REPORT

Payoffs from research and development along the Australian food value chain: a general equilibrium analysis

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Abstract

The payoffs and distribution of payoffs from research and development (R&D) along the food value chain depend on many interacting economic factors. To quantify these we have developed a general equilibrium model of the Australian economy with detailed farming, processing and marketing information. We use the model to assess potential payoffs and distributions from various R&D scenarios that lead to demand expansion and productivity improvement. We find that productivity improvement caused by R&D is unambiguously beneficial to the whole economy while the benefits of export or domestic market demand expansion mainly accrue to the primary producers and processing industry, when the economy is at full employment. Also, productivity improvement from R&D on-farm may benefit processors while improvements post-farm may benefit farmers. However the distribution of payoffs along the value chain differs by the nature of change that R&D induces, the products produced and the markets supplied to. Benefits from productivity growth on-farm for products requiring considerable processing will require processors to invest in more capacity, so farmers will need to share some benefits with the up-stream sector. The benefits of productivity growth in processing will increase the derived demand for farm products thus transferring benefits to farmers. To efficiently allocate R&D funds requires an understanding of these interactions.

Key words: food processing, value chain, general equilibrium, R&D.
1 Introduction

Previous theoretical work has shown that the payoffs and distribution of payoffs from research and development (R&D) along the food value chain depend critically on the economic nature of the value chain (Freebairn et al 1982, Alston and Scobie 1983, Freebairn et al 1983, Edwards and Freebairn 1984, Holloway 1989). The distribution of payoffs can shift up and down the chain depending on many economic variables. In particular payoffs will depend on:

- the nature of the technological or other change caused by successful R&D;
- where it occurs along the chain (on-farm or post-farm);
- the responsiveness to price of many variables such as:
  - supply at various stages in the chain;
  - demand and derived demand;
  - substitution between inputs and final products;
- relative shares of gross value of production at each point along the chain.

This means that successful R&D for the food processing sector can provide payoffs to farmers and successful on-farm R&D can pass benefits along to processors. Given the often large size of the food processing sector, relative to agriculture, R&D in the processing sector may be an important source of benefit to the farming sector. R&D that is adopted both on and off farm can also pass benefits to consumers and other sectors of the economy.

Over the past 25 years The Centre for International Economics (TheCIE) has been involved in building detailed economic value chain models of the Australian food and agricultural industry. Many of these have been partial equilibrium models built around detailed input output structures to define multi-staged production, processing and marketing systems linked to final product demand systems separated by product types for domestic and world markets. These have been used to assess the potential magnitude and distribution of payoffs from successful R&D along the value chain. Results of this work have been used to help guide R&D allocations for most of Australia’s agricultural primary industries.

In this paper we seek to extend the general theoretical understanding provided by the authors cited above and apply them especially to the post-farm processing sector. We aim to draw out findings about the magnitude and distribution of payoffs along Australia’s highly variable food value chains resulting from successful post-farm focussed food

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1 The authors acknowledge the funding of the work reported here by the Commonwealth Scientific and Industrial Research Organisation (CSIRO, Australia) and the Department of Primary Industries, Victoria (DPI, Victoria, Australia).
research. To do this we have built our knowledge about the integration of the fresh and processed components of each individual value chain into a general equilibrium model of the Australian economy broken down by state and including the economy represented by 38 sectors. The model is based on actual Australian data (2005–06) that captures the individual nature of each value chain. The model captures market behaviour about supply and demand between farm, processor and the consumers for fresh and processed products and so includes farming, transport, handling, wholesaling, manufacturing, marketing, retailing, taxes and trading (imports and exports).

Potentially, any of the variables explaining the value chains can be changed to assess economic impacts on input usage, output, profits, wages, prices, costs, household consumption and government taxes. Successful research, development and extension (RD&E) can change the nature and structure of value chains and this can be represented in the model. The complex and indirect economic impacts such changes can cause can therefore be assessed using the model. In this way it is possible to assess the payoffs along each food value chain and for the wider economy. It also provides the capacity to assess the implications of the great differences between value chains.

As such, the model allows practical analysis of likely R&D impacts and priorities and captures not only interactions within a product value chain, but also between that product and other sectors of the economy. Further, the value chain component of our analyses is explicitly multi-commodity, so interactions between agricultural value chains are also captured. Both of these sets of interactions are crucial for practical R&D analysis which often involves allocating research funds between competing activities.

The model combines an extremely rich database with a consistent theoretical foundation. The broad insights of the original theoretical analyses, of course, remain. However our new model allows considerably more detailed exploration of the impact of a very wide variety of economic changes that may be induced by agricultural and processing R&D or other economic changes.
2 The model

The model was developed by the Centre for International Economics based on the publicly available MMRF-NRA model developed by the Australian government’s Productivity Commission (2006).

For the purpose of this study, considerable effort has been put into restructuring the commodities and sectors in the original model. More specifically, the previous broad on-farm sectors are split into 10 more specific ones, and the single food, beverage and tobacco sector in the original version is split into 11 more specific ones (table 2). Consequently, other manufacturing and services sectors are aggregated. As a result, the existing version of the food processing model identifies 38 sectors.

The aggregate data lying behind the Australian food value chain is as represented in chart 1, but the value chain can be disaggregated by the products set out in table 2.

In chart 1, the farm gate value of production is $40.4 billion representing the value of land, labour, capital, plus feed, energy, packaging and chemicals (FEPC), services and other inputs used, as shown in the ‘farm production’ column. In the model, input use is broken down into the thirty eight sectors represented in the model and a production function explains the relationship between input use, substitution between inputs and output from each sector and responses depend on costs of input, prices of outputs and the level of relative technical efficiency between inputs and outputs. Imports and margin activities (retailing, wholesaling, transport and taxes) are added to the farm gate value to provide a wholesale or retail value of fresh produce worth around $53.9 billion a year. Margin activities also use inputs and are represented by relevant production functions.

Some of the $53.9 billion of agricultural output\(^2\) shown in chart 1 (‘fresh consumption column) are consumed directly as fresh produce by Australian households and restaurants, particularly fruit and vegetables; some such as feed grains is recycled back to agriculture, some is non-food, such as wool; about 20 per cent is exported unprocessed, such as wheat; and the rest, about 32 per cent, goes into food processing as meat, fats, market milk, cheese, butter, skim milk powder, flour, bakery lines, wine, raw and refined sugar, confectionary, vegetable oils, processed fruit and vegetables.

In the model, demand is represented by a whole economy constrained demand system. Household demand for each fresh agricultural product is represented as a function of prices, income and population. Demand for exports is represented as an export demand function and therefore a response to price.

\(^2\) For the 10 products on the left-hand side of table 2.
1 Aggregate value chain for Australian agriculture and food processing 2005–06

*Feed, energy, packaging and chemicals.
+ Exports valued at free-on-board (fob) basis and imports on a cost insurance freight (cif) basis.

Data source: TheCIE estimates based on Australian Bureau of Statistics.
2 Food products

<table>
<thead>
<tr>
<th>Agricultural</th>
<th>Processed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cattle</td>
<td>Beef</td>
</tr>
<tr>
<td>Sheep</td>
<td>Sheepmeat</td>
</tr>
<tr>
<td>Raw milk</td>
<td>Dairy products — milk</td>
</tr>
<tr>
<td>Wheat</td>
<td>Flour, confectionary, bakery</td>
</tr>
<tr>
<td>Oilseed</td>
<td>Oil and fat</td>
</tr>
<tr>
<td>Vegetables</td>
<td>Juice</td>
</tr>
<tr>
<td>Other crops</td>
<td>Other food manufacturing</td>
</tr>
<tr>
<td>Other grains</td>
<td>Beverage and tobacco</td>
</tr>
<tr>
<td>Other animals (pigs, poultry, etc)</td>
<td>Dairy products — other</td>
</tr>
<tr>
<td>Fruit and nuts</td>
<td>Fruit products</td>
</tr>
<tr>
<td></td>
<td>Vegetable products</td>
</tr>
</tbody>
</table>

*Data source: TheCIE Food Processing Model.*

Demand by the processing sector is a derived demand affected by the costs of processing and final demand for processed food products. Labour, capital, energy, packaging and chemicals, services such as advertising and marketing, and various other manufacturing inputs are added to the agricultural inputs used for processing to derive a factory gate value of production of $77.8 billion a year (‘processed production’ column). A production function explains the input output relationship in processing in a similar way to agricultural production. Other margin activities of transport, wholesaling, retailing and taxes are added to the $77.8 billion to provide a retail or wholesale value of processed products of $135.1 billion (‘processed consumption’ column). This is purchased by households and food service outlets and restaurants in Australia, some $19.9 billion is recycled within the food processing sector, such as meat going into meat pies and cheese into pre-packed pizzas and other non-food sectors, and the rest (about 12 per cent) is exported. The demand functions represent the use and consumption of processed products in a similar way as in the fresh products case.

It can be seen from chart 1 that:

- the total gross value of the Australian agricultural food chain is around $172 billion per year ($53.9 billion + $135.1 billion – $17.2 billion) with about 30 per cent of value originating from primary production and 70 per cent of value arising from the manufacturing and distribution processes;
- at factory gate the gross value of processed food is $77.8 billion about four and half times the total value of agricultural inputs ($17.2 billion) going into processing;
- the $135.1 billion in processed foods are produced from $17.2 (around 32 per cent of the value of agricultural output) and $10 billion food imports.
- processing uses many other inputs than agricultural ones;
- household and food services consumption of food is predominantly in processed form; and
- Australia exports more processed ($15.7 billion) than unprocessed agricultural products ($8.7 billion).

It should be noted that the data in this model has been drawn from the 2005–06 Input-Output tables compiled by the Australian Bureau of Statistics (2009). The data is broadly consistent with that published by the Commonwealth Department of Agriculture, Fisheries and Forestry (DAFF, 2008). For example, DAFF data shows total food and liquor retailing turnover of $106.6 billion in 2005–06 while the total food, beverage and tobacco consumption in the model is $114.4 billion in the same period. Similarly total food exports were $23.3 billion and $24.5 billion respectively in DAFF data and the model.

The minor differences arise from several factors. First, there may be difference in the coverage of food items in the datasets. Second, the model accounts for all the margins such as transportation, marketing and taxes, while the DAFF data may not. This is why the aggregate values in the model are usually higher. Third, the data has been adjusted in order to be consistent with the balanced requirement of an input-output table and a general equilibrium model.
3 Aggregate gains from R&D along the chain

In an economic sense, there are four main ways that R&D and technological progress generally may impact and change the value chain. These are:

- to expand demand by:
  - improving the quality, features or information about a product either domestically or internationally and either at the farm level or through processing and marketing;
  - reducing barriers to trade or other impediments such as the peril of distance that existed before the invention of refrigerated shipping or through using other preserving techniques such as canning, clever packaging, new ripening techniques or non-thermal processing (domestically or internationally);
  - finding a new use for an agricultural product or by-product of processing;
- to increase the productivity of resource use such as will happen if yields for crops and pastures are increased per hectare, or genetics improves output per animal, if inputs such as fertiliser or water are used less wastefully due to precision agriculture and if in processing, less energy, packaging or chemicals, or capital and labour can be used per unit of output through better, faster or bigger processing economies;
- to decrease waste of agricultural input use in processing;
- to reduce the cost of any input used at any stage in the production process such as might arise from the introduction of more efficient road or rail transport which reduces transport costs to farmers or processors and marketers.

Each of these changes can have different economic impacts along the value chain. Here we use the model to estimate the impacts of the following changes that might arise from R&D:

- Scenario 1: Export demand (price increase): a one percent increase in export prices to represent an increase in export demand for Australia’s exports;
- Scenario 2: Domestic demand (quantity increase): a one per cent increase in quantity demanded domestically to represent R&D activity aimed solely at increasing domestic demand;
- Scenario 3: Processing production productivity: a separate one per cent increase in processing productivity for all processing factors excluding agricultural inputs used in processing;
- Scenario 4: Transport and handling efficiency (margins on processed products): a separate one per cent increase in productivity for transport, wholesaling, marketing or retail for processed products.
Scenario 5: Waste reduction in processing: a separate one per cent increase in productivity of the use of agricultural inputs in processing;

Scenario 6: Farm production productivity: a separate one per cent on-farm productivity increase for all on-farm variable factors; and

Scenario 7: Transport and handling efficiency (margins on farm products): a separate one percent increase in productivity in transport, wholesaling, marketing and retailing of agricultural output.

In the model these changes are applied as uniform perturbations across the entire aggregated food value chain.

3.1 Application of the model

The results presented here are based on a time frame long enough to allow all adjustments to take place and assuming a situation of strong competition between farmers and processors. As such they measure the long-term gains to the nation from R&D and the distribution of benefits ultimately expected. Competition for agricultural supplies by processors is strong in the long-term. In the short-term some processors or farmers may gain individual advantage due to having an earlier mover advantage or have brands or patents in place to protect their intellectual property. If true, gains to individuals holding the intellectual property may be higher than indicated here, but gains to society are likely to be lower as the new technology is less freely dispersed through the economy. Through time however, retaining any short-term advantage may be more difficult. Others will copy and follow and the technology will be more fully taken up. If necessary, the model can be run to represent short-term outcomes.

Another important assumption relating to the one per cent change scenarios presented here is that they occur separately (ceteris paribus). In reality, successful productivity increases may simultaneously induce increased marketing effort to ensure export markets expand to absorb the increase. This has not been modelled in this example. Of course it could be that some R&D may lead to both productivity increases and simultaneous increases in demand. If so they need to be modelled this way for the specific case.

The one per cent change scenarios assume change is achieved costlessly. No consideration has been given to the cost of any particular R&D development. Here we simply assess the benefits for illustrative and comparative purposes. The results indicate nothing about the prospect of any particular area of R&D, that is, the possible magnitude of change. For a complete benefit-cost analysis, the magnitude of the full change and the costs would need to be quantified.

The purpose of this paper has been to demonstrate several general principles that need to be understood for policy making and strategic planning relating to allocating R&D. These principles are that the allocation of benefits from R&D is complex, sometimes counterintuitive in particular market situations and differs by commodity. The specific results presented here are illustrative only. They should not be used as a basis for specific
R&D allocation. To do this requires carefully running the model to assess the specific R&D under investigation.

### 3.2 Overall impacts

Chart 3 sets out the payoffs in terms of changes in value added (returns to primary factors such as land, labour and capital) from each of the simulated R&D perturbations or scenarios. The results show the magnitude and distribution of benefits of the perturbations between the farming sector and the processing sector.

#### 3 Aggregate food value chain: one per cent improvement: change in value-added

![Chart 3](chart3.png)

**Data source:** TheCIE Food Processing Model.

Table 4 shows the changes in the real value of production due to these perturbations as well as value added and a component of value added, return to land and capital.

The largest potential gains to the farming and processing/marketing sectors can be seen to come from increases in export demand. Gains from increases in productivity along the
chain are generally significant, but in many cases initial gains from productivity increases get passed to others along the value chain and to other sectors of the economy.

Gains to the rest of the economy come from increases in the incomes of others in the economy either due to increased wages paid, increased profits to suppliers, marketers and other industries and from decreased prices to consumers. The increased income and decreased price allow Australians to consume more products and services.

### 4 Aggregate food value chain, 1 per cent improvement changes in various measures of value

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Change in real production $ million</th>
<th>Change in value-added $ million</th>
<th>Change in returns to capital/land $ million</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Farming</td>
<td>Processing</td>
<td>Farming</td>
</tr>
<tr>
<td>Scenario 1</td>
<td>558</td>
<td>1276</td>
<td>246</td>
</tr>
<tr>
<td>Scenario 2</td>
<td>137</td>
<td>409</td>
<td>69</td>
</tr>
<tr>
<td>Scenario 3</td>
<td>121</td>
<td>1101</td>
<td>55</td>
</tr>
<tr>
<td>Scenario 4</td>
<td>21</td>
<td>135</td>
<td>10</td>
</tr>
<tr>
<td>Scenario 5</td>
<td>-91</td>
<td>263</td>
<td>-41</td>
</tr>
<tr>
<td>Scenario 6</td>
<td>210</td>
<td>107</td>
<td>81</td>
</tr>
<tr>
<td>Scenario 7</td>
<td>23</td>
<td>14</td>
<td>8</td>
</tr>
</tbody>
</table>

Data source: TheCIE Food Processing Model.

In chart 5, measures of the increased purchasing power of Australian consumers in aggregate from the simulated gains from R&D are given as increases in real household consumption. This is an aggregate measure of the increase in wealth of Australians from all sources. It can be seen that productivity improvements provide the largest potential benefits to the economy in contrast to the gains to the farming and processing/marketing sectors.

#### 3.3 Export and domestic demand increases: scenarios 1 and 2

By far the greatest value added gains to both the farming and processing sectors come from increasing export demand (scenario 1). Even though the value of exports is relatively low compared with the total value of agricultural and processed food production, expansion of export demand, if it can be achieved, has a far greater impact than increases in domestic demand. The reason being that, expansion in export demand causes domestic prices and export prices to rise. An increase in export demand causes product to be diverted from the domestic market to exports which raise prices domestically. By contrast, any success in raising domestic demand only (scenario 2),

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3 Increases in real household consumption includes increases in value added, something akin to consumer surplus in partial equilibrium studies and flow-on benefits to other sectors of the economy. It is the usual measure of the ultimate benefit to a society in the general equilibrium analysis. It is equal to the effective increase in household disposable income after allowing for saving, depreciation and income earned by foreigners in Australia. As a result, the increase in consumption will be less than the increase in gross national product (GNP).
causes exports to be diverted to the domestic market (and possibly attracts imports) moderating the initial price rises domestically. Because Australia’s market influence in international markets is less than on the domestic market, diverting product away from export markets has less influence in raising prices as it does in lowering them at home.

5 Change in household real consumption: one per improvement

The share of benefits is roughly in proportion to the gross value of production of each sector. That said, the farming sector receives around 40 per cent of the benefit with only a 30 per cent share of the total gross value of the whole food value chain. This reflects the fact that agricultural resources such as land and water (at least) are relatively scarcer than resources used in processing. Increased export demand and higher prices will signal a need for increased production but the response will be limited by the resources available. Given the large size of the food sector and high levels of employment in Australia, labour in agriculture and processing will also limit expansion to some extent. To some extent it
will induce a substitution of capital and other inputs for labour, but the extent to which this can occur is also ultimately limiting.

An increase in demand for the final product (scenario 1 and 2) will raise prices in all parts of the value chain. If R&D results in an increase in demand, say for cheese, this shifts the demand schedule for cheese outward to the right and causes the price of cheese to increase given no change in supply. To meet the increased demand causes the derived demand schedule for milk and processing to shift outward to the right as well. The higher prices induce movements outward along the milk and processing supply schedules which increase the supply of milk, processing services and cheese and a new market equilibrium will be established with higher prices and quantities. The increased returns to cheese are distributed to the farming and processing sectors. The less elastic the supply schedule is for milk (perhaps due to a land constraint), the greater will be the share of benefits captured by the farming sector.

While an expansion in demand is unambiguously beneficial for the food value chain, the gains to the nation are not as great (chart 5). Chart 6 provides a state breakdown of the national results set out in chart 5 for export and domestic demand.

6 National consumption with full employment: state breakdown

Data source: TheCIE Food Processing Model.

The success in R&D in the food industry that helps boost export demand tends to help NSW, Victoria, South Australia and Tasmania to become more competitive by helping these states to retain and grow labour and capital that might otherwise have gone to the mining industry in the boom states Western Australia and Queensland. It also causes a transfer of wealth from consumers to farmers and processors. As export prices rise, so too
do domestic prices. Although farmers and processors gain, consumers lose. When the mining boom wanes in Queensland and Western Australia these negative impacts on export demand growth are likely to become positive.

The state impacts of domestic market expansion are different again. NSW and the ACT as major domestic food importing states are negatively affected by higher prices and these effects are not offset adequately by increases in production.

### 3.4 Increased productivity

From chart 4 it can be seen that the increased value added from productivity gains in processing (scenario 3) provide considerable gains ($376 million) for processing but it also provides considerable benefits to the farm sector ($55 million).

A productivity increase in processing lowers the marginal cost of supplying both the processing services and the final product, say cheese, and so shifts both the supply schedules for processing services and cheese downward to the right. With more supplied at the same price, to induce consumers to absorb more product, the market price for cheese must decline, as it does for processing services and a new equilibrium is established with an increase in quantity. However, because more milk is now required to meet the new market opportunity the derived demand for milk shifts outward to the right. Without a productivity gain in milk production on farm, to induce more supply, the price of milk on farm must increase. This benefits the farming sector. The net gain to the processing sector is the reduction in costs minus the change in price multiplied by quantity produced.

Throughout the history of Australian agriculture, productivity gains in processing have been important to raise the derived demand for raw agricultural products and provide benefits to the farming sector. Refrigerated transport of meat opened up big opportunities to expand the beef and lamb industries for export for instance.

Although some benefits are captured by the processing sector from productivity gain on-farm (chart 3, scenario 6), they are relatively small ($23 million) because agricultural inputs overall are a small proportion of total inputs in processing, so the effect on the derived demand for processing is not as great as when processing achieves an increase in productivity, and affects derived demand from agricultural inputs.

Although the farming sector benefits from productivity gains in terms of reduced costs, if processing capacity is at its limits and productivity gains are not achieved in processing, farmers must lower their farm gate prices to induce processors and consumers to absorb more product produced after the productivity gain. This can mean they pass some of the benefits of on-farm productivity up the value chain. This is particularly true when agricultural inputs are a small percentage of total processing costs, such as the case of dairy. It means that for the processors that are at maximum capacity (which they are likely to be in the long run situation) in order to expand to absorb the increased farm output, they would need to expand their factories and employ more people and find more markets. This is costly and they will need to be induced to do it. For these reasons,
productivity gains in processing are very important to farmers to ensure increasing
derived demand for their products.

An exception to productivity gains in processing being of benefit to the farming sector
occurs if processor efficiency includes using agricultural inputs more efficiently, such as
might occur if they can reduce waste or use less of the same input to achieve the same
output (scenario 5). Then, the derived demand for agricultural inputs decreases and
returns to the farming sector fall. As shown in chart 3, this can cause declines in value
added to the farming sector. That said, where a reduction in wastage occurs through the
development of a new by-product which simultaneously creates a new market demand
building opportunity, the outcome may be different. However, if there is no simultaneous
increase in demand for the final product, the farming sector is likely to experience lower
prices, while consumers will receive significant benefit.

As shown in chart 3, decreases in various marketing margins (scenarios 4 and 7) can also
be of some benefit to the farming sector, but overall, because margins are smaller than
processing costs, the benefits of productivity gains here are commensurately smaller.

Table 7 shows the total and state impacts of productivity increases on the increased
purchasing power of the nation along with changes from other scenarios. Benefits from
increases in productivity (for example scenarios 3, 5 and 6) tend to provide considerably
greater overall gains to the nation than increases in export demand. The reason for this is
that the productivity gains let the nation produce more with the same amount of inputs.
The overall benefits exceed those captured by the food industry. This reflects the fact that
to induce consumers to buy the extra production, food prices must fall ensuring benefits
of R&D are passed to consumers. Ultimately, consumers are the largest beneficiaries of
successful R&D that increase availability of food and lowers prices.

7 National consumption with full employment (real household consumption)

<table>
<thead>
<tr>
<th>State</th>
<th>Export price</th>
<th>Domestic household consumption</th>
<th>All but ag Inputs in processing</th>
<th>Margin for processing</th>
<th>Ag Inputs in processing</th>
<th>Variable inputs in farming</th>
<th>Margin for farming</th>
</tr>
</thead>
<tbody>
<tr>
<td>State</td>
<td>$m</td>
<td>$m</td>
<td>$m</td>
<td>$m</td>
<td>$m</td>
<td>$m</td>
<td>$m</td>
</tr>
<tr>
<td>NSW</td>
<td>40.7</td>
<td>-4.5</td>
<td>176.8</td>
<td>24.1</td>
<td>55.9</td>
<td>47.7</td>
<td>5.7</td>
</tr>
<tr>
<td>VIC</td>
<td>23.1</td>
<td>8.5</td>
<td>154.4</td>
<td>21.3</td>
<td>47.3</td>
<td>36.8</td>
<td>4.1</td>
</tr>
<tr>
<td>QLD</td>
<td>-12.2</td>
<td>12.2</td>
<td>80.9</td>
<td>10.9</td>
<td>26.2</td>
<td>18.4</td>
<td>2.5</td>
</tr>
<tr>
<td>SA</td>
<td>7.9</td>
<td>4.4</td>
<td>43.1</td>
<td>5.1</td>
<td>9.3</td>
<td>10.2</td>
<td>1.2</td>
</tr>
<tr>
<td>WA</td>
<td>-26.7</td>
<td>8.9</td>
<td>28.9</td>
<td>4.0</td>
<td>10.6</td>
<td>9.6</td>
<td>1.2</td>
</tr>
<tr>
<td>TAS</td>
<td>2.1</td>
<td>2.6</td>
<td>14.7</td>
<td>2.0</td>
<td>3.3</td>
<td>3.3</td>
<td>0.4</td>
</tr>
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<td>NT</td>
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<td>0.8</td>
<td>3.2</td>
<td>0.6</td>
<td>1.3</td>
<td>0.1</td>
<td>0.0</td>
</tr>
<tr>
<td>ACT</td>
<td>-4.6</td>
<td>-2.5</td>
<td>26.7</td>
<td>3.7</td>
<td>6.8</td>
<td>6.5</td>
<td>0.8</td>
</tr>
<tr>
<td>Total</td>
<td>23.1</td>
<td>30.4</td>
<td>526.8</td>
<td>71.6</td>
<td>160.7</td>
<td>132.6</td>
<td>16.1</td>
</tr>
</tbody>
</table>

Data source: TheCIE Food Processing Model.
4 Difference between agricultural products

4.1 Export demand by commodity

Table 8 shows the effects on farming and processing sector value added from increases in export demand by commodity. Partly these results reflect the differences in size and opportunities of each industry, but they also show considerable difference in the importance of processing to each industry. The main differences in the value chains for four of Australia’s main agricultural industries are set out in chart 9. In the case of wheat, there are virtually no processed exports, so an increase in export demand transmits quite directly to farmers rather than processors. In the case of dairying, the gross value of processed production is nearly three times higher than for the farm gate value and no farm product is marketed without being processed.

8 Impact of higher export demand (scenario 1)

<table>
<thead>
<tr>
<th>Commodity</th>
<th>Change in real production ($million)</th>
<th>Change in value added ($million)</th>
<th>Change in returns to capital/land ($million)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Farming</td>
<td>Processing</td>
<td>Farming</td>
</tr>
<tr>
<td>Beef</td>
<td>65.1</td>
<td>64.9</td>
<td>33.2</td>
</tr>
<tr>
<td>Sheepmeat</td>
<td>19.0</td>
<td>10.9</td>
<td>10.1</td>
</tr>
<tr>
<td>Dairy</td>
<td>51.5</td>
<td>175.7</td>
<td>25.1</td>
</tr>
<tr>
<td>Wheat</td>
<td>199.5</td>
<td>53.6</td>
<td>85.4</td>
</tr>
<tr>
<td>Oilseed</td>
<td>25.6</td>
<td>16.1</td>
<td>11.0</td>
</tr>
<tr>
<td>Horticulture</td>
<td>44.0</td>
<td>55.7</td>
<td>24.7</td>
</tr>
<tr>
<td>Other</td>
<td>153.6</td>
<td>898.8</td>
<td>56.4</td>
</tr>
</tbody>
</table>

Data source: TheCIE Food Processing Model.

4.2 Domestic demand by commodity

The pattern of payoffs from a successful increase in domestic demand is very different from that for export demand (table 10). The domestic market is relatively less important for wheat than the export market, whereas the domestic market is fairly important for horticulture. That said, the prospects for expanding the export market for horticulture (from its current low base) may greatly exceed that of the domestic market. Perhaps increases of one per cent a year may be possible on the domestic market, but anything more may be nearly impossible. On the other hand, the world market for horticultural products expands each year by the total size of the Australian industry. New Zealand has been able to achieve 10 per cent growth a year in horticultural exports for over a decade.
9 Schematic differences in value chains between agricultural products

![Chart showing schematic differences in value chains between agricultural products.](chart.png)

Data source: TheCIE. Colours and categories correspond to those in chart 3. The magnitudes are scaled such that final uses and consumption of processed products total 100 per cent.

10 Impact of higher domestic demand (scenario 2)

<table>
<thead>
<tr>
<th></th>
<th>Change in real production ($million)</th>
<th>Change in value added ($million)</th>
<th>Change in returns to capital/land ($million)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Farming</td>
<td>Processing</td>
<td>Farming</td>
</tr>
<tr>
<td>Beef</td>
<td>27.6</td>
<td>33.8</td>
<td>14.0</td>
</tr>
<tr>
<td>Sheepmeat</td>
<td>5.2</td>
<td>6.4</td>
<td>2.5</td>
</tr>
<tr>
<td>Dairy</td>
<td>15.9</td>
<td>53.9</td>
<td>7.6</td>
</tr>
<tr>
<td>Wheat</td>
<td>7.7</td>
<td>44.7</td>
<td>2.8</td>
</tr>
<tr>
<td>Oilseed</td>
<td>1.2</td>
<td>7.7</td>
<td>0.5</td>
</tr>
<tr>
<td>Horticulture</td>
<td>53.2</td>
<td>18.2</td>
<td>31.3</td>
</tr>
<tr>
<td>Other</td>
<td>26.5</td>
<td>244.5</td>
<td>10.1</td>
</tr>
</tbody>
</table>

Data source: TheCIE Food Processing Model.
4.3 Productivity changes by commodity

Tables 11 and 12 show the range of outcomes from productivity improvements for commodities for two scenarios, 3 and 6.

Table 11 shows:

- processing productivity improvements (scenario 3) which essentially make beef meat processing capacity more abundant than now, creates increased competition for cattle driving up the price which benefits the farming sector but causes the meat processing sector to give away its initial gains to the farming sector, consumers and other sectors:
  - increased productivity in processing means 1 per cent less capital and labour is needed in the sector than before to produce the same output and although output expands, it expands by only 0.2 per cent due to land and other constraints on farm and difficulties in inducing domestic and international markets to absorb more output — to induce domestic and international consumers to consume more product, consumer prices must also be lowered;
  - because there is a 0.8 per cent reduction in capital needed to process beef than before (1 per cent minus 0.2 per cent) the reduction in capital means that the returns to capital (profit) decline marginally; and
  - the lesser amount of capital, labour and other inputs required is made available to the rest of the economy where it is employed productively and profitably adding to the overall gains of the rest of the economy;

- sheepmeat is similarly affected to beef but to a lesser degree;

- dairy processing also gives a large share of the benefit back to farmers as its more efficient processing capacity encourages it to compete to secure larger volumes of scarce raw milk supplies, but it manages to retain some of the benefit, unlike meat processing, as milk has a lower overall share of the value of inputs used in processing than cattle and sheep do in meat processing and, export markets for milk powders tend to be more absorptive than beef, meaning there are fewer overall constraints to expansion;

- domestic wheat processor profits decline as less capital overall is required and the domestic market cannot be easily expanded and the export market for processed wheat products is virtually non-existent;

- the horticultural processing sector is less constrained in its supply of agricultural input because its increased demand can be met by diverting product from the fresh market, which is not an option in the case of meat;

- the ‘other’ processing sector is very large in value terms but uses proportionally few agricultural inputs by value and so is relatively unconstrained to expand, it produces highly processed products such as frozen meals, ready to eat soups and beverages and its products are fairly highly substitutable with imports, so productivity improvements and expansion can help it displace imports.
11 Impact of higher productivity of non-farm inputs in processing (scenario 3)

<table>
<thead>
<tr>
<th></th>
<th>Change in real production ($million)</th>
<th>Change in value added ($million)</th>
<th>Change in returns to capital/land ($million)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Farming</td>
<td>Processing</td>
<td>Farming</td>
</tr>
<tr>
<td>Beef</td>
<td>16.2</td>
<td>18.6</td>
<td>8.3</td>
</tr>
<tr>
<td>Sheepmeat</td>
<td>1.7</td>
<td>3.3</td>
<td>0.9</td>
</tr>
<tr>
<td>Dairy</td>
<td>33.4</td>
<td>116.5</td>
<td>16.1</td>
</tr>
<tr>
<td>Wheat</td>
<td>5.8</td>
<td>59.8</td>
<td>1.6</td>
</tr>
<tr>
<td>Oilseed</td>
<td>1.5</td>
<td>16.1</td>
<td>0.6</td>
</tr>
<tr>
<td>Horticulture</td>
<td>25.0</td>
<td>52.6</td>
<td>14.4</td>
</tr>
<tr>
<td>Other</td>
<td>37.6</td>
<td>834.3</td>
<td>13.1</td>
</tr>
</tbody>
</table>

Data source: TheCIE Food Processing Model.

Table 12 shows that on-farm productivity improvements (scenario 6) can be good for processing, and benefit farming particularly where there are good export opportunities and they are generally better the lesser the need to process the product before exporting (for example, in the case of wheat), so that increases in processing capability are not a constraint to expansion and do not hold back benefits of productivity in farming. This also points out that for the farming sector to benefit from productivity gains on-farm, productivity gains are needed in processing to ensure there is increased capacity to handle increased agricultural output. Where processing capacity is not needed (such as wheat) gains are greatest.
5 Conclusions and implications

The results of the model used here plus earlier theoretical work indicate that the benefits and distribution of benefits from R&D are likely to be highly indirect and sometimes counterintuitive in particular market situations. Successful R&D has the capacity to greatly change supply and demand in complex ways. Market responses to these changes will ultimately determine who captures the benefits. The markets for Australia’s agricultural products vary greatly in nature and character and the results here show that this can have a large bearing on the payoffs.

The following general conclusions emerge.

- R&D that can successfully expand export demand is invariably and unambiguously adding economic value and is likely to provide the greatest benefits to the farming and processing sectors if it can be achieved. However, benefits to the whole economy are not as great as benefits to farmers and processors.

- Almost invariably, expansion of the export market due to its significantly greater size will provide larger benefits for farmers and processors than for the same percentage expansion of the domestic market. Moreover, considering that expanding the domestic market is likely to be more limited unless large amounts of imports can be displaced, the export market and world demand opportunities are likely to be more open ended if R&D provides a competitive advantage simply because the world market dwarfs the size of the domestic market.

- Productivity gains anywhere along the value chain are invariably good for the whole economy. It means fewer resources are needed to produce the same amount of food. This either means more food can be produced or additional labour, capital and other inputs can be made available to other sectors where they can be productively and profitably employed. It typically also means consumers will enjoy lower prices as downward pressure on prices is required to induce consumers to consume more.

- The farming sectors almost invariably are likely to benefit from successful R&D that either expands demand or increases the productivity of processing and marketing as this will increase the derived demand for their products, and, for processors to profit from their successful R&D they will need to pay farmers more to induce increased levels of supply. This confirms the theoretical finding of Freebairn et al (1982). The only area where farmers are likely to be disadvantaged by successful R&D in the processing sector is if the R&D leads to more efficient use of the agricultural product as an input to processing, as may occur if wastage is reduced. This is likely to reduce the derived demand for the product at the farm gate and lead to lower prices and production. On the other hand consumers receive substantial benefits from waste reduction.
The processing sector can benefit from successful R&D on-farm, as this will increase the availability of agricultural inputs and probably at lower cost. However, the ability of processors to benefit from the farming sector is less than the reverse. This is largely due to the fact that the gross value of agricultural inputs is only a small proportion of the value of all inputs used in processing, whereas the scope for productivity improvements in a higher value processing chain could be considerable as a share of farm value.

The farming sector is likely to give away some gains from successful R&D if the productivity gains lead to increased supplies that exceed the existing capacity of processors to process farmers’ additional output. To be induced to build new capacity and develop new markets, processors will require discounts on buying the input which will transfer benefits to processors and probably consumers.

For farmers to profit from successful on-farm oriented R&D it seems imperative that if they depend heavily on a processing chain to reach the final market, as do dairy and meat at least, they need to ensure that productivity gains are being achieved in processing at the same rate as they are occurring on-farm so that capacity in processing increases in line with their needs.

In making decisions about where to allocate R&D funds requires having a close knowledge of the economic features of each market and the interactions that take place in them. It also requires knowing how successful R&D at any point in the chain will affect relative payoffs. All players in the value chain are likely to benefit from successful R&D conducted at other points in the chain. Allocation of R&D funds needs to consider opportunities along the entire length of the chain, not just those in the sector where the R&D funds are raised.
6 References


Department of Agriculture, Fisheries and Forestry 2008, Australian Food Statistics 2007, Food and Agriculture Division, Department of Agriculture, Fisheries and Forestry, Canberra.


