3% of the mean total benefits, but there is a 95% chance that this will vary between $3.7m to $13m (9 to 32% relative to mean total benefits). As for the benefit to domestic consumers, its value range is $26.8m to $36.3m (66.3 to 89.8% of mean total benefits) with 95% probability. The variability of the percentage benefits to dairy farmers and domestic consumers are graphically shown by the box plots in Figure 5 and 6 respectively.

The variability of the results reflects the uncertainties in the market elasticities. Multivariate stepwise regression (scenario analysis) was performed in @Risk to calculate the significance of each market elasticity variables to the model's output variables. The preliminary results indicate that, for the on-farm research scenario, input distributions that had the largest impact on both farmer and domestic consumers' percentage benefits are: the own price elasticity of supply for raw milk, the own price and cross price elasticity of demand for domestic manufactured milk. While for the processing research scenario, variables that provided the most significant contribution to the changes in farmers' percentage benefits are: the own price elasticity of demand for manufactured milk, the input substitution elasticity, and the supply elasticity of raw milk. Similarly for the domestic consumers' percentage benefits they include: firstly, the own price elasticity of demand for manufactured milk. Secondly, the elasticity of raw milk supply, and then the cross price elasticity of demand for manufactured milk. These results require further analysis as the ranking of the significance of these market elasticity values are based on the assumption that there is no correlation between the elasticity variables.

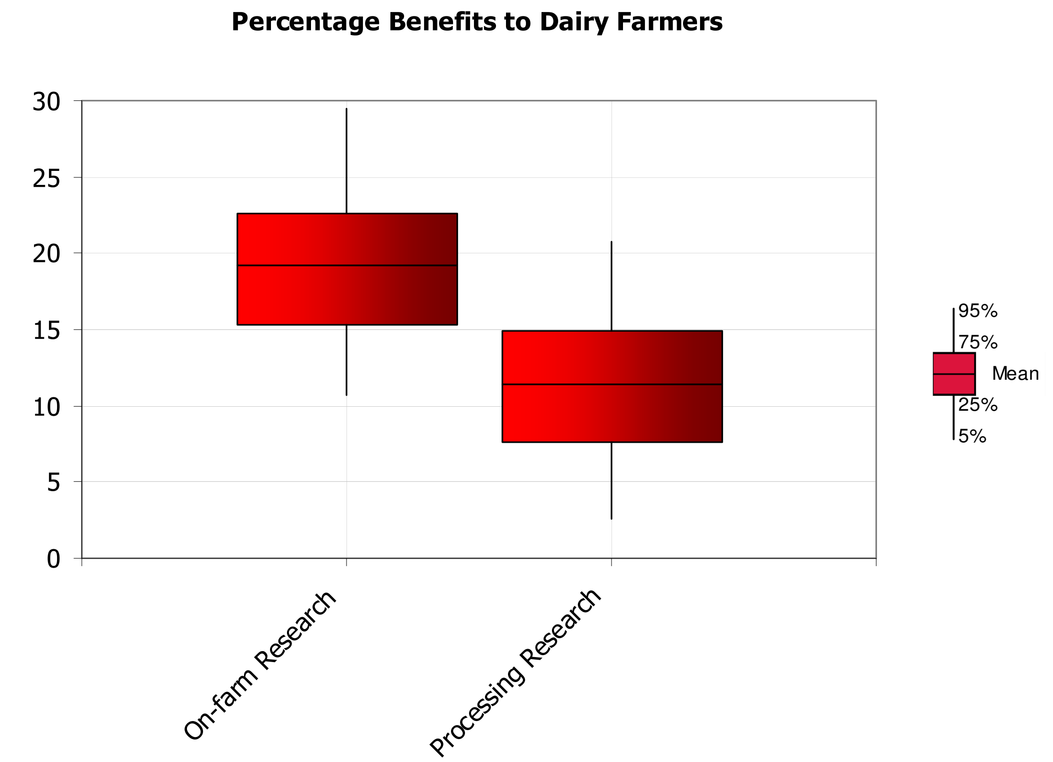

Figure 5. Box plots for percentage benefits accrued to dairy farmers relative to average total benefits

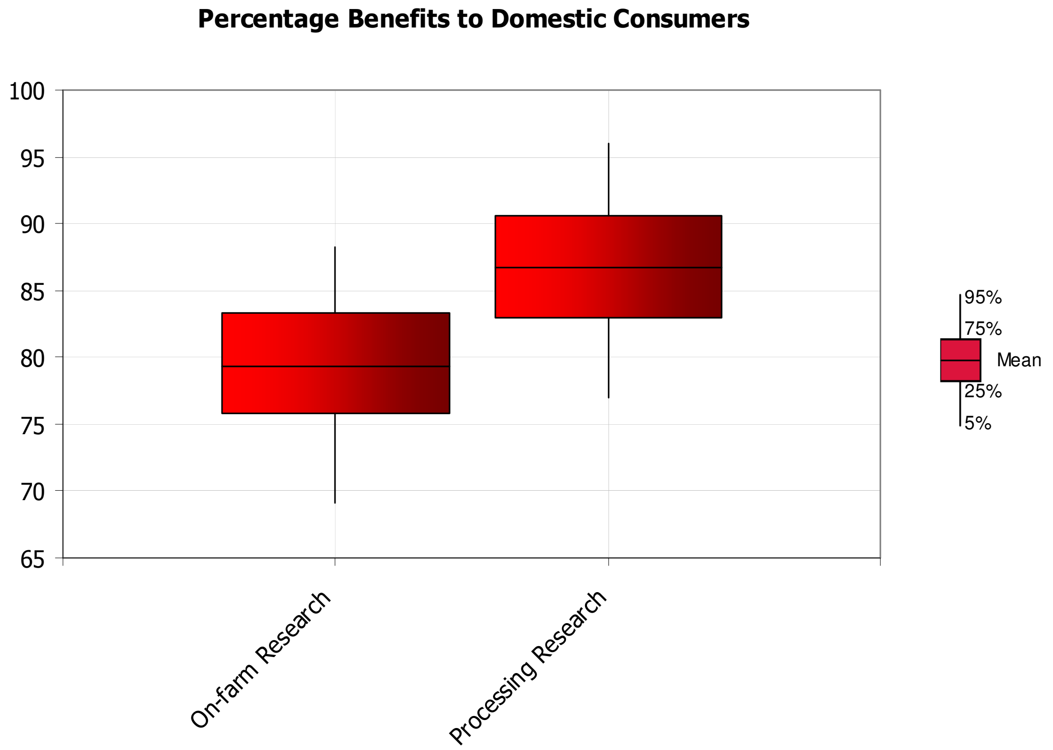

Figure 6. Box plots for percentage benefits accrued to domestic consumers relative to average total benefits

5 Conclusion

Interpreting the results involves considering the cost, practicalities and likelihood of various investments in RD&E directly contributing to the 1% shifts in the supply curve. Modelling outputs of the size and distribution of research benefits presented here demonstrate the potential of our EDM to assist decision makers in the allocation of R&D funds. A 1% cost reduction examined in the farm and processing research scenarios is most likely to provide benefits to all industry groups. Domestic consumers are found to gain the largest share of total benefits, with more than 78%, from on-farm and processing research scenarios. Dairy farmers will also receive significant proportions, around 19% and 11% from on-farm and processing research scenarios respectively. The ability of the EDM to quantify the magnitude and percentage of research benefits received by different industry groups will help decision makers concerned with the important issue of equity.

Table 5. Summary statistics of stochastic sensitivity analysis: Benefit changes ($m) and percentage benefits to various industry group

Industry Group	On-farm Research Scenario		Processing Research Scenario	
	$m	%	$m	%
Dairy Farmers				
Point estimate	7.58	18.74	3.28	11.12
μ	7.79	19.26	3.36	11.38
σ	2.38	5.90	1.68	5.69
95% PI	3.69	9.13	0.24	0.80
	12.99	32.13	6.86	23.21
Processors				
Point estimate	0.72	1.79	1.14	3.87
μ	0.11	0.27	0.18	0.62
σ	0.13	0.32	0.19	0.65
95% PI	0.00	0.01	0.04	0.14
	0.49	1.20	0.78	2.65
O/S Consumers				
Point estimate	0.42	1.04	0.33	1.12
μ	0.47	1.17	0.38	1.28
σ	0.27	0.66	0.21	0.73
95% PI	0.24	0.59	0.19	0.65
	1.02	2.53	0.81	2.74
Domestic Consumers				
Point estimate	31.71	78.43	24.78	83.89
μ	32.06	79.29	25.61	86.72
σ	2.42	5.99	1.72	5.82
95% PI	26.80	66.29	22.11	74.86
	36.29	89.77	28.84	97.66
Total Benefits				
Point estimate	40.43	100.00	29.53	100.00
μ	40.43	100.00	29.53	100.00
σ	0.01	0.03	0.01	0.02
95% PI	40.40		29.52	
	40.45		29.54	

Note: PI denotes probability interval.

Acknowledgements

The authors would like to acknowledge the assistance from a number of people. We would first like to thank Dr. Stuart Mounter for the time he has spent carefully reviewing the model's computer script and excel spreadsheet. Secondly, we are grateful for the data support from Dairy Australia and last but not the least, we would like to thank the guidance and support from team members of the Dairy Directions project.

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