The impact of innovation on the dairy industry over the last 30 years

Evaluating the contribution of industry and government investment in pre farm gate RD&E

Prepared for

Dairy Australia and the Victorian Department of Primary Industries

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Canberra & Sydney

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## Glossary

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Description</th>
</tr>
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<tbody>
<tr>
<td>ABARES</td>
<td>Australian Bureau of Agricultural and Resource Economics and Sciences</td>
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<td>ABV</td>
<td>Australian Breeding Values</td>
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<tr>
<td>ADC</td>
<td>Australia Dairy Corporation</td>
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<tr>
<td>ADHIS</td>
<td>Australian Dairy Herd Improvement Scheme</td>
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<tr>
<td>ADRC</td>
<td>Australian Dairy Research Council</td>
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<tr>
<td>AI</td>
<td>Artificial insemination</td>
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<tr>
<td>DA</td>
<td>Dairy Australia</td>
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<tr>
<td>DfT</td>
<td>Dairying for Tomorrow</td>
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<tr>
<td>DM</td>
<td>Dry matter</td>
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<tr>
<td>DMF</td>
<td>Dairy Moving Forward</td>
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<tr>
<td>DNA</td>
<td>Deoxyribonucleic acid</td>
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<tr>
<td>DNRE</td>
<td>Victorian Department of Natural Resources and Environment</td>
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<tr>
<td>DPI</td>
<td>Department of Primary Industries</td>
</tr>
<tr>
<td>DPIV</td>
<td>Victorian Department of Primary Industries</td>
</tr>
<tr>
<td>DRDC</td>
<td>Dairy Research and Development Corporation</td>
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<tr>
<td>FPFP</td>
<td>Feed Pastures for Profit</td>
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<tr>
<td>GGDF</td>
<td>Geoffrey Gardiner Dairy Foundation</td>
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<tr>
<td>GL</td>
<td>Gigalitres</td>
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<tr>
<td>GVP</td>
<td>Gross value of production</td>
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<tr>
<td>ha</td>
<td>hectare</td>
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<tr>
<td>kg</td>
<td>Kilogram</td>
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<tr>
<td>ME</td>
<td>Metabolisable energy</td>
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<tr>
<td>mL</td>
<td>millilitres</td>
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<tr>
<td>ML</td>
<td>Megalitres</td>
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<tr>
<td>N</td>
<td>Nitrogen</td>
</tr>
<tr>
<td>Acronym</td>
<td>Description</td>
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<tr>
<td>---------</td>
<td>------------------------------</td>
</tr>
<tr>
<td>NRM</td>
<td>Natural Resource Management</td>
</tr>
<tr>
<td>NZ</td>
<td>New Zealand</td>
</tr>
<tr>
<td>OH&amp;S</td>
<td>Occupational health and safety</td>
</tr>
<tr>
<td>OML</td>
<td>Operation Mid Lactation</td>
</tr>
<tr>
<td>OMY</td>
<td>Operation Milk Yield</td>
</tr>
<tr>
<td>ORL</td>
<td>Our Rural Landscape</td>
</tr>
<tr>
<td>QA</td>
<td>Quality Assurance</td>
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<tr>
<td>R&amp;D</td>
<td>Research and development</td>
</tr>
<tr>
<td>RD&amp;E</td>
<td>Research Development and Extension</td>
</tr>
<tr>
<td>RDC</td>
<td>Rural Development Corporation</td>
</tr>
<tr>
<td>TheCIE</td>
<td>The Centre of International Economics</td>
</tr>
<tr>
<td>TMR</td>
<td>Total Mixed Ration</td>
</tr>
<tr>
<td>US</td>
<td>United States</td>
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Summary

This evaluation

Dairy Australia (DA) and the Victorian Department of Primary Industries (DPIV) with in-kind support from the Geoffrey Gardiner Dairy Foundations (GGDF) commissioned this evaluation to determine the impact that their investments in (pre-farm gate) RD&E have had on changes in industry performance from 1980 to 2010.

This high level evaluation is intended to inform future investment including the implementation of the Dairy Moving Forward National Strategy to create a more coordinated approach to addressing national RD&E priorities.

Key findings

- Major increases in on-farm production are estimated to have increased Victorian dairy farm profitability by around $10 billion over the three decades from 1980 to 2010.
- Nearly half of this appears to be attributable to farmers’ and industry’s own initiatives. The other half may be attributable to on-farm RD&E which is estimated to have increased farmers’ profitability by around $7.7 billion in net present value terms over the past 30 years.
- This same RD&E is estimated to have cost an estimated $2.3 billion in net present value terms over the same 30 years.
- This suggests an estimated $3.30 economic benefit for each dollar invested in R&D. However, for every dollar dairy farmers have invested, their return may be well over (at least double) $3.30 because more than half of the investment has been paid by external sources. Moreover, many of the benefits from RD&E will continue to flow for some time into the future, representing further returns to investment in RD&E.
- Processors are likely to have also gained from the considerable increase in production RD&E has delivered.
- The major changes driving the increased profitability have been increased pasture production and utilisation, increased supplementary feeding and more efficient cows. Increased farm scale, improved animal health and natural resource management have also been important contributors.
Production has increased strongly despite adverse factors

Without major internal production improvements over the past 30 years, output of the Victoria’s Dairy Industry would have declined by an estimated 23 per cent due to a cost price squeeze and depreciation and obsolescence of technology (chart 1).

- Instead, industry output expanded by around 90 per cent relative to 1980 output.
- But relative to an estimated decrease in output of 23 per cent (in the counterfactual scenario of chart 1), the 90 per cent expansion plus the prevention of a 23 per cent loss, represents an estimated 146 per cent expansion of output due to major internal improvements compared with what could have been. The improvements due to major production improvements appear to be considerably greater than the 90 per cent observed increase in output.

1 Internal improvements in the industry may account for more than a doubling of production over 30 years

Factors contributing to growth

Major factors contributing to the growth in output were identified at a workshop of industry experts as being those outlined in chart 2. The chart also indicates considerable interdependency between these factors.

- Increased pasture production and utilisation was a major impetus to industry growth as this is a low cost feed. More intensive feeding systems were required to improve pasture utilisation through rotational grazing. But to do so required higher stocking rates. Even with increased pasture production through better use of fertilisers and improved species, given the seasonal variability in pasture growth as well as unpredictable rainfall in Australia, feed gaps occurred and
became a greater risk in a more intensive system. This placed emphasis on a need for feed supplements.

- Feed supplements helped fill such feed gaps and helped maintain high stocking rates when pasture growth slowed. Supplements were nominated by the workshop participants as a key ‘success’ in pasture management and utilisation. At the same time, effective grazing management and utilisation were critical to maintaining the economic viability of intensive farms. That said, some experts identified excess reliance on supplementary feeding as a potential negative consequence of the shift towards intensive feeding systems.

- Genetic improvement increased the capacity of animals to use high volumes of feed and to convert feed more efficiently into milk. There was also a structural change in the national herd toward larger Holstein cows from smaller Jersey cows.

- Cow genetics and breeding and more intensive feeding/production systems resulted in unintended adverse impacts in animal fertility. As a result, increased emphasis has had to be placed on fertility in breeding in recent years.

- Milk quality (through controlling mastitis) and more effective management of cow welfare were also essential to maintaining gains in feed intake, cow condition, conversion of feed to milk and fertility and enabling processors to produce high value products.

- The increased production of pastures, the increased use of supplements, higher stocking rates and larger cows all contributed to increased milk output per hectare, per head and per farm. This underpinned the achievement of economies of scale on farm allowing better use of farm labour, sheds and other fixed factors. It also facilitated farm amalgamation and rationalisation resulting in fewer but larger farms. The economies of scales help justify investment in new and better sheds and other farm infrastructure.

- But a consequence of the intensification of dairy farming and increasing political concern about environmental matters has been natural resource management issues. Attention to these has been necessary to underpin and improve the dairy farming system, especially in dairy shed effluent and pasture nutrient management.

- Another consequence of running a more intensive and sophisticated farming system has been the need for better and more commercially oriented management systems.

Technology was imported by the industry from the United States, New Zealand and Europe but often required adaptation and demonstration to achieve high rates of uptake and refine application in the Australian context.
2 Big on-farm changes in dairy and RD&E contributions

- Discussion groups small RD&E
- Apprenticeships small RD&E
- Adoption of business practice small E
- Overall farm business management capability
  (Better business management)
- Pasture management and utilisation: (More pasture)
  - Rotations
  - Fertiliser
  - Ryegrass
  - Mgt
- Supplementary feeding and cow nutrition:
  (Milk yield increased)
  - Feeding
  - Mgt
  - Survival
- Animal genetics and Breeding:
  (Milk yield increased)
  - ABVs
  - Herd record
  - Imported genetics
- Animal health and welfare: (Avoided negative productivity)
  - Infertility
  - Milk quality
  - Collective
- Bigger farms and infrastructure:
  (Cost decreased)
  - Sheds
  - Fodder
- Milk harvesting (Labour saving)
  - Semi auto
  - Workflow
- Natural resource management (Avoided negatives)
  - Effluent
  - Nitrogen
  - Phosphorous
  - DairySAT
- Pasture management and utilisation: (More pasture)
  - Rotations
  - Fertiliser
  - Ryegrass
  - Mgt

Data source: CIE.

Quantitative evidence on factors contributing to growth

Quantitative evidence points to a very strong intensification of the industry over the past 30 years. The effective hectares used for dairy has declined but output per cow has nearly doubled, cow numbers have declined, but stocking rates per hectare and output per cow as well as output per hectare have increased dramatically (table 3).

3 Summary of statewide performance indicators for Victorian dairying

<table>
<thead>
<tr>
<th>Year Range</th>
<th>Effective grazing land</th>
<th>Cow numbers</th>
<th>Stocking rate</th>
<th>Milk yield per cow</th>
<th>Milk yield per hectare</th>
</tr>
</thead>
<tbody>
<tr>
<td>1980-81 to 1989-90</td>
<td>-3.7</td>
<td>-0.4</td>
<td>3.4</td>
<td>3.2</td>
<td>6.7</td>
</tr>
<tr>
<td>1990-1 to 1998-99</td>
<td>1.7</td>
<td>3.8</td>
<td>2.0</td>
<td>2.3</td>
<td>4.4</td>
</tr>
<tr>
<td>2000-01 to 2008-09</td>
<td>-6.0</td>
<td>-3.7</td>
<td>2.8</td>
<td>1.9</td>
<td>4.7</td>
</tr>
<tr>
<td>Trend(^a) 1980-81 to 2009-10</td>
<td>-0.2</td>
<td>0.8</td>
<td>1.0</td>
<td>2.3</td>
<td>3.4</td>
</tr>
<tr>
<td>Cumulative over 30 years</td>
<td>-35.2</td>
<td>-2.6</td>
<td>50.8</td>
<td>94.0</td>
<td>192.5</td>
</tr>
</tbody>
</table>

\(^a\) For the period 1980-81 to 2009-10. \(^b\) This is a statistically fitted trend, so estimates maybe influenced by variability over the years.

Data source: ABARES, ABS and CIE estimates.
Using an energy accounting framework it is possible to calculate the probable contribution of various factors to the increase in production that has occurred. The results of this are presented in chart 4. The chart sets out the increase in litres per hectare achieved over the past 30 years. Production has increased from an estimated 2878 litres per hectare in 1980 to an estimated 8419 litres per hectare in 2010, or by 5601 litres per hectare.

- In 1980, the 2878 litres per hectare was produced almost entirely from pasture based feed.
- There was an estimated 47 per cent accumulated increase in pasture production and utilisation which helped underpin a 50 per cent increase in stocking rate, suggesting pasture improvements might account directly for a 1341 litre increase in milk production per hectare (chart 4).
- The increased use of supplements per hectare to 1.5 tonnes of dry matter per cow means that the 2010 cow now consume 33 per cent more non-pasture dry matter per year than the 1980 cow which translates into a 950 litre increase in milk per hectare relative to the 1980 situation. However, combined with a 50 per cent increase in stocking rate, on a per hectare basis the increase translates into a total increase of 1425 litres of milk per hectare from supplements (950 + 475, chart 4).
- Cows are an estimated 34 per cent more efficient than 1980 cows at converting feed to milk due to genetic selection and improvement allowing for a further 1919 litre per hectare of milk increase (chart 4) from an enlarged feed base resulting from increases in pastures and supplements.
- This leaves 856 litre of milk per hectare as a residual (chart 4), but there is also the 23 per cent reduction in production that might have occurred due to negative terms of trade and technological obsolescence to consider. This translates into 661 litres per hectare of lost production that has been prevented over the period. Together with the residual, this suggests 1517 litres of milk per hectare that is unaccounted for. There is no data to guide us on which factors have underpinned this, but qualitative evidence might suggest it is due to NRM, animal health and other issues such as investment in other factors such as better sheds (chart 4).

**Revenue profit and costs**

Chart 5 (LHS) reports the cumulative increase in the value of output per hectare relative to the counterfactual over the 30 year period reported in real 2010 dollar terms. It shows that gross revenue per hectare earned over the full 30 year period has been an estimated $27,944 higher than it would have been without internal changes over the full 30 year period.\(^1\)

\(^1\) Estimates are made using TheCIE Dairy Industry model.
Factors driving 192.5 per cent increase in milk production per hectare

Chart 5 (RHS) shows the cumulative increase in costs per hectare over the entire 30 year period required to achieve the increase in revenue. It is shown as an estimated $15 426 per hectare. It also shows that $7566 per hectare was the estimated increased costs of supplements feed and $3268 was the increased cost of pasture production. Comparing cumulative revenue with costs indicates an estimated profit before interest and tax of $12 518 per hectare in total from 1980 to 2010.

For the whole state, the increase in profit amounts to around $10 billion over the period in 2010 dollar terms and this compares with a cumulative gross value of production over the entire period of around $63 billion in 2010 dollar terms.
The impact of innovation on the dairy industry over the last 30 years

5 Revenue, cost and profit per hectare: internal changes

![Chart showing revenue, cost, and profit per hectare over time]

Data source: TheCIE.

The estimates presented in chart 5 suggest that for farms remaining in the industry over the 30 year period, internal changes were reasonably profitable.

Contribution of RD&E to change

RD&E is one of the sources of innovation on farm in addition to farmers own innovation and other players across the whole supply chain in the industry. The contribution of RD&D towards driving change is not easily determined or quantified. Nonetheless various indicators point toward a sizeable contribution.

- The first is based on RD&E’s share of total on-farm investment over the period. This is estimated at 35 per cent. Essentially, this assumes that the rate of return from each dollar invested, whether RD&E or other, is the same for each dollar invested on-farm in Victoria.
- The second, 46 per cent, comes from a quantification of the collective opinion from the industry workshop. Industry participants offered a breakdown of how much they thought RD&E contributed to each major area of change relative to the contribution from other factors such as farmers own investments and initiatives.
- The third, at 56 per cent, takes the contributions suggested during the workshop and weights them according to the quantitatively determined importance of each major area of change.

A simple average of these estimates is the mid-point estimate of 46 per cent.

Based on the estimates of increased profit reported in chapter 4 of $10 billion, 46 per cent would suggest benefits to farmers of around $4.6 billion. This compares with an estimated total investment by Victoria in RD&E in 2010 dollar terms of $1.24 billion.
over the period. In present value terms (using a discount rate of 5 per cent) these figures convert to $7.7 billion for benefits and $2.3 billion for costs, giving a benefit to cost ratio of 3.3:1. For farmers, the benefit to cost ratio maybe more than double this based on investment dollars they contributed through research levies. Matching funding from other sources has allowed farmers to leverage up their returns. Moreover, many of these benefits will be ongoing into the future potentially raising the benefit cost ratio further and the benefits to processors from the greatly increased volume are not included.

- At a 7 per cent discount rate, the headline analysis changes to $6.2 billion for benefits and $2.98 billion for costs, giving a benefit to cost ratio of 2.0:1.

In addition to these benefits there, have also been spillover and other benefits to the state and the wider community from the RD&E investments made.

- This has included benefits arising from investments made to address NRM issues that maintain the social license to operate for the industry and secure improved environmental outcomes. Other flow-on economic benefits include the contribution to the maintenance of regional communities in Victoria and benefits to consumers of having access to cost-effective and high quality product.

**Lessons learned**

A number of lessons have emerged from this mega evaluation.

- Improvements are greater than they may at first appear. Major production improvements appear to be considerably greater than the 90 per cent indicated by the increase in output, because without them production would have declined by an estimated 23 per cent over the past three decades due to a cost price squeeze and depreciation and obsolescence of technology.

- Capacity to adapt foreign technology and practices is vital. Much of the improvement achieved has been based on imported technology and practices, but its successful uptake has been due to having the scientific and extension capacity to understand, adapt and demonstrate the viability of the technology to Australian, Victorian and regional conditions. Australia is part of a huge global dairy industry and most broad technological changes will arise elsewhere. Australian and Victorian industries will require continued strong capacity to take up the technology. World leadership in some areas of RD&E is likely to continue to be required to ensure Australia keeps a seat at the international table for dairy RD&E, to ensure it can keep up with cutting edge developments.

- Autonomous farmer/industry improvement is probably as important as RD&E. All indicators point to RD&E being likely to have contributed between a third and a half of the gain. It is difficult to see that RD&E’s contribution would have been

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2 Readers should use these figures with care as they are based on some subjective estimates.
less than a third, but it is also difficult to argue that industry’s own contributions would have been much less than half. Support from others in the supply chain (input suppliers and processors) is also likely to have played an important role in autonomous improvement. Moreover, without industry cooperation high rates of improvement and change are unlikely to have been achieved.

- **Extension is at least as important as R&D.** Extension appears to be as important as research and development. Extension is required to support farmers to manage the system as a whole, particularly where concepts are not easily applied. For example, shorter milking times required more time and resources to get the research findings out.

- **Understanding interdependencies of farming and biological systems is important.** It is difficult to clearly distinguish the role of genetics, feeding systems and pasture improvements, but there does appear to be an important causality of improvement running from pastures to supplements to genetics. Understanding the complex scientific and economic interdependencies and causalities between drivers is important to devise optimal management systems.

- **Spinoff benefits may have been overlooked.** Many benefits of production improvements are indirect and oftentimes not visible. The large increase in production achieved has underpinned the achievement of substantial economies of scale, but these gains are commonly attributed to the scaling up of infrastructure by farmers themselves. Whilst this is true to a large extent, it is also true that it would not have occurred to the extent it did without the major financial gain. Economies of scale and the use of supplements may have provided farmers with more options and flexibility to reduce risk and make better lifestyle choices especially as they relate to milking, labour requirements and use and climatic variability. These need to be accounted for.

- **Natural resource management focus may help counter technological obsolescence.** Quantifying the benefits from natural resource management RD&E is not easy, but the rationale for investing in this area is strong. It helps to prevent technological depreciation and obsolescence brought about by changing (adverse) community and political opinion and tightening regulatory constraints. It may be important insurance to maintain the right to farm.

- **Significant benefits from RD&E still to be derived in future years.** Significant capacity has been built to understand the farm as a whole-of-system: the interactions between pastures, supplements, genetics and animal health and welfare over the past 10 years. This knowledge base is likely to deliver future gains in production and profitability resulting from follow-up research.
1 Introduction and objective

The objective of the Dairy Mega Evaluation project is to evaluate the contribution of pre farm gate RD&E to the dairy industry over the last 30 years. To do this we first need to understand the contribution of various economic drivers to bring about change in the industry.

The economic drivers that have shaped change over the past 30 years are a diverse range of influences. These include Closer Economic Relations with New Zealand, the Uruguay Round of trade negotiations, deregulation and rationalisation of the market milk arrangements, consolidation in processing and marketing, RD&E, autonomous technological transfer, increasing labour costs, declining grain prices, increasing environmental awareness, changing social attitudes toward agriculture and animal welfare, food safety issues, fluctuating fuel, interest rate and exchange rate changes, drought and increasing water prices.

Harris (2011) identifies those drivers, but to better understand their importance we need to understand their relative and absolute contributions in a quantitative sense. Here we use our economic model of the dairy industry to help do that.

- A detailed description of the economic model is contained in appendix A along with a brief assessment of critical relationships and parameters used in the framework.

To understand the contribution and influence of RD&E to these changes we need to separate the main drivers into:

- those occurring outside the industry (external drivers) such as rises in wage rates, changes in fertiliser prices, exchange rates and transport cost; and
- those occurring inside the industry and under the influence of the industry such as on farm investment, increases in pasture, animal, labour and capital productivity.

With this separation we can ask what the industry would have looked like had only the external changes occurred without the internal ones. From such a scenario we can then assess what contribution the internal changes have made. Using data about how pastures, animals and labour have changed, we can then separately assess how each individual internal driver has contributed to industry growth. We then need to assess what contribution RD&E have made to these internal changes.
**Background**

Dairy Australia (DA), the Victorian Department of Primary Industries (DPIV) with in-kind support from the Geoffrey Gardiner Dairy Foundations (GGDF) commissioned the evaluation to determine the impact that their investments in (pre-farm gate) RD&E have had on changes in industry performance. DPIV and DA have funded TheCIE to conduct a high level evaluation that establishes the contribution of RD&E alongside other factors such as policy and regulatory changes.

The exercise is intended to support the implementation of the ‘Dairy Moving Forward’ National RD&E Strategy process currently underway. As well as understanding the impacts of investments in RD&E, the exercise is intended to synthesise and describe the strategic rationales underpinning the investments. Documenting key insights and lessons learned from the outcomes of RD&E investments and policy change is another important element of the exercise to guide further decision-making.

**The focus of the evaluation**

Assessing the contribution of RD&E to an industry is not straight forward. So many variables and interactions determine the outcome of an industry’s performance, that unscrambling those influences is complex and the data available to do so is not perfect.

- The impacts of successful RD&E on agricultural industries can be far reaching and cause many flow-on effects. Production gains on farm not only improve the incomes of farmers but also benefit processors and consumers. Improvements in winter feed can have different market impacts from other feed or animal improvements. Improvements in quality can have very different effects to increases in quantity.

- Some RD&E investments may offer little visible indication of improvements, but may prevent detrimental impacts. To fully understand the impacts of RD&E it is necessary to have a capacity to analyse what would have happened without the investment (the counterfactual). Constantly rising wage rates, changes in feed and water prices, changes in other agricultural industries, exposure to imports and access to export markets can all affect the overall benefits from RD&E. These underlying influences need to be factored in.

- Several counterintuitive economic issues surround value creation and capture from RD&E. Moreover, there can be very long lags between research and adoption. Issues relating to uptake and obsolescence, probabilities of success, the difference between research, development and extension, the roles of public and private investments, the rationales behind public and private investments in RD&E (and DPIV/DA’s strategic, catalytic role), spill-overs and spill-ins, all need to be well understood.
Recognising the complexities of the task and the imperfections of the data, our approach attempts to triangulate findings by drawing on three main sources of information:

- A parallel exercise that documents the brief history of the industry describing how it has changed and what have been the major drivers of change (Harris 2011 referred to above) coupled with the available statistical record;
- A workshop involving key industry players to identify what have been the most important changes on farm and for these where RD&E has made a significant contribution;
- A consolidation of the available reporting and evaluative information on RD&E program investments.

A consistent and rigorous economic framework is used to meaningfully evaluate this material and to unscramble the influence of RD&E from other influences. Only with an economic model of the industry is double counting likely to be avoided and consistent, objective attribution among drivers likely to be possible. A model requires that all assumptions about attribution be identified and made explicit, making them transparent and open to scrutiny. Without such a model, inferences and implicit assumptions will underlie any attribution exercise. Attribution cannot be rigorously tested and cross-checked.

Detailed analysis at the project level is clearly beyond the scope of this exercise. Nonetheless, to illustrate the payoffs from RD&E, case studies are used to highlight particular points.

The RD&E evaluation exercise focuses on Victoria in the context of the national industry. It also has a pre-farm gate focus but influences deriving from the off-farm (processing and marketing) sector will need to be considered for completeness. Within the pre-farm gate RD&E category of drivers of change are a large number of sub-categories such as animal improvements, increases in pasture and feed efficiency, new and better farming systems, more influential extension, better supply-chain relationships, better food safety, better environmental outcomes, changing quality specifications, meeting processor demands, etc.

**The challenge of this exercise**

Chart 1.1 provides a schematic representation of what the exercise aims to identify and measure. The chart shows the actual observable (factual) gross value of production (GVP) increasing over the past three decades. It also shows what would have happened to GVP had there been no changes in external or internal economic drivers under a no change scenario. But it also hypothesizes that another scenario might be one where there were no changes in internal factors, but that negative external drivers such as increasing wage rates, increasing environmental and
1.1 Internal drivers

external economic drivers include:

- world price of milk;
- prices of inputs such as wages, feed, fertilizer and chemicals;
- exchange rate and interest rate;
- income and population growth;
- consumer attitudes and preferences for milk;
- trade access and trade agreements;
- regulation relating to domestic prices or market quotas, environmental restrictions or OH&S requirements;

occupational health and safety regulations, plus depreciation and obsolescence drove industry GVP backwards. This is a possible counterfactual — what would have happened had there been no internal change and improvement in the industry.

The difference between the actual GVP and the counterfactual GVP represents what has been achieved by internal drivers (improvements) in the industry. It can be seen that taking account of the counterfactual may be very important to measuring the benefits achieved by internal drivers. The achievement may be greater than simply comparing the actual with the situation at the beginning, represented by the no change scenario.

Source: TheCIE.
climate; and
competition for water and land.

Internal economic drivers include:
- on-farm investment, risk preferences of farmers and ability to spread risks;
- autonomous farmer driven innovation relating to managerial capability, willingness to and rate of uptake of new technology, opportunity for technological transfer from foreign sources, the effectiveness of farm advisors, input suppliers and help from processing companies and inventiveness of farmers; and
- RD&E.

The structure of this report starts by assessing the influence of external drivers in chapter 2. In chapter 3 we report on the findings of the industry workshop to identify what the industry regards as the key internal drivers on farm and what they collectively regard has been the contribution from RD&E to those changes. In chapter 4, we conduct a detailed quantitative analysis of the impacts of internal drivers on the industry’s performance. In chapter 5, we conduct a historical statistical analysis of where the investments in RD&E have been over the past three decades. This is followed by three chapters assessing the high-level evidence of how RD&E might have contributed to change. These chapters follow through the investments made in each main area of change, the rationale behind the investment and the indicators of outputs, outcomes and success.

- Chapter 6, examines RD&E relating to feed base, pastures and supplements.
- Chapter 7, assesses RD&E relating to animals, breeding, genetics and health.
- Chapter 8, assess RD&E relating to the scale of operations and natural resource management.

In chapter 9 an assessment is made of all the evidence about the contribution of RD&E to the industry and it draws out the various key points and lessons from this study.
2 External drivers

Chart 2.1 shows the actual trend in Victorian production of milk over the past three decades. It also shows what production is estimated would have been had only external factors driven the industry — the counterfactual. It takes account of:

- the fluctuating effects of milk prices and droughts;
- real increases in other costs such as fertiliser, fuel, electricity, water, animal health products and services, transport costs and chemicals;
- decreasing costs of purchased supplementary feeds;
- increases in wages costs in real terms;
- a natural decay in productivity due to generic drift, diseases immunity and resistance, weeds, changing community standards, and capital and labour obsolescence:

The impacts of internal factors such as improvements in pastures and animals as well as a capital expansion effect and the achievement of economies of scale are excluded from chart 2.1.

The chart indicates that were it not for various internal industry improvements over the past three decades, production would have declined due to the combination of external factors. Declining purchased feed costs would have had a positive effect, but increases in other costs and natural productivity decay and obsolescence would have more than offset this. Without the major internal output and input improvements that occurred, output of the Victorian dairy industry would have declined by an estimated 23 per cent over the past three decades due to a cost price squeeze and depreciation and obsolescence of technology.

- Instead, industry output expanded by around 90 per cent.
- Relative to an estimated decrease in output of 23 per cent (in the counter-factual scenario), the 90 per cent expansion plus the prevention of a 23 per cent loss, represents an estimated 146 per cent expansion of output due to major production improvements compared with what could have been.
- The improvements due to major production changes appear to be considerably greater than the 90 per cent observed increase in output.

---

3 The counterfactual is estimated by changing the external factors in TheCIE Dairy Industry Model and assessing the impact on output.
2.1 Internal improvements in the industry may account for a near doubling of production over 30 years

Dairy prices received

The Australian, and especially the Victorian dairy industry, is directly connected to the world market through exports of manufactured product. Chart 2.2 shows that the world prices of our exports has been largely flat in nominal terms with strong demand and short supply causing price peaks in the middle to late 2000s.

2.2 World prices of Australia processed dairy products

Data source: ABARES, Commodity Statistical Bulletin.
Depreciation of the Australian dollar has played a key part in setting prices up until the middle of the 2000s. Chart 2.3 shows that in nominal terms, for export prices received, priced peaks in the early and late 2000s. On average export prices received increased by an annual average rate of 2.8 per cent over the past 30 years.

The domestic market is also an important driver for the industry. Chart 2.4 shows that over the past 30 years total expenditure of food on a per person basis has increased at an average annual rate of 4.5 per cent.

2.3 **Average export prices of processed dairy products**

![Chart 2.3](chart1.png)

*a Nominal prices.

Data source: ABARES, Commodity Statistical Bulletin.

2.4 **Growth in expenditure per person on food — Australia**

![Chart 2.4](chart2.png)

Data source: ABS, Catalogue no. 5206.0.
However, this simple representation of growth in the total market cannot reflect the way in which the domestic market has transformed, especially since deregulation, in terms of moving to a sophisticated market based on a wide range of products and brands which has encouraged further growth in the category.

The world market — including factors such as total growth, liberalisation of trade and competitiveness of other suppliers — plus transformation of the domestic market have a large impact on domestic prices. Chart 2.6 shows that nominal farm gate returns were directly related to export returns.

On a trend basis, nominal farm gate milk prices have increased by 2.6 per cent over the past 30 years. The linkage between export prices in Australian dollar terms and farm gate prices is reasonable strong, as shown in chart 2.6, but with some suggestion of a widening margin since regulation.

**Prices paid by dairy farmers**

While nominal prices received have increased over time, so have nominal costs.

Chart 2.7 shows that while most (nominal) costs tracked general (nominal) price levels in the rest of the Australian economy through the 1980s and the majority of the 1990s, (nominal) prices of key inputs increased dramatically during the 2000s especially:

- grain prices and ration costs as a result of the drought on the east coast of Australia; and
- high oil prices which flowed through to fuel and fertiliser costs in the late 2000s.
2.6 Domestic milk and export prices are highly correlated

![Graph showing domestic milk and export prices](chart)

Data source: ABARES, Commodity Statistical Bulletin.

2.7 Changes in key input farm costs over the evaluation period

![Graph showing changes in key input farm costs](chart)

Data source: ABARES, Commodity Statistical Bulletin.

**Dairy terms of trade**

Table 2.8 summarises the impact of prices received and prices paid for the major cost items identified.

- During the 1980s, farmgate prices of milk kept pace with many input costs, but it is obvious that the costs of feed and in particular feedgrains increased at a slower rate than other costs (excluding the impact of the 1982–83 drought).
- The 1990s was a period of price-cost squeeze where nominal prices received where less than primary costs, importantly feed and fodder costs increased...
mainly as a response to world prices and a widespread move to more intensive feeding systems throughout the Australian livestock industries.

This pressure intensified during the 2000s as there were a number of fundamental shifts in key markets:

- widespread drought on the east coast of Australia, combined with the inability to import feed grains, lead to increases in the cost of feed grains and irrigation water - recently this has been offset somewhat by better seasonal conditions and the capacity to import oilseeds at very favourable exchange rates;
- world oil price spike which flowed through to inputs with high energy contents such as fuel, fertilisers and grains.

While the dairy industry faced favourable market conditions for much of the 30 years, key costs have been increasing at a faster rate creating pressure to achieve higher levels of production and cost savings.

Chart 2.9 shows the impact of adverse seasonal conditions through the 2000s which reduced production and more importantly increased costs, especially of purchased feeds. Over the past 30 years costs have increased faster than prices received:

- nominal prices have increased by 2.4 per cent; while variable costs have increased at an annual average 3.5 per cent therefore the terms of trade has fallen by just over 1 per cent each year over the past 30 years.

Chart 2.10 shows the distinct downward trend for total terms of trade but this fall remains lower than for other agricultural industries.

### Decay, depreciation and obsolescence

The underlying rate of decay in the efficiency of production due to factors such as genetic drift, diseases immunity and resistance, weeds, changing community standards, and capital and labour obsolescence, is a key unknown but is acknowledged to exist and it is considered to be greater with more applied RD&E.

<table>
<thead>
<tr>
<th>Period</th>
<th>Farm gate prices</th>
<th>Hired labour</th>
<th>Fodder and feed stuffs</th>
<th>Fuels</th>
<th>Fertilisers</th>
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</thead>
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<tr>
<td>1980–89</td>
<td>5.7</td>
<td>6.5</td>
<td>1.0</td>
<td>5.8</td>
<td>6.2</td>
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<tr>
<td>1990–99</td>
<td>1.4</td>
<td>2.7</td>
<td>2.7</td>
<td>2.0</td>
<td>2.1</td>
</tr>
<tr>
<td>2000–10</td>
<td>4.7</td>
<td>3.3</td>
<td>5.1</td>
<td>6.7</td>
<td>8.5</td>
</tr>
<tr>
<td>1980–2010</td>
<td>2.6</td>
<td>3.9</td>
<td>3.7</td>
<td>4.6</td>
<td>4.0</td>
</tr>
<tr>
<td>Cumulative</td>
<td>115</td>
<td>214</td>
<td>194</td>
<td>289</td>
<td>223</td>
</tr>
</tbody>
</table>

*a Average annual increase for each period.

2.9 Victorian dairy farmer’s returns and cash costs

Data source: ABARES Commodity Statistical Bulletin and survey data.

2.10 Victorian dairy farmer’s terms of trade

Data source: ABARES Commodity Statistical Bulletin and survey data.

- It has been estimated elsewhere that maintenance RD&E may absorb up to a third of all agricultural research in the United States (Alston, Norton and Pardey 1998).

- Fuglie (2010) estimates that net productivity growth in global agricultural productivity has been around 2 per cent a year over the period 1977 to 2007 in industrial countries — if half this net gain is attributable to RD&E (1 per cent) and one third of all agricultural research is going to maintenance which is unmeasured, the measured productivity increase due to RD&E would only be two thirds of the total, implying maintenance may be contributing 0.5 per cent productivity growth per year (0.5/1.5 per cent = one third). The converse of this is that this maintenance is required to offset productivity decay.
Here we had assumed a rate of decay in production of 0.5 per cent a year as being plausible and this has been built into the counterfactual.

**Other relevant external drivers**

There are a number of other drivers facing the milk and milk processing chain that are significantly more difficult to quantify.

Both farm and processing businesses in the dairy industry have benefitted significantly from investment in new capital — which in most cases have been imported. This has occurred especially since deregulation and has become very attractive from a number of perspectives:

- investment in machinery and equipment embodies high levels of technology that improves overall output — this would include investment in:
  - new dairy shed design and milking machinery and vat capacity at farm level
  - machinery and equipment such as large volume driers and milk storage (‘investing in steel’) by manufacturers
- the high exchange rate has made investment more attractive and cost-effective.
3 Findings from industry experts on major internal drivers

As part of this project industry experts were invited to a workshop aimed at identifying what they collectively considered to be the major internal drivers of change on farm in the industry over the past three decades. They were also asked to identify the main contributions of RD&E to those changes.

Findings were that the major areas of farm change/innovation in pursuit of higher milk yields and increased profitability were:

- better pasture management and utilisation;
- use of supplementary feeding and its contribution to cow nutrition;
- incremental improvements in animal genetics and breeding;
- close attention to animal health and welfare issues to avoid negative impacts on output;
- economies of scale achieved from bigger farms and better shed infrastructure and management;
- containment of emerging natural resource management issues arising as a result of farm intensification; and
- better management and business skills.

Emerging from the workshop was a sense of the interdependency between these drivers. This is depicted schematically in chart 3.1.

- Increased pasture production and utilisation was a major impetus to industry growth as this is a low cost feed. More intensive feeding systems were required to improve pasture utilisation through rotational grazing. But to do so required higher stocking rates. Even with increased pasture production through improved use of fertilisers and improved species, given the seasonal variability in pasture growth as well as unpredictable rainfall in Australia, feed gaps occurred and became a greater risk in a more intensive system. This placed emphasis on a need for feed supplements.
- Feed supplements helped fill such feed gaps and helped maintain high stocking rates when pasture growth slowed. Supplements were nominated by the workshop participants as a key ‘success’ in pasture management and utilisation. At the same time, effective grazing management and utilisation were critical to maintaining the economic viability of intensive farms.
3.1 Big on-farm changes in dairy and RD&E contributions

- **Overall farm business management capability**
  - (Better business management)
  - Discussion groups small RD&E
  - Apprenticeships small RD&E
  - Adoption of business practice small RD&E

- **Pasture management and utilisation**
  - (More pasture)
  - %E %R&D
  - Rotations 70 5
  - Fertiliser 40
  - Ryegrass 30
  - Mgt 10

- **Supplementary feeding and cow nutrition**
  - (Milk yield increased)
  - %E %R&D
  - Feeding 33 33
  - Mgt 30 50
  - Survival 70 20

- **Animal genetics and Breeding**
  - (Milk yield increased)
  - %E %R&D
  - ABVs 30 30
  - Herd 80 record
  - Imported 20 genetics

- **Animal health and welfare**
  - (Avoided negative productivity)
  - %E %R&D
  - Infertility 30 30
  - Milk quality 20 20
  - Collective 10 mg

- **Bigger farms and infrastructure**
  - (Cost decreased)
  - Sheds 30% RD&E
  - Fodder 20% RD&E
  - Feed pads 30% RD&E
  - Irrigation 50% RD&E

- **Natural resource management**
  - (Avoided negatives)
  - Effluent big RD&E
  - Nitrogen big RD&E
  - Phosphorous big RD&E
  - DairySAT big RD&E

- **Milk harvesting**
  - (Labour saving)
  - Semi auto 25% RD&E
  - Workflow 15% RD&E
However, some experts identified excess reliance on supplementary feeding as a potential negative consequence of the shift towards intensive feeding systems.

Genetic improvement increased the capacity of animals to use high volumes of feed and to convert feed more efficiently into milk.

Structural change in the herd toward larger Holstein cows from smaller Jersey cows may also have contributed to more efficient feed conversion to milk volume. A consequence of breeding for increased production and profit has been a trend toward larger framed cows. However, both Holstein and Jersey cows now produce more per year than they used to in 1980.

Cow genetics and breeding and more intensive feeding/production systems resulted in unintended adverse impacts in animal fertility. As a result, increased emphasis has had to be placed on fertility in breeding in recent years.

Milk quality (through controlling mastitis) and more effective management of cow welfare were also essential to maintaining gains in feed intake, cow condition, conversion of feed to milk and fertility and enabling processors to produce high value products.

The increased production of pastures, the increased use of supplements, higher stocking rates and larger cows all contributed to increased milk output per hectare, per herd and per farm. This underpinned the achievement of economies of scale on farm allowing better use of farm labour, sheds and other fixed factors. It also facilitated farm amalgamation and rationalisation resulting in fewer but larger farms. The economies of scales help justify investment in new and better sheds and other farm infrastructure.

But a consequence of the intensification of dairy farming has been emerging natural resource management issues and attention to these has been necessary to underpin and improve the dairy farming system.

Another consequence of running a more intensive and sophisticated farming system has been the need for better and more commercially oriented management systems.

There were varying opinions around the contribution of each of these key sources of industry improvements. However, there was wide consensus that each was required to achieve the whole of system output improvements. Many of the technologies and practices were imported by the industry from the United States, New Zealand and Europe but often required adaptation and demonstration to achieve high rates of uptake and refine application in the Australian context.

Major changes and innovations in the first four areas identified by industry experts each had an R&D and/or extension component although this contribution varied widely as shown in chart 3.1.
Industry opinion was that pasture production, productivity and utilisation improved considerably over the period. This is attributed to a number of critical factors each with varying contributions of R&D and extension.

- Important areas identified were improved grazing management relating to rotational grazing and better growth and utilisation of pastures as well as better fodder conservation, fertiliser application, better grasses and overall better systems management of pastures. Rotational grazing practices increase the rate of pasture utilisation and regrowth including the two to three leaf grazing strategy and fodder conservation strategies. Rotational grazing originated in New Zealand but research and development played a small role in refinement and adaptation to suit regional dynamics. Workshop participants suggested that extension played a big role in improving pasture management and R&D played a big role in improvements in fertiliser use and grasses. Extension activities through RDC and Target 10 delivered critical leadership resulting in rapid adoption.

- An increase in the use of fertilisers was important to supporting pasture growth and overcoming pasture production constraints caused by limiting nutrients. Fertiliser demonstration projects and research to refine yield responses from fertiliser application, particularly phosphorous, trace elements and more recently nitrogen played a role.

- In addition, new and better species of ryegrass, supported through research to demonstrate their potential, contributed to the commercialisation of new species. A final critical area in grazing management and utilisation was the contribution of improved management of the system including feeding to manage seasonal surpluses and gaps through combining silage, concentrates, fodder conservation, more effective application and timing of nutrient applications.

Both R&D and extension enabled the introduction and rapid uptake of supplementary feeding systems, although the major change in management of the feed and milk supply was often driven by drought.

- R&D defined the responses to enable optimisation and gave industry the confidence to use grain/concentrates in their feedbase. According to industry R&D and extension played a critical role in assisting industry to manage the farm system as it became increasingly complex under more intensive feeding systems. Extension in pasture management and utilisation and cow nutrition lead to a better use of grain/concentrates in a pasture-based system.

- Supplementary feeding was essential to drought management in the 2000s; industry experts regard extension as having played a critical role.

Changes and innovations contributing to output gains in animal genetics and breeding identified at the workshop included the Australian Breeding Values (ABVs) and herd recording. Industry reports that ABVs were successful in improving selection for increased milk fat and protein whilst herd recording provided an opportunity for farmers to select for improved genetic merit across a range of traits.
The research and approach underlying ABVs was supported by dairy industry leadership through ADHIS whilst herd recording was achieved through extension activities. RD&E contributions may have been improved through undertaking an economic analysis.

Participants at the workshop acknowledged the role of RD&E in key changes and innovations in this area.

- Difficulties getting cows in calf quickly drove considerable changes in calving systems; R&D supported improved herd reproductive management and adaptation to low fertility, such as through extended lactation, rather than actually fixing the fertility issues. According to industry, fertility issues have been reduced in Victoria as a result of the move by many farmers from a seasonal to a split calving system and other adaptations. Some workshop participants held the view that the effectiveness of this R&D had been limited by a failure to maintain R&D effort on fertility to directly address the problem.

- Improvements in milk quality were important although driven by market factors (the dairy companies drive for higher quality milk) with contribution from R&D to develop best practice, and measuring chemical residues. Extension played ‘an important role’ in achieving significant reductions in cell counts more broadly across the industry.

A theme common to each of these areas is the role of improving overall farm business management capacity. As farms became increasingly complex, but farmers wanted to achieve profit and lifestyle changes, there was a significant shift in attitudes with farmers reluctant to remain in the industry without making a reasonable return on their labour. Government policy and farmers drove this change and workshop participants suggest that R&D had very little impact on this aspect of the dairy industry. However, extension had a significant impact via one-to-one discussions and small groups across a range of programs: CowTime, Countdown Downunder, InCalf, Phosphorous application and so on. Extension assisted farmers to understand how to integrate their increasingly complex farm systems and input-output relationships.

Larger sheds and new shed technology imported from overseas (mostly through private suppliers) supported the aforementioned four major areas of farm innovation. Shed technologies reduced the labour requirement per cow and increased automation, enabling economies of scale to be achieved from farm consolidation and larger herds. Sheds, hay and silage handling technology, feed pads and irrigation systems all required to varying degrees adaptation and refinement to the Australian context in which RD&E played a role but recognising that private companies mostly supplied the base technologies. Development and extension activities assisted industry to maximise attainable labour productivity gains; industry participants cited CowTime as a particular success.
Investment in natural resource management also supported gains achieved through the key four output drivers. Over the period environmental issues associated with nutrient levels and effluent management became more prominent as did the awareness that these required targeted RD&E. Industry participants acknowledge a large role of RD&E in:

- dairy shed effluent management in which there was rapid implementation of practice change;
- nitrogen and phosphorus application to improve efficiency and reduce the impact of runoff; and
- integration of whole-of-system approach to environmental management such as through DairySAT.

In the next chapter we attempt to quantify the contribution each major change made to the industry. This is followed by several chapters examining the evidence of RD&E’s contribution to the changes as a follow up to support key aspects of the evaluation undertaken by industry through the workshop.
4 Internal drivers

To quantitatively assess the contribution of individual internal factors to major changes in the industry we measured both the relative contribution of factors to changes to observed production and secondly, the contribution of each factor to profitability. These assessments are undertaken through two distinct tasks. Firstly we use an energy accounting framework that takes account of dairy herd energy supply and consumption to determine the role of key factors including supplements, pasture utilisation and cow genetics to increased milk production. We then use TheCIE dairy model to assess the contribution of each of these factors to profitability of the industry.

The energy accounting framework

To understand the internal factors that have contributed to the increased output of milk in Victoria over the past three decades it is necessary to quantitatively take account of the following factors and the interactions between them.

- Increased milk output per cow and per hectare.
- Increased stocking rate of cows.
- Change in number of hectares used by milking cows.
- Change in the total number of cows.
- Increased cow size and increased feed conversion potential.
- Increased dry stocking rate.
- Decreased number of effective hectares/milking cow.
- Increased pasture growth.
- Increased use of supplementary feeds.
- Increased quality of feeds and increased feed conversion efficiency.

Stocking rates have increased by over 40 per cent

Over the past 30 years, a notable feature of the Victorian dairy industry is that the numbers of dairy cows and the total amount land used by dairy farms have varied little but that the production of milk and output per cow has expanded strongly.

This change reflects intensification in the industry. Chart 4.1 and 4.2 show that while the total land of Victorian dairy farms have fallen since deregulation of the industry,
4.1 Victorian dairy cow numbers and land use

![Graph showing Victorian dairy cow numbers and land use from 1980 to 2009.](chart)

*a Calculated from statewide data on number of farms and average farm size. Data source: ABARES, ABS, DPIV and CIE estimates.*

4.2 Total Victorian dairy land and effective grazing land

![Graph showing total Victorian dairy land and effective grazing land from 1980 to 2009.](chart)

*Data source: ABARES, ABS, DPIV and CIE estimates.*

The effective grazing land used by milking cows has fallen at a greater rate reflecting the increased stocking rates across the herd. Total effective grazing land appears to be 30 per cent lower now when compared to 1980. With increasing herd sizes, more land has had to be devoted to dry stock as well. With milking cow numbers roughly constant, and with an increase in the proportion of dry stock held on farm, stocking rates have increased by over 40 per cent over the past 30 years (chart 4.3).
4.3 Stocking rates for Victorian milkers

![Graph showing stocking rates for Victorian milkers from 1980-89 to 2006-07]

* Milkers per hectare of effective grazing land.

Data source: ABARES, ABS, DPIV and CIE estimates.

Production of milk per cow and per hectare has increased strongly

Table 4.4 shows that performance in terms of milk production per cow and on a per hectare basis has grown steadily and consistently over the period. Seasonal variations, especially through drought periods, still have a significant impact around this distinct trend.

Table 4.5 summarises average annual increases in performance across a number of indicators over the past 30 years. While effective grazing land has fallen by 30 per cent, milk yields per cow have doubled over the period or increased at an average

4.4 Victorian milk yield per cow and per hectare

![Graph showing milk yield per cow and per hectare from 1980-81 to 2008-09]

Data source: ABARES, ABS and CIE estimates.
4.5 **Summary of statewide performance indicators for Victorian dairying**

<table>
<thead>
<tr>
<th></th>
<th>Effective grazing land</th>
<th>Cow numbers</th>
<th>Stocking rate</th>
<th>Milk yield per cow</th>
<th>Milk yield per hectare</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>%</td>
<td>%</td>
<td>%</td>
<td>%</td>
<td>%</td>
</tr>
<tr>
<td>1980-81 to 1989-90</td>
<td>-3.7</td>
<td>-0.4</td>
<td>3.4</td>
<td>3.2</td>
<td>6.7</td>
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<tr>
<td>1990-1 to 1998-99</td>
<td>1.7</td>
<td>3.8</td>
<td>2.0</td>
<td>2.3</td>
<td>4.4</td>
</tr>
<tr>
<td>2000-01 to 2008-09</td>
<td>-6.0</td>
<td>-3.7</td>
<td>2.8</td>
<td>1.9</td>
<td>4.7</td>
</tr>
<tr>
<td>Trend(^a) 1980-81 to 2009-10</td>
<td>-0.2</td>
<td>0.8</td>
<td>1.0</td>
<td>2.3</td>
<td>3.4</td>
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<tr>
<td>Cumulative over 30 years</td>
<td>-35.2</td>
<td>-2.6</td>
<td>50.8</td>
<td>94.0</td>
<td>192.5</td>
</tr>
</tbody>
</table>

\(^a\) For the period 1980-81 to 2009-10. \(^b\) This is a statistically fitted trend, so estimates maybe influenced by variability over the years.

**Data source:** ABARES, ABS and CIE estimates.

annual rate of between 2.3 and 3.2 per cent.

As a result of more productive cows on less grazing land, milk production per effective hectare has increased by around 190 per cent over the past 30 years growing at an average annual rate of 3.4 per cent.

**Contribution of feeds**

A driver of this overall performance has been increased use of feeds from both pastures and supplementary (non-pasture) feeds. This reflects a structural change from a pasture-only feeding system through to more intensive feeding and stocking systems observed today. Chart 4.6 shows that use of supplementary feeds has increased from virtually nothing to around 1.5 tonnes per cow.

4.6 **Use of supplementary feed per cow, Victoria\(^a\)**

![Graph showing use of supplementary feed per cow, Victoria](chart)

\(^a\) Includes grains and meals, concentrates and by-products and maize silage.

**Data source:** ADC and ABARES survey, Doyle (2000), and CIE calculations.

Annual per cow pasture consumption (grazed plus consumption of pasture and silage made from pasture) can be calculated, on average, by accounting for the
energy requirements of the average dairy cow. These energy requirements are a function of increases in its liveweight (and therefore maintenance requirements) and milk production over time. The contribution of pasture is then calculated by deducting the contribution from supplementary feeds from the total energy requirement. This simple framework is set out in detail in appendix B.

Chart 4.7 shows that the average cow’s annual consumption of pasture has increased from just over 4 tonnes to 4.5 tonnes dry matter over the period. The contribution of pasture to the average cow’s total nutritional requirement has declined from 100 per cent in 1980 to 75 per cent in 2010.

4.7  **Implied increase in consumption of pasture per cow, Victoria**

![Graph showing the implied increase in consumption of pasture per cow, Victoria](image)

*Pasture includes grazing, conserved hay and silage.  
Data source: ABARES survey, DPIV Farm monitor and CIE calculations.

*Pasture production and utilisation have increased by nearly 50 per cent*

To get a better indication of increased pasture production to overall increases in yield, the outcome in chart 4.8 should be adjusted by the stocking rates to provide an overall indication of increased utilisation of pasture on a per hectare basis.

- Overall pasture utilisation has increased from 4 to 6 tonnes per hectare over the past 30 years. The majority of the increase occurred in the 1980s and the 1990s.
- Successive droughts over the east coast during the 2000s reduced the scope for increases in production from pastures and so have reinforced the structural change moving to more intensive feeding systems in the industry.
4.8 Derived statewide utilisation of pastures for Victoria

It is possible that increases in the application of fertilisers, and urea in particular, in concert with improved management of grazing systems has lead to improvements in pasture production beyond that implied by chart 4.8 for the 2000s.

- The implication is that on average effective pasture utilisation of pasture may have declined during the 2000s.
- A driver of this outcome could be risk: increased seasonal variations and the increased likelihood of drought have resulted in producers requiring a buffer level of pasture use that is below the optimal productive potential. This is especially so given the increased use of contracts and performance targets for individual farms.

_Growth in use of supplements has been particularly strong_

Table 4.9 shows the annual average growth rates of the key feed inputs that underlie the performance metrics outlined in table 4.6.

- Average growth rates for supplementary feeds are very high due to the zero base in 1980s as farms moved from pasture only to bail-only feeding systems.
- While this intensification slowed in the 1990s, it increased again during the 2000s in response to sustained drought conditions and the requirement to fulfil contracted production levels.

Over the past 30 years, our framework suggests that pasture utilisation on a per hectare basis has increased by an average of 1.3 per cent each year, where the majority of this increase took place in the 1980s and early to middle 1990s. As already noted, this probably represents the _minimum_ of increases in production of pastures over the past 30 years.
4.9 Increase in supplementary feeds and pasture utilisation for Victoria

<table>
<thead>
<tr>
<th></th>
<th>Supplementary feed</th>
<th>Pasture utilisation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1980-89</td>
<td>34.7%</td>
<td>4.2%</td>
</tr>
<tr>
<td>1990-99</td>
<td>11.1%</td>
<td>2.3%</td>
</tr>
<tr>
<td>2000-09</td>
<td>7.5%</td>
<td>2.8%</td>
</tr>
<tr>
<td>1980-81 to 2009-10</td>
<td>12.5%</td>
<td>1.3%</td>
</tr>
<tr>
<td>Cumulative</td>
<td>3289.7%</td>
<td>46.6%</td>
</tr>
</tbody>
</table>

* Average annual change for each period. **Because these a statistically fitted trend, estimates are influenced by significant variation between the years.

Data source: CIE calculations.

Here the quantitative evidence strongly supports the views of participants to the workshop.

**Contribution of factors other than feeds**

In addition to increased feed, there are also a number of other factors whose contribution is more difficult to quantify. These include:

- change in genetic composition of cows due to genetic improvement and changes in breed which have resulted in moves toward larger framed cows and selection of higher yielding cows for a given liveweight:
  - modern cows capable of higher feed intakes and milk yields can achieve higher efficiency in feed use on a per cow basis compared with the equivalent cow in the 1980s — because:
    - if fed to high levels of dry matter intake and milk yield the proportion of feed used for milk versus maintenance will be greater;
    - although modern larger framed cows require more feed for maintenance per cow, they require less per litre of milk output if fed to high levels;
    - selection has led to genetic change favouring cows that can make best use of a mix of pastures and supplementary feeds;
  - although the correlation between genetic merit for milk yield and weight is weak (about 0.3), evidence from ADHIS data suggests that the overall improved genetic merits of cows between 1981 and 2008 could potentially account for increases in milk yields of 1000 litres per cow per year and field trials suggest that modern cows with genetic improvements can perform even better with high levels of feeding (Goddard 2011);
  - larger framed cows were not an objective of the ABV or selective breeding program but do improve feed use efficiency of dairy cows and is certainly a consequence of current industry trends based on imported genetics;
  - chart 4.10 shows that the total energy requirement per cow, per litre of milk produced, has declined by 25 per cent since the 1980s as a result of the higher proportion of feed consumed that is now available for milk production relative
to the requirements for cow maintenance — noting that the energy requirement per litre of milk is unchanged at around 5 to 5.5 MJ per litre of milk.

Other factors that have driven changes in production over time include:

- improvement in herd health (reduction in mortality, morbidity and mastitis); and
- seasonal variations impact on the feedbase (that result in dry matter consumption that is above or below trend on a per cow basis).

**Attribution to each of the contributing factors**

Some of these factors are more easily quantified than others but all are inter-related. The approach taken here is to start with the factor being investigated while the levels of all other factors are held at 1980 levels. The approach is set out in detail in appendix A and the results are summarised below in table 4.11.

### 4.11 Contribution of key factors to observed growth in milk yield

<table>
<thead>
<tr>
<th></th>
<th>Yield per cow</th>
<th>Yield per hectare</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>litres per cow</td>
<td>%</td>
</tr>
<tr>
<td><strong>Feeding</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Increased supplementary feeding only</td>
<td>950</td>
<td>33.8</td>
</tr>
<tr>
<td>Increased pastures only</td>
<td>40</td>
<td>1.4</td>
</tr>
<tr>
<td><strong>Genetics</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Higher yielding cows</td>
<td>958</td>
<td>34.1</td>
</tr>
<tr>
<td>Other factors</td>
<td>866</td>
<td>30.8</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>2 814</td>
<td>100.0</td>
</tr>
</tbody>
</table>

*Data source: Appendix A.*
The most significant point is that the contribution of each factor is different between yield per cow and yield per hectare.

- Increased use of supplementary feeds has had the largest single impact on both yield measures. It has resulted in higher yields per cow plus also has enabled higher stocking rates, for pastures.
- While increased utilisation of pastures has had minimal impact on yield per cow, it has contributed around one third of the gains to milk yield per hectare.
- Genetics has potentially a very large contribution to observed increase in yields per cow but less impact on yield per hectare basis without concomitant increases in feed — without more feed (particularly supplements) modern cows would require stocking rates to fall to the increase in output per cow. It makes little sense to select for higher yielding cows without initiatives that support higher levels of nutrition.
- Because of this close interdependency, there is no correct way to attribute gains between these two factors as they are clearly linked.

The final category ‘other factors’ is the residual or unexplained proportion and this varies considerably over time because it comprises a mix of positive and negative factors identified earlier including:

- seasonal variations in the availability of the feedbase (mainly negative);
- the synergies (cross-over effects) between genetics and more intensive feed systems (positive); and
- the net impact of improved herd health offset by higher levels of infertility and other problems that may have reduced output below those levels that could be expected.

**Another interpretation of attribution**

Chart 4.12 sets out the increase in litres per hectare achieved over the past 30 years. Production has increased from 2 878 litres per hectare in 1980 to 8419 in 2010. We can observe the following.

- In 1980, the 2 878 litres per hectare was produced almost entirely from pasture based feed.
- The 47 per cent accumulated increase in pasture production and utilisation (table 4.9) and increased stocking rate this has enabled suggests pasture improvements might account directly for a 1 341 litre increase in milk production per hectare (chart 4.12).
- The increased use of supplements per hectare to 1.5 tonnes of dry matter per cow means that cows now consume 33 per cent more non-pasture dry matter per year which translates into a 950 litre increase in milk per hectare relative to the 1980 situation (chart 4.12). However, combined with a 50 per cent increase in stocking
rate, on a per hectare basis the increase translates into a total increase of 1,425 litres of milk per hectare from supplements (950 + 475, chart 4.12).

- The combined increase in pastures and supplements has provided an enlarged feed base which supports cows that are 34 per cent more efficient than 1980 cows at converting feed to milk (chart 4.10 and table 4.11) allowing for a further 1,919 litre per hectare of milk increase (chart 4.12).

- This leaves 856 litre of milk per hectare as a residual (chart 4.12), but there is also the counterfactual element mentioned in chapter 2 to consider. The 23 per cent reduction in production that might have occurred due to negative terms of trade...
and technological obsolescence translates into 661 litres per hectare of lost production that has been prevented over the period. Together with the residual, this suggests 1517 litres of milk per hectare that is unaccounted for. There is no data to guide us on which factors have underpinned this, but qualitative evidence might suggest it is due to NRM, animal health and other issues such as investment in other factors such as better sheds (chart 4.12).

**Time path and sequence of technical changes**

Chart 4.13 and 4.14 show the impacts of various factors on yield growth per cow and per hectare. On a per cow basis, growth in supplements and pastures explains much of the observed growth until the early 1990s. After that higher yield cows and other factors explain much of the growth.

4.13 **Time path of contribution of key factors to milk yield per cow — Victoria**

![Chart 4.13 Time path of contribution of key factors to milk yield per cow — Victoria](chart.png)

Data source: CIE calculations.

However, on a per hectare basis in chart 4.14, it is mostly the growth in supplements and pastures that has allowed growth to continue beyond the early 90s on a per hectare basis. Although cows have got larger, they would not have been able to produce as much milk as they did per hectare without more feed per hectare (pasture and supplement).

**Farm costs**

The increased production observed above has resulted in significant changes in farm costs and profitability as a result of a mix of factors:

- increased expenditures of feed costs for supplementary feeds and inputs to pasture production have occurred; but
lower costs on a per litre of milk basis for a range of other inputs particularly shed and associated hired labour costs.

Understanding changes in farm costs also helps cast light on production changes and on the profitability of those changes.

The first panel of chart 4.15 shows that expenditures on purchased feeds have increased dramatically over the past 30 years, while pasture costs have grown at around half that rate. The second panel of chart 4.15 shows that while per hectare labour costs have increased; there has been a considerable fall in other cash costs through to the middle 2000s.
Table 4.16 identifies annual growth rates or changes for each of the cost categories between the three decades.

- Per hectare expenditures on purchased feeds grew strongly over the entire period at an average annual rate of 9 per cent.
- There has also been increased expenditures on costs related to pasture (fertiliser, seed, fuel etc) of around 3.7 per cent each year.
- Other cash costs representing a number of farm overhead costs fell dramatically from the mid 1980s through the 1990s and the trend rate of decline over the three decades was 2.2 per cent. The decline in this cost component is a result of economies of scale being achieved.

### 4.16 Average annual growth in Victorian dairy expenditures on a per hectare basis

<table>
<thead>
<tr>
<th></th>
<th>Pasture costs</th>
<th>Purchased feed</th>
<th>Herd and shed costs</th>
<th>Other cash costs</th>
<th>Hired labour</th>
<th>Cash costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>%</td>
<td>%</td>
<td>%</td>
<td>%</td>
<td>%</td>
<td>%</td>
<td>%</td>
</tr>
<tr>
<td>1980–81 to 1989–90</td>
<td>5.1</td>
<td>7.6</td>
<td>1.9</td>
<td>6.8</td>
<td>-0.8</td>
<td>5.0</td>
</tr>
<tr>
<td>1990–91 to 1998–00</td>
<td>2.6</td>
<td>12.5</td>
<td>0.0</td>
<td>-6.1</td>
<td>3.4</td>
<td>1.9</td>
</tr>
<tr>
<td>2000–01 to 2009–10</td>
<td>4.6</td>
<td>9.3</td>
<td>1.9</td>
<td>3.3</td>
<td>4.6</td>
<td>1.1</td>
</tr>
<tr>
<td>Trend 1980–81 to 2009–10</td>
<td>3.7</td>
<td>9.6</td>
<td>-0.6</td>
<td>-2.2</td>
<td>3.8</td>
<td>2.7</td>
</tr>
</tbody>
</table>

*Based on per hectare costs over the period 1980–81 to 2009–10 in 2009–10 dollars.

Data source: DPIV and ABARES farm surveys.

Overall, there was a surge in all cash costs during the 1980s (5 per cent increase each year) reflecting the intensification of the industry, which slowed through the past two decades. Therefore industry outcomes observed today are a combination of:

- increases in the intensity of input use especially purchased grains and other feed compounds;
- rationalisation of the industry especially in terms of increased herd size for given fixed costs leading to economies of scale and falling costs in the other cost and herd and shed cost categories; and
- output from of each of pastures and utilisation factors identified in table 4.9 and the combined impact between them.

### Revenue profit and costs

Chart 4.17 (LHS) reports the cumulative increase in the value of output per hectare relative to the counterfactual over the 30 year period reported in real 2010 dollar terms. It shows that gross revenue per hectare earned has been an estimated $27,944
higher than it would have been without internal changes over the full 30 year period.\textsuperscript{4}

Chart 4.17 (RHS) shows the cumulative increase in costs per hectare over the entire 30 year period required to achieve the increase in revenue. It is shown as an estimated $15,426 per hectare. It also shows that $7,566 per hectare was the estimated increased costs of supplements feed and $3,268 was the increased cost of pasture production. Comparing cumulative revenue with costs indicates an estimated profit before interest and tax of $12,518 per hectare.

For the whole state, the increase in profit amounts to around $10 billion over the period in 2010 dollar terms and this compares a cumulative gross value of production over the entire period of around $63 billion in 2010 dollar terms.

The estimates presented in chart 4.17 suggest that for farms remaining in the industry over the 30 year period, internal changes were reasonably profitable. They also suggest that revenue per unit of input increased considerably.

\textsuperscript{4} Estimates are made using TheCIE Dairy Industry model.
5 Patterns of RD&E investments

There are no accurate data on the exact investment in dairy RD&E. Nonetheless, by piecing together various sources, it would appear that over the past 30 years the accumulated investment in on-farm RD&E in Australia has been around $2 billion in 2010 dollar terms (from ABARES farm survey data 1980–2010). This compares with total net increases in investment on-farm by the industry of $3.6 billion. Therefore, on farm RD&E has represented around 35 per cent of all on-farm investment.

Investment in on-farm RD&E in the dairy industry has come from a range of funding sources including the research and development levy which is invested by the national Industry Service Body, Dairy Australia, and the organisations formerly established to deliver industry services: DRDC, the Dairy Research Committee and the Dairy Research Council.5 Other major funding contributors include the Victorian Department of Primary Industries and previous equivalent organisations, other states departments of primary industries, the Commonwealth Government (including CSIRO), universities, dairy companies and Victoria’s Gardiner Foundation.6

Table 1 contains estimates of the order of magnitude of this investment by time period. Estimates of total industry funding for the 1980s are based on the research program allocations for the major industry research investment body as obtained in industry annual reports7, and CIE expectations on its relationship with total industry funding.

Currently, own-source funds from Dairy Australia contribute almost one in every four dollars or 23 per cent spent on RD&E (including Commonwealth government contributions). This relationship is underpinned by data produced from an evaluation of funding contributors and providers completed (Juffs and Oates, 2008) for the year 2006–07. Although difficult to verify due to limited information, it is

5 Dairy Australia was set up in 2003 to amalgamate all industry services activities within one industry-based organisation.

6 In addition to these organisations, regional development partnerships, consultants and companies supplying goods and services have played a role in the provision of extension services. In the 1980s prior to the establishment of the National Centre for Dairy Education Australia, VCAH Dookie and MacMillan were involved in the provision of extension.

estimated that the predecessor of Dairy Australia, the Dairy Research Council, contributed approximately one in every 13 dollars invested.

Based on these expectations, as shown in table 5.1, TheCIE estimates that on-farm investment increased substantially between the late 1980s and early 1990s. An evaluation produced by Harley Juffs and Associates in 1995 on RD&E investment in 1993-94 provides sound basis for estimates for the early 1990s. If we have underestimated the potential contribution of the industry body as a share of total investment in the late 1980s then this gap in funding would be even more prominent. Our expectations around the total contribution to RD&E in the 1980s relative to the 1990s is also founded by a number of contributing factors.

5.1 Estimated annual investment in Australian dairy industry by period (2010 dollars)

<table>
<thead>
<tr>
<th></th>
<th>Investment by DRC/DRDC/DA</th>
<th>Total investment</th>
<th>Total on farm investment</th>
<th>DRC/DRDC/DA as a share of total exp</th>
<th>On farm as share</th>
</tr>
</thead>
<tbody>
<tr>
<td>Early 1980s</td>
<td>3 400</td>
<td>43 200</td>
<td>24 300</td>
<td>8%</td>
<td>52%</td>
</tr>
<tr>
<td>Late 1980s</td>
<td>5 400</td>
<td>68 000</td>
<td>27 300</td>
<td>8%</td>
<td>50%</td>
</tr>
<tr>
<td>Early 1990s</td>
<td>19 400</td>
<td>106 800</td>
<td>57 200</td>
<td>18%</td>
<td>54%</td>
</tr>
<tr>
<td>Late 1990s</td>
<td>31 600</td>
<td>164 600</td>
<td>92 000</td>
<td>19%</td>
<td>56%</td>
</tr>
<tr>
<td>Late 00s</td>
<td>39 500</td>
<td>169 300</td>
<td>103 700</td>
<td>23%</td>
<td>61%</td>
</tr>
</tbody>
</table>


Note: Estimates of DRC/DRDC/DA expenditure incorporate qualifying expenditure on RD&E and capital expenditure, less depreciation. Expenditure on industry services is not included.


- In 1993 DRDC investment was approximately $19.3 million in 2010 dollars, more than 300 per cent of the Dairy Research Council expenditure in the late 1980s. This can partially be explained by the movement in 1989 to progressively double the rate of research levy in recognition of the need for joint action and the increase in the levy collection resulting simply from significant increase in milk production through the 1990s.
  - It may also be explained by a potential increase in Commonwealth government contributions, which are broadly reflective of industry contribution (due to matching funding provisions).

- Anecdotal evidence also suggests that investment from a number of other contributors may have increased from the 1980s to the 1990s:
  - Dairy industry experts suggest that the dairy companies recruited more field staff from around 1988, possibly in the order of 25 per cent additional staff.
  - They also suggest that company providers of goods and services to the dairy industry were more heavily utilised in the 1990s than the 1980s.
The share of funding dedicated to the farm sector increased throughout the period from around 50 per cent in the 1980s to more than 60 per cent in the 2000s (see table 5.1). TheCIE estimates on farm RD&E has increased from around $21 million (in 2010 dollars) in 1980 to $108 million in 2010. Chart 5.2 provides an indicative representation of the trajectory and components of RD&E over the period.

5.2 Estimated national industry and industry entity investment over 30 years

Expenditure on manufacturing as a share of total investment fell from approximately 48 per cent in the late 1980s to 40 per cent in the late 1990s and 37 per cent in the late 2000s (see chart 5.3). The residual is comprised of investment in education, economics and marketing activities.

5.3 On farm component as a share of total national investment

Data source: TheCIE.
Investment in manufacturing RD&E is predominantly made up of research and development (80 to 90 per cent), with only a small share of funding allocated to extension (10 to 20 per cent). For this reason, in aggregate terms the investment on extension-related activities has been smaller than R&D investment (see table 5.4).

5.4 Share of national RD&E - on farm, manufacturing and total investment

<table>
<thead>
<tr>
<th></th>
<th>On farm</th>
<th>Manufacturing</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>R&amp;D</td>
<td>Extension</td>
<td>R&amp;D</td>
</tr>
<tr>
<td>1993-94</td>
<td>59</td>
<td>41</td>
<td>91</td>
</tr>
<tr>
<td>1998-99</td>
<td>43</td>
<td>57</td>
<td>84</td>
</tr>
<tr>
<td>2006-07</td>
<td>53</td>
<td>47</td>
<td>83</td>
</tr>
</tbody>
</table>


However, on farm investment has been more evenly split between R&D and extension. In two of the three years for which a detailed evaluation of funding was undertaken, R&D represented more than 50 per cent of investment in on farm R&D. On balance, we would expect R&D accounted for just over half of on farm investment.

Components of farm sector investment

Table 5.5 presents an indicative breakdown of investment in the farm sector. The estimates are based on several sources which TheCIE has attempted to reconcile to enable comparison between periods across common categories. It should be noted that farm sector investment shown for the 1980s reflects the investment focus for the Dairy Research Council as outlined in their annual reports which may provide an indication of the funding priorities for this decade.

The sum of on farm investment in RD&E over the three decades is estimated to be approximately $1.96 billion in today’s terms (2010 dollars). Applying the proportion of Victorian GVP as a share of total GVP (approximately 63 per cent) to this number suggests investment in on farm RD&E for Victoria may have been around $1.24 billion.

The estimated share of investment shown in table 5.5 is utilised to represent the broader funding objectives for the corresponding decade, to derive total farm investment under each area. This is derived by applying the weightings for each year to the corresponding sum of on farm investment in each decade.
5.5 Estimates of components of Australian farm sector investment

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>%</td>
<td>%</td>
<td>A$m</td>
<td>%</td>
<td>A$m</td>
<td>A$m</td>
</tr>
<tr>
<td>Pasture/forage improvement and utilisation</td>
<td>20</td>
<td>34</td>
<td>35</td>
<td>5.5</td>
<td>31.3</td>
<td>36.4</td>
</tr>
<tr>
<td>Feed use and nutrition</td>
<td>14</td>
<td>7</td>
<td>4</td>
<td>3.8</td>
<td>6.5</td>
<td>4.3</td>
</tr>
<tr>
<td>Animal breeding and reproduction</td>
<td>39</td>
<td>18</td>
<td>15</td>
<td>10.7</td>
<td>16.9</td>
<td>15.2</td>
</tr>
<tr>
<td>Cow welfare</td>
<td>15</td>
<td>6</td>
<td>10</td>
<td>4.1</td>
<td>5.6</td>
<td>9.9</td>
</tr>
<tr>
<td>Business and human resources</td>
<td>0</td>
<td>13</td>
<td>8</td>
<td>-</td>
<td>11.7</td>
<td>8.5</td>
</tr>
<tr>
<td>Milking systems</td>
<td>8</td>
<td>0</td>
<td>9</td>
<td>2.1</td>
<td>-</td>
<td>9.2</td>
</tr>
<tr>
<td>Natural resource management</td>
<td>3</td>
<td>20</td>
<td>15</td>
<td>0.7</td>
<td>18.4</td>
<td>16.0</td>
</tr>
<tr>
<td>RD&amp;E capacity building</td>
<td>2</td>
<td>1</td>
<td>4</td>
<td>0.5</td>
<td>1.1</td>
<td>4.3</td>
</tr>
<tr>
<td><strong>Total on farm investment</strong></td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>27.3</td>
<td>91.5</td>
<td>103.7</td>
</tr>
</tbody>
</table>


Note: Note the late 00s is on the basis of provider not funder whereas the late 80s and 90s are on the basis of funder.

Data source: CIE estimates based on a range of sources.

just a snapshot of the funding priorities over each decade the estimates presented in table 5.6 may only be indicative of the potential funding priorities over the period.

The single largest area of investment appears to have taken place around management of the feed base, with approximately one third of investment estimated to have taken place in the area of pasture/forage improvement and utilisation (33 per cent) and a smaller share of investment (around 6 per cent) is estimated to have been directed towards feed use and nutrition. The split between funding on pastures and on feed use and nutrition is consistent with qualitative evidence on the research priorities. An industry review produced for the National Dairy Alliance in 1999 stated that ‘the broad thrust of RD&E in this area (relevant to the feedbase) has been to find ways to further improve the level of utilisation of pasture as the lowest cost element of the feedbase’ (National Dairy Alliance, 2000).

Table 5.6 shows considerable investment was also undertaken in animal breeding and reproduction, approximately $374 million or 19 per cent of total on farm investment, whilst approximately 15 per cent of funding or over $300 million has been spent on natural resource management.

Share of public, industry and private investment

Decomposing the sources of funding into public, private and industry entities shows that the percentage of public sector investment declined as a share of total investment though public sector investment still remains the dominant source of investment (see tables 5.7 and 5.8). Private sector contributions to on farm RD&E increased from approximately one in ten dollars to one in five dollars spent. Industry contributions to on farm and total investment in RD&E increased markedly over the period, principally as a result of increasing levy contributions. Industry now contributes approximately one in every five dollars spent on RD&E.
5.6 Potential investment in national on farm RD&E by area — 30 year period

<table>
<thead>
<tr>
<th>Investment area</th>
<th>Total</th>
<th>Share</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pasture/forage improvement and utilisation</td>
<td>643</td>
<td>33</td>
</tr>
<tr>
<td>Feed use and nutrition</td>
<td>126</td>
<td>6</td>
</tr>
<tr>
<td>Animal breeding and reproduction</td>
<td>374</td>
<td>19</td>
</tr>
<tr>
<td>Cow welfare</td>
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<td>Business and human resources</td>
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<tr>
<td>Milking systems</td>
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<td>Natural resource management</td>
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<tr>
<td>RD&amp;E capacity building</td>
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<td>Total on farm investment</td>
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Data source: TheCIE.

5.7 Estimates of total investment in RD&E by source

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<tr>
<td>Private</td>
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Note: Public funding incorporates Commonwealth government contribution to DA/DRDC/DRC, state and federal government contributions (including through CSIRO), universities and other public bodies. Private investment incorporates expenditure by dairy companies, overseas organisations, consultants, companies supplying goods and services and so on. Industry funding incorporates Industry Services Levy, industry organisations and bodies (including NCDEA and Gardiner Foundation).

Data source: TheCIE.

5.8 Estimates of investment in farm sector RD&E by source

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Note: Public funding incorporates Commonwealth government contribution to DA/DRDC/DRC, state and federal government contributions (including through CSIRO), universities and other public bodies. Private investment incorporates expenditure by dairy companies, overseas organisations, consultants, companies supplying goods and services and so on. Industry funding incorporates Industry Services Levy, industry organisations and bodies (including NCDEA and Gardiner Foundation).

Data source: TheCIE.

General emphasis of RD&E over the past three decades

RD&E investments have occurred in most areas of the major changes in the industry over the past three decades. There have been scientific developments in adapting new technologies to local conditions and programs to accelerate the rate of change across the industry.

Considerable uncertainty surrounds these estimates.
Investments in RD&E have involved a combination of:

- strategic and applied research that developed a scientific knowledge base for addressing specific issues;
- experimental development work to adapt, refine or prove the practical application of domestic and overseas research results; and
- extension programs to disseminate R&D knowledge and encourage the adoption of technological advancements.

The contribution of RD&E needs to be placed in perspective. There have been technical advancements but in many areas the research knowledge or development of new farming practices originated from overseas. Much of the RD&E effort has involved adapting, refining and extending these technologies and ideas. Europe, North America and New Zealand have been key sources of new developments.

- Other sources of research and innovation include other players in the chain such as those who are suppliers of inputs, equipment manufacturers, independent consultants and companies involved in the processing sector.

In some areas the RD&E has not been confined to dairy specific initiatives. There have been collaborative efforts and wider applications involving other rural industries. RD&E on issues such as pasture production, grazing management, fertiliser use, ground-water degradation and soil salinity are some examples. The knowledge and new developments from these investments were adapted and applied in dairy farming regions.

RD&E has not been the lead factor in all the changes that have occurred. Some have been driven by the autonomous efforts of farmers — independent reactions to changes in their operating environment or improvements in existing technologies. RD&E may have had a supporting role by establishing the optimal application or accelerating the pace of change.

There were RD&E investments in each of the main areas of change identified in the industry workshop. It is informative to provide an overview of the key RD&E activities that were aligned with these areas of change. DPIV invested in a range of dairy R&D projects and their extension service delivered state and regional programs in specific areas. Dairy Australia and its predecessor implemented national extension programs with a Victorian component that used DPIV extension staff.
6 Contribution of RD&E: feed

The success of Australian and Victorian dairy industries has been dependent on the ability of the industry to produce low cost feed through pastures. Improvement in pasture management and production was identified as an important contributor to the growth of the industry over the past three decades by participants in the industry workshop.

**Pasture management and production**

Management practices that affect pasture production, quality and timing are wide-ranging and include the selection of plant varieties, fertiliser use, water use and interactions of plants with the grazing stock.

**RD&E resources dedicated**

Improved pastures and the introduction of better performing pasture plants has been an established feature of the industry for some time. There has been R&D into new varieties and, in recent times, there has been a substantial investment in genomic research on pasture plants. However in the 1980s and 1990s the key focus of RD&E in this area was pasture and grazing management practices.

- It is estimated that between 20 and 30 per cent of on farm RD&E expenditure has been dedicated to issues of pasture utilisation over the past 30 years.
- This has been aimed at increasing the quantity and quality of dry matter per hectare per year produced and consumed to meet cow dietary requirements throughout the year through five major strategic areas:
  - optimisation of pasture management to increase the rate of growth of pastures as well as the digestibility of pastures relying on grazing at the optimal point of growth in the growth cycle of the plant, minimising selective grazing, maintaining appropriate composition of species in the sward and minimising senescence;
  - optimising fertiliser use for particular soils and seasonal conditions;
  - optimising fodder conservation and use of feed supplements to underpin an efficient grazing management system;
  - development of better pasture varieties and compositions; and
- measurement and refinement of pasture supply and demand budgeting into integrated computer-based management systems.

Some of these strategies have involved the uptake of foreign technologies and have involved considerable amounts of extension, but some R&D has been required to adapt foreign technologies to the unique and oftentimes more variable climate in Australia.

Examples of major extension initiatives include:
- Target 10;
- ABC farms project;
- Project 30 30;
- Feeding Pastures for Profit; and
- Grains to Milk.

In the late 1980s and early 1990s some specific major R&D priorities (see box 6.1) for dairy pasture research were:
- drought tolerant and disease resistant strains of pasture cultivars;
- pest and disease management controls;
- diagnostic tests for the nutrient status of soils for fertiliser management; and
- water use efficiency and salinity management strategies for irrigated pastures.

**Rationale for RD&E investment and expected outcomes**

Pasture based production systems underpin Victoria’s low cost dairy industry. Pasture is normally the lowest cost feed source. Improving pastures increases carrying capacity and subsequently the potential output of milk per hectare. Before 1980, Australian pasture utilisation was low relative to potential and relative to other countries (Mason et al 1987, DFA undated).

The key constraint to all pasture-based dairy production systems is the amount of feed grown and the proportion of this that is utilised (Doyle and Stockdale, 2008).

The efficient use of pasture production through rotational grazing and higher stocking rates to maximise pasture utilisation was developed by McMeekan in the 1950s and 1960s in New Zealand (Macdonald et al, 2010). The uptake of this technology was slow in Australia but economic pressures in the early 1980s to become more cost competitive with New Zealand created pressure for the uptake of best practice grazing systems. It is now also being taken up in other parts of the world, including the United States. This technology had the potential to greatly increase dry matter output, consumption, stocking rates and milk production per hectare. Rotational and strip grazing practices can increase pasture production by between 30 and 60 per cent:
6.1 Further details on R&D investment in pastures

DPIV’s investments in dairy RD&E in the late 1990s were directed by the Dairy Industry Strategy. There were seven initiatives including a pasture plant improvement project on developing improved cultivars for key pasture legumes and grasses. The R&D involved plant gene biotechnology. It was a long term investment in developing white clover and perennial ryegrass with new genes for resistance to disease, drought and cold tolerance, enhanced nutritional quality and improved feed growth.

A related R&D initiative funded in the 1990s was the ‘Feed Base Utilisation’ program. This initiative supported projects on pasture growth and utilisation. It also included projects on pasture nutrient intake by dairy cows and supplementary feeding. These projects provided technical information that supported another major area of industry change that is discussed in the next section — supplementary feeds and animal nutrition.

A closely related area of R&D investments was soil health and fertiliser use. The nutrient balance in soils is a key factor in pasture productivity. DPIV had invested in regionally focused R&D projects on fertiliser use in the 1980s and 1990s. In general the projects had potential applications across all livestock grazing industries. The R&D shifted to a state wide focus in the mid 1990s.

In the mid 1990s a strategic review of DPIV’s Dairy Industry Program identified future R&D priorities that included nitrogen fertiliser research for the dairy industry in South East Australia. The ‘Soil, Water and Nutrients’ project was established in the late 1990s with a three year subproject on nitrogen fertiliser use. One of the aims of the project was to establish guidelines to minimise nitrogen losses while maintaining pasture productivity.

There were subsequent collaborative R&D projects on fertiliser use in pastures that had applications in the dairy industry. The research progressed into the area of soil nutrient budgeting. Key projects were ‘Better Fertiliser Decisions’ (2003–07) and ‘Accounting for Nutrients on Australian Dairy Farms’ (2006–10). They focused on the efficiency of nutrient use and minimising the environmental effects of nutrient loss into ground water — the development of a nutrient budgeting approach to fertiliser use was a useful advance that supported changes in pasture and grazing management practices.

In the past decade there was a shift in the orientation of R&D activities by DPIV towards longer term public good research projects. The Our Rural Landscape’s (ORL) initiative (2000–07) was established with a program focused on plant genomic technologies. The R&D funds invested in the ORL initiative have been substantial.
an increase of 2.7 tonnes of DM per hectare per year for perennial ryegrass white-clover in the northern Victorian irrigation region has been reported by Kelly (1993 in Doyle et al, 2000) from the use of better grazing management practices — this might amount to around a 35 per cent increase in pasture productivity assuming an average of around 8 tonnes of DM per hectare reported by Mundy (1993) in Doyle et al (2000);

- in the United States gains from the introduction of New Zealand-style rotational grazing in recent years of 35 per cent for Oklahoma; 37 per cent for Georgia; 44 per cent for Arkansas; and 61 per cent for Virginia have been demonstrated (Henning et al, undated).

- Increased output of pastures from more efficient grazing management must use more soil nutrients, so to further increase pasture production supplementary soil nutrients are required in the form of fertilisers. Research around the world showed that there could be good returns from applications of nitrogen and phosphorous, but optimal amounts are likely to vary by prices of milk and the cost of the fertiliser, the nature of the soil and the climate. Research was needed to identify fertiliser responses and evidence is that gains of between 20 and 30 per cent in pasture production can be achieved (Doyle et al, 2000).

- Mundy (1993) shows 25-33 per cent gains in annual dry matter production from applications of 50 kilograms of nitrogen per hectare in northern Victoria.

- Gourley (unpublished) reports 20 per cent gains in dry matter per hectare per year for 70 kilograms of phosphorous per hectare per year for Gippsland.

- With intensive grazing and fertilizer application, the margin for error diminishes (raising certain types of risks if the margin for error is crossed) requiring management strategies to deal with new constraints as they emerge. Having better information about pasture and fertiliser responses helps. Using fodder and supplementary feeds to fill feed or nutrition gaps helps. Having information about interactions between pastures, other feeds and animal responses also helps. Being able to integrate and synchronise all these complex interacting factors through a computer based system may allow farm resources to be used to achieve the highest output of milk from the lowest input of fertilisers, labour, other feeds and funds.

- The rationale for investing in understanding the optimal development and use of supplementary feeds relates to the need to support intensive grazing management systems including cow nutritional needs. Being able to maintain high stocking rates even under variable pasture growing conditions are important for maintaining the economies of scale and scope of a dairy farm.

- Investment in pastures remained important throughout the period despite increasing use and reliance on supplementary feeding systems. Decision rules aimed at high levels of pasture eaten per hectare remained of ‘equal importance’ for complex systems as for ‘all pasture’ based systems (Macdonald et al, 2010).
Evidence of success, failure and uptake

The considerable investment in agronomic and grazing management RD&E that has been undertaken over the past three decades (and which continues today through such programs as Feeding Pastures for Profit) has resulted in the development and uptake of a considerable amount of knowledge.

- There is now a considerable body of information on DM intake in relation to pasture allowance. Relationships have been developed to predict pasture intake when many factors vary such as pasture allowance, pasture type, pasture mass, cow type and stage of lactation. The knowledge of and ability to predict the nutrient content of pastures improved markedly over the 1990s. The information is summarised in databases available by computer (Doyle et al, 2000).

- Some of the R&D investment focused on experimental work to adapt research results from other sources to Victoria’s grazing conditions. In particular, the timing and intensity of strip grazing, fixed rotational grazing and strategic rotational grazing were important areas of applied R&D that contributed to improvements in grazing management practices. Some of the research efforts had wider applications and contributed to pasture management gains in other livestock industries.

- Forage selection by cows during grazing and the digestibility of the intake are additional factors to consider in pasture management and high rates of digestion mean more energy is consumed by the cow. R&D has helped:
  - provide understanding the nutrient content of pastures and the dry matter that is ultimately digested by the cows which has been important for feed budgeting calculations; and
  - extend the knowledge base on relationships between feed management and milk yields.

- ‘Investment by key stakeholders in pasture plant improvement over the past decade has seen the formation of world class scientific team, with expertise across the traditional pasture plant genetics and breeding and newer biosciences (functional genomics) and access to state of the art infrastructure’ (Doyle et al, 2010).

Importance to the industry

Indicators are that the impacts have been far-reaching.


- Doyle, Jacobs and Henry conclude (2010) that ‘traditional pasture systems in different dairy regions have underpinned the competitive advantage of Australian dairy farm businesses. Leading pasture-based farmers have fully
exploited the current potential of these systems at farm scale and are now seeking alternatives to drive output improvements from their resource base’.

- Wales et al (2006) conclude that increases in milk production per hectare have been achieved by better forage management and through increased stocking rates, although supplementary feeding has played a key role since the 1982 drought as well.

- Some RD&E has helped assess and test the merits of alternative forage crops to traditional perennial ryegrass-based pastures and helped further strengthen the evidence on the robustness of the latter (Jacobs and Woodward, 2010) which can be helpful for farmers strategic planning.

**Overall impact on the industry**

There is no comprehensive evaluation on the payoffs from the various RD&E programs that has been undertaken in the last 30 years, although evidence presented in table 4.9 is that pasture production and utilisation appears to have increased by around 50 per cent. There are also a number of partial indicators suggesting considerable gains have been achieved from RD&E involvement.

- An evaluation of the Target 10 Grazing Management Program completed in 2000 reports net improvement in pasture consumption of around 8 per cent and of a further 2.5 per cent increase in milk production among program participants. This was suggested to be worth $8 804 among participating farms in 2000 dollar terms (Department of Natural Resources, 2000).

- In addition, an evaluation of the Target 10 fertiliser program estimated gains worth $1100 per farm per year from optimal fertiliser use. See box 6.2 for further details.

- A later study by Habgood and Drysdale (2009) indicated much larger potential gains from the Feeding Pastures for Profit Program. This program was based on new research emphasising the importance of the three leaf stage and residuals on pasture growth rate and differed from previous grazing management programs in providing more refined design making tools for handling complex biological and economic systems.
6.2 Case study: Target 10

Target 10 was a State wide extension program initiated by DPIV with financial support from the DRDC. The first phase of the project (1993–95) ran for three years and began as a Gippsland regional initiative with a focus on pasture consumption. A pilot program showed changes in grazing practices achieved a 15 per cent increase in per ha pasture consumption with reduced grain feeding (O’Brien and Hepworth, 1994).

The project name reflected the aim — a 10 per cent increase in per ha pasture consumption on 50 per cent of the State’s farms over five years. This was expected to yield a gross financial gain of $16 000 on a typical dairy farm. The two key objectives were to:

- improve the skills of farmers in pasture and grazing management; and
- develop and evaluate systems to achieve an increase in pasture consumption.

The extension approach was a combination of technical training, peer group discussions, on-farm practical application and benchmarking. Regional project committees were set up to guide the core extension activities on pasture management. Some related non-core activities were implemented on issues such as animal health, nutrition and water use.

Pasture management tools were developed and distributed. Assorted written materials pasture and grazing management practices were distributed. Seminars were held on non-cores issues such as animal health and cow nutrition. An irrigation drainage manual was developed and distributed.

In phase two (1996–99) the scope of the project was widened to take a boarder view of feed management issues. It ran for three and a half years and the aim was to encourage the adoption of more efficient and sustainable farm management practices. There were five components of extension activities — grazing management, soils and fertilisers, nutrition, natural resource management and business management.

The focus of the first component was improved grazing management practices. Training in pasture assessment skills and feed budgeting techniques were key elements of the training. This involved skills development in areas such as:

- pasture height and dry matter per ha availability;
- grazing rotations, stocking rates and pasture recovery rates;
- conservation of spring surplus; and
- use of feed supplements and developing feed budgets.

(Continued next page)
6.2 Case study: Target 10 (Continued)

The aim of the soils and fertilisers component was to encourage cost-effective fertiliser management decisions. There was training in plant nutrient requirements, estimating soil nutrients, fertiliser selection and application strategies. A comprehensive manual on fertilising pastures was distributed and advice was provided on the environmental issues associated with fertiliser use.

The investment in the first phase of Target 10 was $5.8 million. In the second phase the investment was increased to $7.8 million.

The target 10 program had an extensive impact across the State. In the first phase there were 149 grazing management courses and 26 per cent of farmers (2786) attended. There were 140 farmer discussion groups formed and 2128 farmers participated in 2450 group meetings. Follow up inquiries at the end of phase one found 63 per cent of participants changed their pasture and grazing management practices. By the end of phase one over 40 per cent of Victoria’s dairy farmers had participated in Target 10 extension activities (Boomsma et al, 1996)

There was a strong acceptance of the extension advice which was reflected in widespread intentions to alter paddock subdivisions, fodder conservation practices and stocking rates. Pilot program results in Gippsland showed participants achieved:

- 15 per cent more dry matter consumption per ha than non-participants;
- 2 per cent more cows milked than non-participants; and
- 10 per cent more butterfat production per ha than non-participants.

An evaluation of phase one found a net benefit of $63 million across the state (Appleyard et al, 1996). Two other studies found net benefits of between $38 and $68 million in NPV terms and a benefit cost ratio of between 5 and 10 to 1 (DPIV, 1996).

In the second phase 49 grazing management courses were held and 792 people attended. Around 90 per cent of participants reported increased per ha pasture consumption after applying the training advice. In Gippsland the increase was 22 per cent but there was no non-participant estimate for comparison purposes.

There were 30 soils and fertiliser courses across the state and 582 participants. There was strong acceptance of the need for soil testing and fertiliser use plans. Around 66 per cent of the participants changed their fertiliser use practices with adjustments in application rates, timing of applications and the type of fertiliser.

A phase two evaluation found annual benefits of $3.2 million for the Gippsland region. A state wide extrapolation suggested an annual benefit of $8.5 million (Continued next page).
6.2 Case study: Target 10 (Continued)

(Boomsma et al, 1999). It was an assessment based on three activity areas — grazing management, soils and fertiliser and nutrition. The economic benefits were worth $13 900 per farm with 63 per cent of the gains generated by the training on grazing management ($8800 per farm). Evaluation work suggests net gains in pasture consumption of about 8 per cent and milk production increases of 2.5 per cent (DNRE, 2000).

The soils and fertiliser component generated benefits of $1100 per farm — 8 per cent of the total. Gains were more cost-effective fertiliser use and environmental improvements from less nutrient run-off into water ways. About a quarter of the participants achieved cost savings from changing their management practices.

A range of self help extension materials on fertiliser use have been made available in recent times. In 2005 a second edition of the Target 10 training manual on fertiliser use was published (DPIV, 2005). The BFD project assembled all the technical information on soil nutrient testing for pasture production. It developed the Farm Nutrient Loss Index to help farmers identify and reduce pasture nutrient losses (DPIV, 2007). But there has been no assessment of the uptake and impact of these extension efforts.

The Feeding Pastures for Profit (FPFP) program was principally extension focused but, importantly, was based on new research emphasising the importance of the three leaf stage and residual on pasture growth rate (Habgood and Drysdale, 2009). Research showed that a grazing interval based on plant leaf regrowth stage optimised the persistence, production, utilisation and quality of temperate pasture species (MacDonald et al, 2010).

- Habgood and Drysdale (2009) suggests benefits from growing and using more pasture of up to 3.8 tonnes extra pasture consumption per hectare for a typical farm scenario moving to best practice. They show improvements from a base case starting point of an operating surplus of around $100 000 rising to around $250 000 per farm. Conservatively they estimate the benefit cost ratio from the program to be between 29 and 42 to 1 for the 151 farms involved in the program over six years. Also see box 6.3.
- A case study by Wales et al (2006) of one farm in Northern Victoria indicates that through a strategy of strategic use of nitrogen fertilizer and improved grazing management, pasture output was increased by 20 per cent and profits by 14 per cent.
6.3 Case study: Feeding Pastures for Profit

Fulkerson and Donaghy (2001) concluded that relating grazing interval to leaf number enabled farmers to maximise growth and persistence of ryegrass and optimise nutrient levels through setting the minimum and maximum grazing intervals at the 2 and 3 leaves/tiller stages, respectively.

Through the FPFP program participants were offered support to make grazing management and supplement decisions in the context of seasonal conditions, changing milk price and supplement costs (Habgood and Drysdale, 2009). The program provided farmers with a framework to short term daily adjustments through establishing a Body of Evidence, and longer term rotation and pasture conservation decisions through the Rotation Right tool and the Blocks system.

Improvements in pasture growth and cow nutrition attained by participants enabled higher milk production, reduced supplementary feed costs and surplus. FPFP delivery staff reported (Habgood and Drysdale, 2009):

- improved pasture quality, increased pasture quantity, and greater strategic use of fertiliser among over 90 per cent of program participants;
- improved pasture density and persistence among 60 per cent of farms;
- increased conservation of fodder among 50 to 70 per cent of farmers and more timely conservation of fodder among 20 to 40 per cent of farmers;
- increased milk production among 20 to 50 per cent; and
- a wide range of other benefits from improved cow management outcomes to the selection of forage species.

Adoption of FPFP practices including increased use of nitrogen fertiliser is estimated to have resulted, on average, in pasture consumption increases from 6.2 tonnes DM per hectare (3.4 tonnes per cow) to 7.7 tonnes DM per hectare (3.8 tonnes per cow). By expanding the number of cows milked to fully exploit potential benefits from the grazing management strategies, pasture consumption could increase to 10.0 tonnes DM per hectare or 4.0 tonnes per cow. This often required investment in farm infrastructure and additional cows.

The FPFP is expected to bring forward and increase the adoption of optimal grazing management practices resulting in a project benefit cost ratio of 35:1 (at a discount rate of 10 per cent). Whilst the analysis does not account for any potential on farm investment required to attain the associated benefits, the benefits are illustrative of the positive (and potentially significant) returns achieved.
Limitations

Although a great deal of high-quality R&D in feedbase production and utilisation has been undertaken, some stakeholders are of the view that this has not necessarily resulted in significant on-farm change everywhere. The uptake since the 1990s (relating to the management of traditional perennial ryegrass systems) has not been as rapid as it could be evidenced by the fact that programs such as Feeding Pastures for Profit are still ongoing (Doyle et al., 2010).

- Considerable potential still exists to increase feed production in other regions through more appropriate use of fertiliser and through management practices which overcome the effects of water logging and pugging (Doyle et al., 2000). A conclusion of Jacobs and Woodward (2010) is that even the very best commercial farms appear to achieve considerably less than what might be possible under experimental conditions.
- The complexity of feed management decisions increased as the R&D knowledge base expanded, especially in the 2000s, when farmers were faced with a range of external challenges — including drought, water security, NRM constraints including, labour and succession issues, and large variations in milk prices and input costs, especially as a result of the global financial crisis in 2008–09.
- This all required a commensurate improvement in the skills of farmers to apply the knowledge. R&D results and technical manuals could not alone achieve a widespread adoption of new pasture and grazing management practices. There was a clear strategic rationale for investments in extension efforts such as Target 10, the FPFP program and advisory materials on fertiliser use from the ‘Better Fertiliser Decisions’ project.

Outcomes from RD&E on grazing management and pastures

The strategic rationale for RD&E investments in pasture and grazing management was because of the critical importance of low cost pasture feed for industry competitiveness and long term economic sustainability. Scientific advances, alternative production methods and R&D results from other sources often had to be adapted, refined or proved to be viable. The natural resource base and climatic conditions of dairy farming areas varies across the State and differ from other countries. Many advances and refinements in scientific knowledge relating to the natural resource base and climatic conditions of dairy farming in Victoria are unique. This was a feature of the strategic rationale for many RD&E investments in this area.

The key RD&E challenges, outputs and outcomes related to pasture utilisation over the past three decades are summarised in table 6.4.
6.4 Grazing systems and pastures

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<tr>
<th>Industry challenges</th>
<th>Outputs of RD&amp;E</th>
<th>Outcomes</th>
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<tr>
<td>Low pasture utilisation.</td>
<td>R&amp;D gains in understanding pasture productivity and relationships to predict pasture intake when a range of factors vary (Doyle et al 2000). Validation of relationships with computer models such as Grazfeed.</td>
<td>Strong biological understanding of pastures</td>
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<td>Research in irrigated pastures was very limited.</td>
<td>Ability to predict milk responses from pasture allowance to pasture intake and selection differentials.</td>
<td>Better use of nitrogen fertiliser and improved ability to use less phosphorus without adverse impact on DM grown</td>
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<td>Inefficient pasture management systems – lack of persistence with improved species</td>
<td>Pasture research identified frequency of allocation of pasture to improve cow performance.</td>
<td>Improved pasture utilisation rates</td>
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<td>Lack of integration of the excellent body of research</td>
<td>Research focus in late 1990s on options to improve perennial ryegrass plant and tiller densities via renovation and oversowing options and refinements to grazing practices.</td>
<td>Increased pasture production</td>
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<td>Better integration of knowledge</td>
<td>Significant advances in rotational grazing management</td>
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<td>Improved linkages between pasture management and farm profitability under variable conditions</td>
<td>Increased planting of alternative forages (cheaper)</td>
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<td></td>
<td>Development of high energy fructan perennial ryegrass and high digestibility forages</td>
<td>Home grown fodder replacing purchased concentrates</td>
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<td></td>
<td>Still opportunities for further take up of technology</td>
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<td></td>
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<td>Still gaps in knowledge of interactions with supplements</td>
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Source: TheCIE.

Feed supplements

The use of supplementarily feed in annual feed budgeting decisions was a major change in the approach to dairy farming. Instead of managing herds around the seasonal growth of pastures and conserved feed (that is, hay and silage), high energy supplements sourced from outside the farm were introduced. The acceptance of the approach largely grew from observing the results of grain feeding in the 1982–83 drought and the increased use of incentive payments by processors to maintain production levels..

RD&E investments: supplements

The broad thrust of RD&E related to feed has been to improve the level of utilisation of pasture as the lowest cost element of the feedbase (National Dairy Alliance, 2000). However, it is estimated that between 5 and 10 per cent of on farm investment in RD&E has been spent on feed use and nutrition over the past 30 years. RD&E in supplements has been undertaken in the following areas:
research focused on the remaining area of uncertainty concerning the interactions between pasture and supplements and the responses to supplements at critical times (National Dairy Alliance, 2000);

research focused on the optimum use of all feed sources, including forages and some less traditional feeds (National Dairy Alliance, 2000);

attention to the development of the feedbase that makes best use of all components, such as the use of molasses to supplement the low energy, high fibre, tropical grasses (National Dairy Alliance, 2000);

development of decision support systems utilising research on interaction of cows, pastures and supplements under low to moderate amounts of grain to assist farmers in decisions about feedbase utilisation (National Dairy Alliance, 2000);

and

supplement rationing skills needed to apply effective utilisation and pasture management profitably (National Dairy Alliance, 2000).

‘A major research objective over the past 10 years has been to understand the interactions between pasture, concentrate supplements fed in the dairy and cows to enable development of feeding systems that are profitable’ (Doyle and Stockdale, 2008).

In the early 1980’s there was very little RD&E funding in the area of feed supplements. The focus was on pasture feed production and utilisation which received around 40 per cent of ADRC funding on farm related RD&E in 1982–83. The emphasis changed when the first five year plan prepared by the ADRC (1986–1991) for RD&E was developed. One of the strategic priorities was trial feed base development work and extension that included the use of by-product or concentrate supplements.

Early RD&E focussed on reviews of the scientific knowledge base in the nutrition area to establish the strategic direction for future RD&E. Attention was focused on the nutrient intake from pastures and the interactions between pastures, supplements and milk production.

R&D on the milk yield response to grain feeding was undertaken at Ellinbank and Kyabram. It led to a state wide extension project ‘Operation Milk Yield’ (OMY) which ran for three years (1985–87) which used selected farms in each of Victoria’s dairying regions to assess the response of established herds to concentrate feeding. The aim was to examine the effect on animal improvement and farm profitability. The two main areas of investigation were intensive production and the effect of feeding concentrates in mid to late lactation.

There were two streams of RD&E in the area of feed base supplements. One involved the nutrient requirements of cows and how it influenced lactation performance. The other focused on the production and utilisation of non-pasture feed supplements to
cover feed gaps. This second area of activity had implications for stocking rates that were set to maximise pasture utilisation during the peak growth period.

The Victorian DPI program in dairy RD&E in the early 1990s had eight key initiatives including an activity on feed base supplements. This activity accounted for 4 per cent of program funding in 1994–95. In 1991–92 around 16 per cent of RD&E expenditures were allocated to this activity area (Kefford et al, 1992).

A series of regional workshops were held by DPIV in the mid 1990s to establish RD&E priorities in feed supplements area. It led to the development of a state wide program of work on the nutrient intake of cows with joint funding from the DRDC. The aim of the 'Feed Base Utilisation' program of work was to improve feed utilisation and increase annual milk output by 6 per cent. This program was one of seven initiatives in DPIV’s portfolio of RD&E work in the late 1990s which was directed by the Dairy Industry Strategy.

Program activities included collating the available information on the nutrient value of pastures and feed supplements. It also included a review of best practise management for silage making. One of the outcomes of the work was to develop guidelines on a range of issues associated with supplement use in pasture production system. This included:

- how cows on pastures respond to different supplements;
- the effect of supplements on pasture intake;
- use of supplements in irrigation areas in the autumn; and
- the need for mineral supplements.

The shift towards supplementary feeding involved considerations about cow nutritional and nutrient requirements. As already indentified earlier in the report, this shift was in the context of an ongoing move to more intensive feeding systems in response to these requirements and to greater climate variability.

It increased the complexity of feed management decisions and farmers needed to improve their skills in this area: this has been a key area of focus for extension programs, particularly over the past decade as highlighted in DMF and its Feedbase and Animal Nutrition priorities for the industry.

**Rationale for RD&E investment: supplements**

The need for RD&E on supplements evolved from RD&E in pasture management. One objective was to develop cost effective feed supplementation strategies to complement increased pasture utilisation associated with the first phase of the Target 10 extension program. A strategic rationale for this area of work was related to the changes in pasture and grazing management that evolved during the 1980s and 1990s.
RD&E investments were demonstrating the gains in pasture utilisation that could be achieved from adopting new management practices. The key to improved pasture utilisation is increased stocking rates when pasture growth is highest. This requires greater use of supplements and improved feed management skills to handle feed gaps in periods when pasture growth is limited. R&D knowledge and advice on the optimal use of supplements in feed budgeting decisions was an important contributor to the changes in pasture management and gains in farm performance.

The importance of supplementation has increased due to higher cow nutritional requirements resulting from genetic selection towards higher yielding cows. Supplementary feed concentrates include grain which gives it a higher energy concentration. Cow performance can be improved when the nutritional quality of the feed input is enhanced by combining concentrates with pasture feed.

The interest in supplements was further stimulated by concerns about the relatively low milk yields being achieved in comparison to other countries. The nutritional content of feed inputs, the requirements of cows and mid-to-late lactation performance became important areas of RD&E activity in the late 1980s and 1990s. There was a focus on changing management practices in the use of supplements and in hay or silage conservation to cover nutritional feed gaps when pasture growth diminished:

- the RD&E efforts showed that substantial gains in profitability could be achieved from improving the nutritional content of feed inputs during lactation;
- the benefits of using feed supplements came from milk yield gains in mid-to-late lactation and supporting higher stocking rates based on improved utilisation of pasture feed during the peak period of pasture growth.

In general farmers were unsure about the optimal use of feed supplements in the early 1980s. Substantial gains could be achieved in cow performance but the optimal feeding strategy had to be assessed in the context of enterprise profitability, taking into account considerations of milk prices, the cost of supplements and cow performance. There was a clear strategic need for applied research in Victoria’s farming conditions and a complementary investment in extension efforts to improve management skills.

The adoption of existing information on supplementary feeding was still relatively poor in the early 1990s and industry knowledge of production costs remained limited whilst the requirements for sophisticated management skills were increasing as farms consolidated and intensified.

Passive extension activities were unlikely to be sufficient to generate the improved management skills that were necessary. It required an investment in extension activities such as Target 10 which involved training, peer group discussions and farm visits. The objectives of RD&E related to supplementary feeding included:
training scientists on the role and benefits of feed supplements in the nutrition of dairy cattle;
identifying dietary deficiencies that reduced the utilisation of feed nutrients; and
develop extension advice for farmers of the profitable use of supplements.

**Evidence of success, failure and uptake: supplements**

Supplementary feeding has been necessary to achieve the dramatic increase in the genetic merit of dairy cows in relation to milk production over the past 20 years. There is evidence that Holstein Friesians selected for their high production potential are not capable of eating significantly more dry matter (DM) on diets with a high proportion of pasture than cows of lower production potential (Beever and Doyle, 2007). Cows consuming large quantities of supplementary feed such as through mixed rations are capable of consuming more DM and nutrients leading to higher milk production, increased milk production and less body condition loss in early lactation (Beever and Doyle, 2007).

RD&E on supplementary feeding provided an improved understanding of the dietary limitations to milk production from pasture fed cows:

- the investments in applied RD&E on balancing the nutrient content of alternative combinations of pasture and supplements were necessary because the advice had to suit the physical operating conditions of Victoria’s dairy industry;
- R&D from overseas was not directly applicable — it had to be refined, advanced and adapted to the characteristics or our pasture based production systems.

**Operation Milk Yield**

‘Operation Milk Yield’ (OMY), which ran for three years (1985–87), used selected farms in each of Victoria’s dairying regions to assess the response of established herds to concentrate feeding. The aim was to examine the effect on animal improvement and farm profitability. The two main areas of investigation were intensive production and the effect of feeding concentrates in mid to late lactation.

- The project provided information on the tradeoffs involved with more intensive farming. The optimal use of concentrates could allow increased stocking rates and per hectare milk output while maintaining or increasing per cow milk yields. It was a major contribution to the knowledge base on concentrate feeding and subsequent farm production gains.
- The project also provided information on the gains from concentrate feeding in summer and autumn. Lower quality and quantity of pasture in the mid to late lactation period affected milk yields. The research provided evidence on the yield gains from using concentrates to supplement feed gaps. It showed there were other benefits in extending the length of lactation, improving cow condition and aiding pasture management.
OMY was one of the first extension programs to take a whole farm approach to feeding dairy cows. It proved it was more profitable to use feed concentrates to increase both the stocking rates and milk yields rather than just increase per cow milk production. Through various forums the extension aspects of the project disseminated information on:

- the production and economic results of strategic feeding of cereal grains to grazing dairy cows; and
- related farm management issues such as calving patterns, breeding management, and quantifying the nutrient requirements of milking cows.

The OMY project was a combination of development work on the application of research results and associated extension activities. It made use of earlier investments in applied research by DPIV on the effects of concentrate feeding on milk yields.

Operation Mid-Lactation

The OMY project was followed up with a related project that focused on improving milk yields after peak lactation. The ‘Operation Mid Lactation’ (OML) project was developed for the north of the State and ran for two years (1990–91). The OML project used 600 farms across the region to demonstrate the effect of feed and pasture management on post-peak milk yields.

- The aim was to encourage farmers to develop their overall feed management skills — it was not focused on concentrate feeding. This was achieved by setting realistic targets for milk yields and self-analysis of the reasons for performance changes. But it also focused attention on related herd management issues. Over time the scope of the extension advice evolved to cover other enterprise management issues.
- The project provided information on how to raise milk production in mid to late lactation. Participants were able to assess the yield gains from altering their management decisions. They were given technical advice and recommendations for monthly planning on pasture and feed management.
- Manuals with guidelines on supplementary feeding in conjunction with pastures were prepared and made available to farmers. Feed management tools were developed including programs to assist decision making on the profitable use of feed supplements in the context of overall feed budgeting.

Target 10

The Target 10 project was established in the early 1990s. The second phase of the project (1996–99) had six core components including a program on dairy cow nutrition.
This was a natural complementary addition to the extension efforts on grazing management. In general the aim was to improve feed budgeting skills when supplementary feed inputs were combined with pasture inputs.

Project participants received training on how to calculate cost-effective feed inputs that matched the farming system. This required formulating feed rations that used the low cost pastures first and then adding the more expensive supplements. It involved considerations of pasture growth response to changing in seasonal conditions, understanding the cow nutrition needs and knowledge of the nutritional content of the alternative feed inputs.

A manual was prepared on best practise and feed budgeting programs were developed. An estimated 707 farms participated in the training on nutrition across the state.

The farm level benefits of the Target 10 extension efforts were generated by improved management practices in meeting the nutritional needs of cows. Skills were developed in assessing the most cost effective mix of feed inputs as pasture conditions changed during the lactation cycle. Apart from higher milk production there were additional gains from improved fertility and reduced disease susceptibility as cows were receiving the required nutritional requirements.

Other extension activity

Before the Target 10 there were several regionally focused dairy cow nutrition extension activities across the state. The Target 10 activities ensured there was consistency in the advice with recognition of regional differences in production systems.

In 2007, the ‘feed.FIBRE.future’ project was delivered as a national response to effects of a critical fodder shortage which dominated winter feeding decisions.

It is important to note that projects, such as ‘Feed.FIBRE.future’ and the subsequent ‘Dealing with Today: Planning for Tomorrow’ project, were not strategic extension activities, but responses to crisis which were notable for the high level of industry-wide collaboration.

The project was funded by the Commonwealth government with a co-investment by the beef and dairy industries. It was an extension project, which provided information and advice to farmers on how to manage feed deficiencies during the period. The combined funding for the project was $1.1 million.

The aim of the project was to develop and disseminate technical information on nutrition, animal health and the relative profitability of feeding options. Advice was provided on the options for managing feed shortages and meeting the nutritional needs of livestock maintenance. A set of fact sheets was distributed to all dairy farmers. There were also opportunities to attend advisory workshops and engage in consultations with nutrition and business management experts.
The industry’s Future Grains initiative in 2004-2007 led to the Grains2Milk program being launched in 2007. Grains2Milk R D & E activities have helped the industry move on from arguing about ‘which is the best grain feeding rate or best feeding system?’ to an acceptance that any grain feeding rate or feeding system can be profitable given an appropriate mix of management, milk price and input costs.

Since 2007, Grains2Milk RD&E activities have included:

- defining five main feeding systems and provided farmers and advisers feed conversion efficiency targets for each system;
- working with DPIV to promote pasture utilisation and FCE as two key feeding system performance measures and provide a measurement tool;
- delivered new information and tools on managing risks associated with buying supplementary feed (quality, supply and price risks);
- researching wastage rates associated with supplements when fed by different methods;
- better understanding the interaction between grain feeding rate, feeding system performance, profit and risk in pasture-based feeding systems (TasMilk60 project);
- progressing RD&E on heat stress and its mitigation (Cool Cows); and
- the ‘Flexible Feeding Systems’ research project being progressed at DPIV Ellinbank (funded by DPIV and DA) which is helping better understanding cow performance in partial mixed ration versus bail feeding systems (systems 2 & 3).

**Overall impact**

There is no broad economic evaluation of the benefits of the investment in applied RD&E on supplementary feeding in Victoria available. However, several indicators suggest considerable gains have been achieved. Supplementary feed use increased during the 1980s and 1990s and in general farmers became more adept in managing the use of supplements in a profitable way. Milk yields increased significantly in the decade from the mid 1980s and some of the gains can be attributed to the use of supplements in conjunction with improved pasture utilisation.

There were evaluations of the Target 10 program. A phase two evaluation reported annual benefits of $3.2 million for the Gippsland region and state wide benefits of $8.5 million (Boomsma et al, 1999). There was an assessment based on three of the activity areas which included the nutrition component. At a farm level the economic benefits were worth $13 900, more than half the gains generated by training on grazing management:

- 44 training courses were delivered under the nutrition component of the program across the State;
the evaluation estimated the annual farm level benefits of the nutrition component were worth $3995 per farm — about 29 per cent of the total program benefits.

An assessment of the effectiveness of the Target 10 extensions activity on nutrition was made from a post project survey of program participants 144 farms (62 per cent). There were 232 farms participating in the program and two thirds were surveyed. The assessment found that 81 per cent of participants had changed their approach to feeding cows. Around half of the participants had adopted ration formulations after the training.

An economic evaluation of the ‘feed.FIBRE.future’ project was undertaken. It estimated there was a one-off annual benefit of $12.5 million for dairy farmers across Australia. More than 600 dairy and beef farmers participated in workshops across Australia and others received project advice through service providers. It is not possible to judge the benefits for Victoria’s dairy industry from the evaluation.

Limitations

‘Considerable R&D has been undertaken in Australia into the interactions between cows, supplements and grazed pasture when low to moderate amounts of grain are fed in the dairy. Substitution, the reduction in pasture intake for each kilogram of supplement consumed, is relatively well understood for the traditional perennial ryegrass-based systems’ (Doyle et al, 2010). ‘However, the negative and positive interactions (affecting ME available from the diet and the efficiency of nitrogen utilisation) that occur when concentrate supplements are fed to grazing cows, are less well defined and ultimately affect the efficiency of conversion of feed into milk and marginal responses to more supplement’ (Doyle et al, 2010). These interactions are particularly important when high amounts of grain are fed.

The inability of the today’s dairy cow to consume sufficient herbage at grazing to meet nutrient requirements has posed significant challenges to the profitability of traditional pasture-based production systems. Thorrold and Doyle (2007) concluded that ‘while benefits had been captured on many farms, inappropriate use has adversely affected profit on others’ (Doyle et al, 2010). Whilst feed conversion efficiency is a key determinant of dairy herd performance, in northern Victoria ‘few farmers in the region measure feed conversion efficiency on an annual, seasonal or shorter term basis’ (Wales et al, 2006). Wales et al (2006) conclude that the measurement and recording of such measures may assist in properly defining the magnitude of the long term marginal milk production responses to cereal grain supplements. It would also enable the difference between ME intake and ME consumed to be properly measured.
7 Contribution of RD&E: animals

Genetic improvement has been an important contributor to gains in herd performance and industry output. It has a gradual compounding effect that is permanent. A herd will typically have cows of different genetic merit. As replacements are introduced the genetic content of the herd changes and, all else unchanged, this will influence the performance of the herd as a group.

Animal genetics

Herd recording, AI and the selection of genetic material are management decisions that can affect the rate of genetic improvement in a herd. Genetic improvement takes time and the selection of genetic material requires objective, independently measured data on a range of performance traits. It also requires a method for combining performance traits in order to make an informed decision that meets long term breeding objectives.

There has been a long standing commitment to RD&E in this area. It recognises the fact that output gains from progressive genetic improvement will increase enterprise profitability. Milk yields, milk composition and milk quality are some of the areas that can be influenced by genetic improvement. It is one of the factors that support longer term industry competitiveness.

RD&E investments

In 1982–83 around 27 per cent of ADRC funding in farm related R&D was allocated to the breeding area. There were only two projects, one of which was support for the RD&E work being undertaken by ADHIS. The first five year plan prepared by the ADRC for dairy RD&E maintained this commitment.

- In the late 1970s the DPIV established a project to estimate breeding values for each State and the ADRC funded a national program of genetic evaluation. The R&D activity by DPIV included the development of programs for managing a national database on performance traits and analysing the data for estimates of breeding values.
- The ADHIS released the first ABVs (Australian Breeding Values) for production traits in January 1983. There had been a substantial investment in R&D in the lead-up to the release of the first ABVs with funding contributions from DPIV and the industry. ABV’s for milk, fat, and protein were released. ABV’s for other traits
were progressively released during the 1980s. Technical support for ADHIS was provided by DPIV, a commitment that continues today.

In the early 1990s ADHIS convened a workshop to establish strategic priorities for the future development of ABVs. It re-affirmed support for ADHIS activities and the strong commitment to R&D for genetic improvement in dairy herds. A method for combining performance traits to establish a genetic selection criteria had been developed. Further investments were made in the ADHIS system for collecting, storing and analysing data on performance traits.

Since then the contribution of ADHIS activities to genetic improvements has continued to evolve. It currently calculates ABV and Potential Breeding Values (PBVs) indices for bulls and cows. The ABVs estimate the genetic value of bulls and provides a method for farmers to rank genetic inputs through various selection traits. The PBVs provide an early estimate of the genetic value of young bulls. The availability and continual updating of ABV and PBV selection traits has provided an objective basis for accelerating gains in herd performance from genetic improvements.

DPIV’s program in dairy RD&E in the early 1990s had eight key initiatives including an activity on animal performance. This activity accounted for 14 per cent of program funding in 1994–95 which was a significant increase on previous funding allocations. In 1991–92 around 6 per cent of RD&E expenditures were allocated to this activity area.

RD&E on genetic improvement was a major part of the animal performance activity. There was a continuing investment in the ADHIS which included enhancements to the data handling and evaluation programs that supported the calculation of selection traits. R&D investments were also made in other areas:

- the top quality milk project was established to investigate the application of molecular genetics in improving milk protein quality and quantity;
- there was research on DNA markers that could be used to establish selection criteria for young bulls on specific milk quality traits — the Accelerated Genetic Improvement Program was an initiative that investigated the development of genetic tests for specific selection traits in dairy and other livestock industries.

In the late 1990s the DPIV’s investments in RD&E was directed by the Dairy Industry Strategy. There were seven initiatives including an animal performance project that continued the investment in molecular genetics research to improve milk quality.

In the past decade there was a shift in the orientation of R&D activities by DPIV towards longer term public good research projects. The Our Rural Landscape’s (ORL) initiative (2000–07) was established with a program focused on animal genomic technologies. The R&D funds invested in the ORL initiative has been substantial.
The objective of the initiative was to reduce farming practices that were detrimental to the environment by adapting plants and livestock to the natural farming conditions. A further objective was to improve the production and quality of products that are adapted to the natural environment. The ‘High Value Livestock in Sustainable Rural Landscapes’ program continued the investment in genetic research:

- two of the core areas of research in animal genomics were bio-actives in milk and milk production;
- the milk production project focused on identifying molecular markers for genetic traits such as milk yield, milk composition and mastitis resistance;
- the milk bio-actives project focused on identifying milk proteins that have human health enhancing properties;
- other areas of research include gene mapping with a focus on identifying genes that activate milk production;
- between 2003–04 and 2006–07 funding for the program was $14.3 million.

Extension efforts in the area of animal genetics have largely relied on ADHIS activities. The organisation was registered public company in 1984. A range of extension tools and materials were developed to raise farmer awareness of the ABVs and their potential role in the selection of genetic material. As new genetic information has been developed and released, additional extension materials have been prepared.

**Rationale for RD&E investment**

Genetic improvement in dairy herds has been a focus of on-farm RD&E investments for some time. It has long been recognised that significant economic benefits can be achieved from gains in herd performance that arise from introducing improved genetics. The gains are incremental but permanent if there is a long term commitment to a continual up-grade in the genetic pool of the herd.

- The introduction of AI in the 1950’s and use of herd recording gave farmers the means to accelerate the rate of herd performance gains from genetic improvement. But the full potential of these management activities could not be realised without access to data for comparing the performance traits of alternative genetic material. R&D investments were made to establish this capability.
- These developments enable farmers to accurately assess the potential of genetic material and make selections based on the performance traits that matched their breeding objectives.
- A reliable source of independent assessments on the performance traits of alternative genetic material is required to maximise the economic gains from genetic improvement. The provision of such information can accelerate the rate of gain. It can also reduce the risk of genetic decline through poor selection.
Continual revisions to the performance assessments as new data becomes available help to maintain the rate of improvement.

- In the late 1970s this information was not available. There was little prospect of a private assessment service developing and the effectiveness of efforts to achieve faster rates of genetic gain was limited. An independent source of information on the genetic merit of alternative bulls was necessary. It had the potential to generate herd performance and output gains that would help to improve industry competitiveness.

This was the strategic rationale behind the DPIV decision to invest R&D funds in the calculation of breeding values in the late 1970s. It was also the strategy behind investing industry funds in establishing the ADHIS. Collectively these decisions provided the basis for objective comparisons of genetic material and in time faster rates of genetic gain.

The development of ABVs for different selection traits and a method for combining the selection traits was a major advancement for the industry. Over time incremental gains in the efficiency of feed to milk conversion, milk composition and milk yields have been beneficial for industry production and profitability.

Evidence of success, failure and uptake

The ABVs are widely used in the industry and it has contributed to a faster rate of genetic improvement. This has been assisted by the widespread use of AI which has risen from 70 per cent to over 80 per cent. Extension efforts have been undertaken involving:

- technical notes prepared and distributed by ADHIS on a range of topics associated with the ABVs and related issues;
- ADHIS and DPIV extension services cooperating in the delivery of training courses and workshops to educate farmers and service providers on issues related to genetic improvement and the use of performance measures such as the ABVs;
- ABV updates being publically released twice a year and guides on genetic selection have been made available — the Good Bulls Guide provides regularly updated advice on bull selection with listings of traits such as type, longevity, mastitis resistance, production and profit; and
- in 2010 ADHIS producing the first genomic based breeding values for bulls and this has been accompanied by extension efforts to help farmers and their advisers understand the presentation of the information.

The extent of the contribution of genetics RD&E to industry development is difficult to assess — a number of factors have contributed to performance gains over the past 30 years. Genetic selection using ADHIS estimates of production performance traits
are expected to have contributed to incremental gains in herd performance that have accumulated over time:

- some overseas studies have shown there are significant farm profitability benefits from genetic selection based on key performance traits such as milk yield (VanRaden 2004, Roibas and Alvarez 2010, Lopez-Villalobas et al 2000);
- an Australian study has shown the APR (Australian Profit Ranking) index of performance traits published by the ADHIS is a reasonable predictor of future performance (Haile-Mariam et al, 2010) and there has been an evaluation of ADHIS suggesting significant benefits from the use of ABVs in genetic selection decisions (BDA Group, 2007), with an estimated $200 million in net benefits to Australian dairy farmers at a cost of about $10 million; based on cost over three year and benefits extending out until 2025 plus full uptake of the technology.

The ORL initiative has shifted the balance of R&D funding away from a previous heavy reliance on applied R&D to strategic, public good research. It is difficult to quantify the benefits of project outcomes because it is long term research still in the early stages of development.

An evaluation was made of the ORL milk production project (URS, 2007). It focused on the benefits of the genetic marker identification technology that allows DNA based selection for milk production traits. AI companies can use the technology to select bulls with the highest ASI breeding values. The ASI measures the net income (dollars/cow year) from the extra sales of milk that arise from improved selection.

Adopting the technology was expected to generate a net income gain of $6 per cow per year for the life of the cow. The potential annual gross benefit was estimated to be worth $17 million. The gains would likely to be shared between semen suppliers and farmers that made use of the improved genetic selection technology. With further research the technology could result in reduced progeny testing costs for AI companies. This potential extra benefit was not included in the evaluation.

Farmers that purchase semen from Genetics Australia and other artificial breeding companies for AI will benefit from the adoption of the technology. Easier identification of genetic markers will improve the quality of semen purchases. Dairy Australia has funded an extension effort to raise farmer awareness of the benefits of the technology for improving genetic selection in semen.

There was an earlier evaluation of the potential economic benefits from the DPIV investment in genomics research under the ORL initiative (Allens, 2006). It reviewed R&D developments under the initiative over the 1999–2005 period under the assumption the new technologies are successfully applied.

The evaluation included ‘High Value Livestock in Sustainable Rural Landscapes’ program. Potential future benefits from the dairy production project suggested gains from the application of DNA markers for bulls could be worth $200 million in annual
cost savings after 10 years. The evaluation also suggested the adoption of new grass varieties in the dairy industry could be worth $50 – $100 million.

The evaluation was based on the use of ABVs to test DNA markers developed in the animal genomics program. It showed the DNA markers would have achieved higher rates of genetic gains. Using genetic markers for selection traits could generate production cost savings of 1 to 2 per cent per year.

Genetics Australia is a commercialisation partner for DPIV’s genetic marker technology. It supplies around 40 per cent of dairy industry genetics (bull semen). There are expectations that Genetics Australia will soon be testing for a range of genetic traits using the DNA marker technology developed through the animal genomics R&D program.

Animal health and fertility

Animal health and welfare is an important issue for herd performance. It affects milk production and milk quality. Improvements in animal health can enhance output and increase the value of the milk. The two issues identified at the industry workshop as major areas of change were mastitis control and herd fertility.

Milk quality and mastitis control

Bacterial cell counts are the critical factor in milk quality. The higher the somatic cell count, the lower the milk quality. High cell counts limit the options for dairy product manufacturing and reduce milk returns. It generally indicates animal health issues and/or poor dairy shed hygiene.

RD&E investments

In general the strategic objective of the animal health R&D was to improve output and enhance animal welfare. For example, in 1982–83 about 22 per cent of industry funding was allocated to 16 projects on animal health issues including mastitis. In the late 1980s one of the strategic priorities in the first five year plan for industry RD&E was investigation of the control of diseases in dairy cattle including mastitis.

In the early 1990s DPIV’s dairy program allocated around 14 per cent of the budget to animal health projects (AV, 1995). The Dairy Industry Program (1993–98) was a $25 million investment with a $3.3 million contribution from the DRDC. Animal health was one of eight activity areas and in 1994–95 it accounted for over 13 per cent of program funding.

* Countdown Downunder was a national extension project established by the industry in the late 1990s. The objective was to improve milk quality by promoting best practise mastitis control and improved animal health management (DRDC 2001, 2005). There were three phases to the project — each
phase ran for three years. The first phase began in 1998–99 and the third phase ended in 2006–07:

- the project had separate Victorian components for the North, South-East and Gippsland — DPIV staff participated in the delivery of the project;
- the national RD&E investment for phase one was $1.6 million — the investment for phases two and three is unknown.

- Technical information used by the project was based on the results of scientific research on mastitis from a variety of sources. During the 1980s and 1990s the industry invested in a range of R&D projects that focused on mastitis control issues. Projects were undertaken by the CSIRO and State Departments of Agriculture including DPIV.

- The extension effort in *Countdown Downunder* was initially targeted at people that gave advice to farmers to ensure their recommendations were consistent and appropriate. Some of the advisers were subsequently used to deliver farmer training courses:
  - phase one training focused on the development of mastitis control plans;
  - phase two focused on best practice disease management; and
  - phase three focused on risk management.

**Rationale for RD&E investment**

High cell counts are largely caused by mastitis infections. The degree and incidence of infection across a herd affects the quality of the milk harvest. It also affects milk yields and clinical cases may require the removal of a cow from the herd. Management plans for the prevention and control of mastitis can generate significant benefits for producers.

Milk with low cell counts is highly valued by dairy manufacturers. Payment systems with price penalties and premiums for milk quality were introduced in the mid 1990s. A price premium of about 1 cent/litre was typical for milk with cell counts of less than 150 000 to 250 000 cells/mL. Cell counts began to decline after the incentive was introduced as it encouraged a stronger focus on mastitis control.

Early detection and high levels of hygiene for milking machines was the key to effective mastitis control. If a mastitis problem developed, identifying and correcting the cause was difficult. Farmers often received confusing and inconsistent advice. This limited the rate of improvement in cell counts. Many farmers were unaware of best practice management and the accumulated R&D knowledge on mastitis issues.

The strategic rationale for the project was to encourage a cultural change in mastitis management in line with incentives in milk pricing. Expectations changed when Europe introduced higher standards for milk cell counts. National targets were set in
1998 and the project was established to help farmers develop the skills to achieve the targets.

**Evidence of success, failure and uptake**

One of the strategic objectives of RD&E on animal health was to investigate more effective strategies of mastitis control. A new antibacterial therapeutic agent for assessing mastitis treatment was developed as part of this investment.

A best practice manual with guidelines for the prevention and control of mastitis was also prepared. Supplementary sets of technical notes provided scientific evidence to support the advice in the manual. The two documents provided the basis for training activities and became the core reference materials for farmers and dairy advisers.

The recommendations in the manual were guided by the Australian Mastitis Advisory Council. Various technical working groups were formed to distil the findings of the available science and design training activities.

The documents and training contributed to improvements in farmer planning for effective mastitis control.

- By the end of phase one of Countdown Downunder 46 per cent of Australian dairy farmers were using the manual — over 8000 copies were purchased. Around 5500 farmers and milk harvesters attended meetings on mastitis control.

- In phase two a Farmer Short Course on best practise management was the key activity. More than 1800 farmers participated in the training course. A key goal was to achieve a cell count of less than 400 000 cells/mL across Australia and for 90 per cent of the milk supply to be less than 250 000 cells/mL. The goal was strategically important for maintaining the industry’s reputation as a supplier of high quality dairy products on world markets.

- There is no evaluation of the economic payoffs from the project in Victoria. But there are indicators that it did make a contribution to lower cell counts and higher milk quality. The manual on mastitis control was widely distributed. Course attendance in phase two suggests there was a significant direct impact:
  - 54 farmer training courses were run across the state over the three year period;
  - 16 per cent of Victoria’s dairy farmers participated in the courses.

There is evidence of progressive gains until drought conditions from 2003 forced some farmers to reduce expenditures on the products and services required for effective mastitis management:

- across Australia there was a declining trend in average herd cell count from 89 per cent below 400 000 cells/mL in 1997–98 to 92 per cent by 1999–00;
- in 2003 cell counts below 400 000 cells/mL were 94 per cent nationally;
- cell counts below 250 000 cells/mL were 71 per cent nationally;
by the end of phase two 66 per cent of participants reported they had lowered the average cell count in their herds after completing the course.

The economic benefits of lower cell counts are premium payments for milk that meets specified thresholds, increased output because of improved udder health and a reduced incidence of clinical mastitis. The average cost saving from reducing the incidence of clinical cases was $169 per cow in 2004. Reduced culling for mastitis treatment has an additional benefit in the form of reducing the temporary loss of production.

Herd fertility

The competitive advantage of Victoria’s dairy industry is linked to the availability of low cost pasture feed in the spring and early summer. Seasonal calving patterns have to be aligned with the available pasture feed supplies to maximise returns. This requires cows to be in-calf within a specified period after their last calving.

RD&E investments

In the late 1980s one of the strategic priorities in the first five year plan for industry RD&E was investigation of the control of diseases in dairy cattle. This included R&D on improved methods for recognising fertility problems and investigating non-infectious infertility problems. Research activities on herd infertility included heat detection, abortion and conception failures.

RD&E projects on fertility issues have been a continuing area of investment over the past 30 years. The DRDC funded projects with a national focus that were undertaken by various research institutions across Australia. The results added to the knowledge base on managing fertility issues which included R&D results from a range of overseas sources.

In the mid 1990s, a project was undertaken to establish the influence of breeding selection for production traits on herd fertility. The project used ABVs and herd recording data on mating and calving rates to show there was no genetic link between high milk production and fertility. This was an important study because of the genetic and breed changes that were occurring since the ABV selection traits were introduced in the 1980s:

- it focused attention on the role of changes in animal management practices to address herd fertility issues;
- the RD&E investment strategy was to focus on extension efforts.

InCalf is a national research and extension project established by the industry in 1996. The aim was to provide information on ways to improve herd fertility through changes in management practices. It drew on the available scientific knowledge to
develop resources and tools to assist dairy farmers in measuring and improving herd fertility on their farm.

Rationale for RD&E investment

Infertility is the primary reason for culling cows. But the interval between calving and the next conception is a critical issue for the profitability of a dairy enterprise. Cost effective milk production needs cows lactating when pasture availability is highest. Prolonged delays in getting cows in-calf affects herd performance — more pasture feed is used for maintenance purposes instead of milk production. There are a range of factors that can affect fertility rates.

Reducing the losses from poor fertility could only be addressed if the causes were clearly understood. Obtaining information through RD&E focus on management practices was crucial.

InCalf was established because around 70 per cent of the variation in reproductive efficiency between farms is due to herd management issues. But many farmers were unaware of best practise management and the accumulated R&D knowledge. Farmers often received confusing and inconsistent advice.

Investments were made in updating and reviewing the R&D evidence on the five factors that affected fertility. The information was assembled and summarised to give farmers a consistent source of advice on recommended changes in management practices. There was a clear strategic need to invest in the project because of the impact of low fertility rates on enterprise profitability. The aim of the current phase of the project (2010–12) is to review industry concerns on fertility management and develop a plan for collective action.

Evidence of success, failure and uptake

To understand the causes of an expert group was assembled to undertake a major study focussing on identification of causes and best practice remedies. Over a three year period the breeding records of nearly 40 000 cows from over 200 dairy herds were used to compile a database that provided detailed information on management practices that would deliver good fertility outcomes.

- There have been several phases to the project and it remains an active area of investment. In the initial phase of the project new methods of measuring reproductive success were developed.
- Key areas of animal management that affect fertility were identified and advisory information on each area was prepared. A package of extension materials were developed including a reference manual and tools for assessing herd fertility:
- Training programs for farmers and advisors were developed and implemented.
The focus of the extension advice was to raise the success rate in getting cows in calf as soon as mating starts. Areas of management change depended on the production system. Improvements in each area can improve fertility rates and the effects are additive.

The InCalf extension advice covered five factors:

- nutrition management — preparing cows for calving and mating with a balanced nutritional diet is the key to getting more cows in calf, sooner;
- bull management — the number of bulls per 100 cows at the start of mating is the key factor in fertility success rates;
- heat detection — a good detection system ensures cows on heat can be submitted to AI or mating as soon as possible after calving.
- heifer growth — a feed plan for heifers with high-quality supplements is important as especially at critical times when there is a shortage of quality pasture;
- AI — conception rates are higher with the use of professional AI technicians.

The InCalf reference manual is considered to be an essential source of advice for farmers on measuring fertility and changes in management practices. It presents all the accepted R&D knowledge on fertility issues including results of the InCalf farm research project. Distribution figures for the manual in Victoria were not available.

There is no evaluation of the economic pay-offs from the project in Victoria. It has made a contribution to improving management practices but indicators of change in fertility rates were not available. Fertility rates can be measured by indicators such as a six-week in-calf rate for seasonal calving herds. An alternative is the 150 day not-in-calf rate. Research in western Victoria suggests 6 week in-calf rate have been declining in recent years and the 150 day not-in-calf rate has been rising (WT, 2010).
8 Farm scale and resource management

The average size of a dairy enterprise has increased considerably over the 30 year period with owner-operators running larger herds with greatly expanded output per labour unit and per hectare. The growth in the scale of dairy farms over the past 30 years has had implications for labour utilisation. Managing larger herds at milking time and handling larger volumes of feed have required labour efficiency improvements through infrastructure and machinery investments.

Farm scale and milk harvesting

Feed management has gradually become more complex and time consuming. Irrigation, hay making and silage production are areas where farmers have become more efficient in the use of their time. The shift to round bales of hay and mobile irrigation equipment are examples of changes that have occurred. Much of the change was autonomous responses through the introduction of new technologies developed by input suppliers. The RD&E investments in these areas have been minimal.

Milk harvesting is the source of the greatest demand for farm labour. As herds expanded, milking times increased. Over time there have been investments in more efficient milking machines and large scale dairy sheds. This is an area where some strategic investments in RD&E have been made.

Milk harvesting and labour productivity

Reductions in milking times can generate significant benefits. Farmers have more time to devote to other management activities and it reduces the need for supplementary labour. It can also have lifestyle benefits. Upgrading to a larger, more efficient milking system is a major capital expenditure for a dairy enterprise. It is a complex decision that requires planning to accommodate future capacity requirements.

Management practices are another factor in the efficiency of milk harvesting. The milking process extends from the time the cows leave the paddock through to the cleaning of the shed. Milking times have an impact on labour costs and it may affect herd performance through the length of time and stress of the process.
**RD&E investments**

DPIV’s Dairy Industry Program (1993–98) was a $25 million investment and milk harvesting was one of eight activity areas. In 1994–95 about 2 per cent of program funding was allocated to this activity area (AV, 1995). The main objective was to conduct a benchmarking study of milk harvesting processes in order to identify priority areas for future RD&E. A national strategic plan for RD&E on milk harvesting was developed from a DRDC/DPIV workshop.

DPIVs program in dairy RD&E in the late 1990s had seven initiatives including a milk harvesting activity (DNRE, 2000). It focused on labour inputs and utilisation of the dairy shed. The aim was to provide objective information on the choice of milking systems to accommodate future herd growth and met the milk quality standards set by dairy manufacturers.

The RD&E investments in this area were essentially focused on extension efforts. New milking systems technologies had been developed overseas and had been available for some time. Technical advice on decisions to upgrade was provided by the manufacturers of the milking systems but advice of harvesting practices was limited.

*Cowtime* (2001–09) was a national extension project which ran for seven years (DPIV 2004). The objective was to improve milk harvesting labour productivity by 20 per cent (DPIV, 2007). It also aimed to improve energy efficiency and reduce the stress if milking on cows and farmers. The project had three phases — funding for the final two stages of the project (2004–09) was around $2.4 million (DPIV 2009; DPIV 2007).

**Rationale for RD&E investment**

It was evident from international benchmarks that significant economic gains could be achieved from improved herd management at milking times and shed re-developments.

In the late 1990s there was a growing focus on finding ways to improve the efficiency of milk harvesting and support the lifestyle aspirations of dairy farmers. The labour required for milking twice a day was using 40 to 50 per cent of the time used to operate a dairy enterprise. Larger herds, inefficient milking practices and inadequate harvesting systems had become a constraint on labour usage.

A strategic assessment by the DRDC in 2001 identified production improvements in milk harvesting as a high priority area of research. Milking was a big user of labour and capital inputs for a dairy enterprise that affected economic, environmental and lifestyle outcomes. The growth in herd sizes during the 1990s had increased the pressure for more efficient, larger scale milking systems:

- investments were progressively occurring in semi-automated milk harvesting systems based on technologies developed overseas;
but it was difficult to find objective, independent information and advice on the selection, installation and operation of milk harvesting equipment;

- equally important issues were the management practices and efficiency of the milk harvesting process.

Cowtime was established to encourage farmers to critically assess the efficiency of their milk harvesting process and to identify areas for improvement. The benchmarking and training activities were key elements in improving farmer management skills. A further strategic need was to fill the information gap on milking system upgrades.

The strategic rationale for an RD&E investment in this area was the lack of Australian information on the efficiency of milk harvesting practices. Because milk harvesting accounts for 40 to 50 per cent of farm labour and the capital invested in the dairy shed accounts for around 25 per cent of farm assets, this is an obvious area for cost savings (DPIV, 2009). Milking efficiency is one of the key factors limiting overall farm productivity (Cocks et al, 2010).

Farm consolidation and intensification has been accompanied by a general trend toward the installation and improvement of milking shed systems and equipment. Larger sheds have supported an increase in the milk production per week of farm labour, such that the type of shed has been identified as a critical determinant of farm performance. Imported and locally developed milk harvesting equipment also presented opportunities for system automation, improved capability to monitor the status of each cow.

Deficiencies in the provision of information and advice by suppliers of milking systems was another factor that supported a strategic investment in this area.

Output gains in milk harvesting from better management practices are potentially significant form the industry. Milk harvesting costs vary between 3.8 to 8 cents/litre. A 20 per cent reduction in labour use could generate cost savings of about 1 cent/litre. If this could be achieved it would significantly improve profitability. Annual cost saving would be in the order of $108 million across Australia.

**Evidence of success, failure and uptake**

Indications are that Cowtime made a contribution to improvements in milk harvesting productivity.

- A consultative committee of experts was formed to assess the available R&D information and guide the preparation of the reference manual.
  - The principle extension activity was a training course on the principles of efficient milk harvesting which included farm visits to encourage change in milking practises.
- It also provided advice on energy savings through better wash routines, water recycling and equipment upgrades:
- DPIV extension services were responsible for the delivery of Cowtime training activities in Victoria.

- Cowtime provided objective information to guide farmers in decisions on investing in a new milking system and shed upgrade.
- It also provided advice on harvesting practices to optimise the use of existing facilities.
- A training course was developed and a reference manual with milk harvesting guidelines was prepared for distribution in 2003. Extension tools were developed on:
  - milk harvest monitoring to facilitate comparisons with other dairy farmers as a first step in identifying options for system improvements;
  - energy monitoring to measure energy use and make comparisons with industry benchmarks; and
  - dairy shed designs and system performance assessments.

In the first phase of the project participation in the training courses was low and only five courses were run (DPIV 2004). The course was re-designed for the second phase. Over the 2003–09 period, 146 courses were run with more than 4052 people attending. In Victoria 101 course were held and 2114 people attended (DPIV 2007, DPIV 2009).

A follow-up survey of course participants found 62 per cent had made changes to their milk harvesting system and management practices. The benefits were reduced milking times of 15 to 20 minutes and reduced energy usage.

Initially the program was established to assist farmers invest in new technology. With the onset of the drought, program coordinators adapted the program to focus on low cost high-impact strategies to achieve the stated objectives, for example, reducing the stress of milking for cows by improving cow flow and stock-handling at milking. The extension program principally utilises one-day courses (called Shed Shake-ups) and supporting online material. The CowTime program initially benchmarks the milking and energy performance of farmers prior to identifying options for improving their current system.

Over 4000 farmers attended Shed Shake-up programs between 2003 and 2009 or 17 per cent of the industry (BDA Group, 2009). A review of CowTime in 2009 identified a benefit cost ratio from CowTime of 10:1 for the investment in the program for the period 2008–09. Of the 755 farmers involved over this period, it was found that 55 per cent had made alterations to their milking system. The quantified benefits included reduced milking times and associated socio-economic benefits from an
estimated average time saving of 100 hours a year in the dairy\(^\text{10}\) (BDA Group, 2009). The value of benefit to the average farm is estimated to be $2000 each year. BDA concluded that the major (albeit unquantified) benefits of the program were from the reduction in operator stress during milking.

The Milk Harvesting Industry Performance Survey suggests that labour productivity improvements have been in excess of 20 per cent since 2000. ABARE data suggests that milking efficiency in terms of cows milked per unit of labour has increased by over 40 per cent whilst improvement in terms of litres of milk produced per unit of labour has increased by around 66 per cent from 1999–2000 to 2008–09. CowTime may have contributed to this industry improvement.

An economic evaluation for the second phase of the project (2004–07) found a benefit cost ratio of between 10 to 1 and 17 to 1 across Australia (Klinworth and Carr, 2007). The net benefits were estimated at between $8.1 and $14.9 million in NPV terms. This evaluation was based on the gains from reductions in labour use during milking times that were attributable to the training course activity. Other benefits that could not be quantified include the reductions in stress for both stock and farmers.

**Natural resource management**

Emerging from the industry workshop was the view that investment in RD&E in natural resource management has played a critical role in delivering a platform for industry credibility and a framework to integrate R&D on natural resource management. Although difficult to establish what would have occurred without investment in Natural Resource Management (NRM) RD&E, it is likely that the investment has prevented to some extent reductions (including future reductions) in the availability of productive natural resources particularly land and/or increased regulations and higher compliance costs.

**RD&E resources dedicated**

It is estimated that approximately 15 per cent of total on farm investment over the past 30 years has been undertaken on natural resource management issues. This investment is expected to have largely taken place over the last two decades. Although there was a small amount of work being undertaken in the 1980s, such as extension on laser grading and initial work on effluent design systems, investment in natural resource management appears to have increased substantially from the 1990s.

\(^\text{10}\) Estimates from Richard Habgood Consulting based on a time saving of around 10 minutes per milking and was obtained from a survey of CowTime participants between 2004 and 2007.
The major areas of RD&E in the area of natural resource management have been:

- Dairy shed effluent management — effluent extension became widespread in the 1990s and R&D was being undertaken to develop industry guidelines and integrate effluent management into nutrient management plans. Part of this related to forage responses to effluent application (first pond sludge and second pond effluent).
- soil nutrient management including nitrogen and phosphorous;
- salinity in northern Victoria;
- investment in greenhouse gas reductions and adaptation including cross industry and focus on basic research in greenhouse production, mitigation and abatement/sequestration;
- irrigation and water use efficiency such as:
  - irrigation scheduling and re-use systems in 1990s;
  - the Smart Water and Irrigation Management courses which represented the most intensive extension effort on water use and management on farm, giving participants an action plan;
  - targeted irrigation project outcomes were integrated into the drought response ‘covering issues such as water budgeting, water allocation updates, water trading, costing water relative to other feeds, timing irrigations and fodder selection’ (Shaw et al, 2007a);
  - research around precision technologies and demonstration of water use efficiency of irrigated annual and perennial plant systems; and
  - work in unregulated areas emphasising more efficient capture, storage and reticulation of stock and domestic water systems integrated with extension to help mitigate potential threats to the environment.

In the late 2000s there was work done to identify DNA markers that could be used to select dairy cattle suitable to future farming systems (which markers contribute to the production response under different feeding levels, heat stress and so on) and biomarkers for methane production that can be used in future experiments. In addition, work undertaken to investigate development of methodologies for selection of dairy cows (via ABVs). This complements a broader area of research emerging over the past decade to examine novel farming systems which will be designed to deliver major benefits in the use of scarce natural resources.

Examples of projects in this area have included:

- soil nutrient management: Better Fertiliser Decisions; Accounting for Nutrients and numerous regional National Landcare; Dairying For Tomorrow; Natural Heritage Trust and Caring for Our Country funded programs; Phosphorous in Dairy Farms, Accountable Dairying, Montagu Catchment Study, Dairy Catch, GipRip, Queensland Riparian Assessment, Brucknell Creek, Coastal Dairy
Catchments, Understanding Dairy Catchments, grazing strategies to reduce nutrient losses from Australian dairy farms, and spatial and temporal modelling of water and nutrient flows from Australian Dairy catchments.

- Better Fertiliser Decisions’ project commenced in 2003 to:
  - provide regionally specific and scientifically validated fertiliser-pasture production responses for various pasture types, climatic zones and soil types;
  - better define fertiliser management practices that account for nutrient loss processes and pathways; and
  - integrate production and environmental information into materials and tools that can assist industry and government networks including fertiliser company advisers, environmental agencies, consultants, extension officers and farmers, also developed was the ‘Farm Nutrient Loss Index’.

- Target 10 introduced nutrient/effluent management in the early 2000s via DairyGain$, statewide nutrient projects and regional effluent/nutrient projects.

- Investment in irrigation systems, planning and technology: Feasibility of Subsurface Drip Irrigation, Efficient Irrigation Technologies to Match Soils and Dairy Farming Systems, the QDO WUE program, DEC Water workshops, Helping Dairy Farmers Secure Surface Irrigation within the Murray Dairy Region, Linking Farm and Catchment Programs to Irrigation Modernization and Future Farming Systems — Our Rural Landscape.

- Investment in GHG reductions:
  - nitrous oxide research program — focused on options to reduce N₂O from Australian soils and coordinated with GRDC;
  - reducing emissions from livestock research program — focused on reducing methane from ruminants (coordinated by MLA);
  - a soil carbon research initiative focused on understanding the national soil carbon picture and impact of management and options for sequestration; this was not a specific dairy industry initiative; and
  - mitigation and adaptation in the Australian Dairy Industry — focused on demonstrating currently applicable technologies and developing the next generation of farm ready options.

- Investment in climate change adaptation programs:
  - confidence to Grow;
  - climate Change Adaptation Program; and
  - numerous state government initiatives and Australian Government Farm Ready Projects.
Rationale for RD&E investment and expected outcomes

A significant factor driving investment in RD&E in natural resource management has been to maintain the right to access markets and use natural resources. The rationale lies in the recognition that the public perception of unsustainable use of resources is both a domestic and international market risk relevant to this industry (Phelps et al, 2011). It could result in increased regulatory control over the use of land, water and air, resulting in reduced access or use. Land could be taken out of production for instance. Perceived unsustainable use could result in reduced access for Australian dairy products in international markets and possibly in domestic markets as well. Further, investment was undertaken to prevent the loss of productive land from environmental problems such as salinity which was being considered a threat to the condition of the industry’s soil assets in most dairy regions (NLWRA, 2008).

Part of maintaining market access is related to the ability to ‘be articulate and well informed about the industry’s performance and the science and practice underpinning that performance’ (Phelps et al, 2011). An important part of the industry’s response to this challenge has been DairySAT program which ‘is seen by some dairy companies as providing a basis for voluntary reporting of environmental management practices by farmers’ (Phelps et al, 2011).

Significant investment in dairy shed effluent management has occurred in response to the increasing intensity of farms and inadequate farm infrastructure and practice to deal with the associated effluent. In 2000, only 30 per cent of farmers were meeting industry expectations around effluent management (Shaw et al, 2007b). The use of feed pads has increased the scale of the problem in effluent management in recent years. Further, the efficiency of fertiliser use in the 1990s was poor which had potential environmental and economic ramifications (DA, 2006).

The State Environmental Protection Policy requirements in Victoria protect surface and ground waters from pollution from the farm (Parminter and Pedersen, 2000). In 2000, the resources invested in extension and regulation were not achieving adequate compliance levels to satisfy EPA legislation (Parminter and Pedersen, 2000).

The importance of this issue to government and regulators is highlighted by the development of a compliance framework for the industry in 2011 (DPIV, 2011). The rationale for the investment in the measurement and abatement of greenhouse gas emissions is also strongly linked to maintaining the future social licence to operate and avoiding adverse regulatory and market consequences of failing to properly keep up with environmental issues. Another key dimension to the rationale for investment in NRM was that industry acknowledged it was one of the largest users of irrigation water and access to water was becoming increasingly constrained. Access to irrigation water has been demonstrated to be highly correlated with farm profitability in Australia. In addition, farm planning decisions increasingly required farmers to take into account water availability issues including the tradeoffs between
growing or buying fodder, buying, selling or storing water and expanding or reducing milk production. Considerable emphasis has in the past 10 years for these reasons been placed on R&D to identify ways to increase profit per unit of water on irrigated dairy farms, as well as to improve farm competitiveness in a highly water-constrained environment.

**Evidence of success, failure and uptake**

The intensification of Australian dairy farms including higher concentrate feeding regimes and fertiliser use, as well as higher stocking rates and larger herds exacerbated nutrient and effluent management issues. For instance, ‘many farms have been importing a substantial amount of concentrates and forages which can make a significant contribution to plant growth when returned to the farm in animal manure or pose a potential risk of environmental pollution’ (Chataway, 2007).

The potential results from applying nitrogen and phosphorous to pastures has been demonstrated and fertilisers assist farmers in managing predicted feed gaps at various times of the year when climatic conditions are appropriate. Fertilisers are likely to have contributed to pasture improvements which TheCIE estimates are likely to have been in the order of around 50 per cent on a per hectare basis or at a rate of approximately 1.7 per cent per year over the investment period. DPI (2008) suggests that many pastures are capable of producing a response of 10 kilograms of dry matter per kilogram of nitrogen although ‘larger and smaller responses are possible depending on season, soil fertility, moisture availability, temperature, species present, etc’.

Local investment in phosphorous (P) fertiliser has been important for the Australian dairy industry as P is essential for rapid pasture and crop growth and not naturally abundant in Australian soils (DA, 2008). Similarly prudent management of P (and hence R&D into management) has been important due to the potential for P to be lost in surface runoff or by leaching (DA, 2008).

Whilst plant growth from nitrogen application is well documented and predictable, grazing animals are very inefficient in utilising nitrogen (Lucey, undated). Australian and New Zealand data shows a poor correlation between nitrogen fertiliser use and operating profit on dairy farms (Staines et al, 2011). Gourley et al (2011) conclude that poor relationship between P,K and S fertiliser inputs and milk production from home-grown pasture and crops ‘is not surprising given the high soil P,K and S levels measured on these farms and the relative availability and supply capacity that already exist on these dairy farms’. At the levels detected, ‘most pastures and crops are very unlikely to produce additional dry matter from fertiliser inputs’ (Gourley et al, 2011).

Chatway (2007) suggests that a simple farm gate nutrient balance is able to quickly identify gross distortions in the whole farm nutrient balance. When complemented
by soil tests at the paddock scale, this information can assist in the development of fertiliser programs (Chatway, 2007). Soil testing by farmers increased strongly in the 1990s (NLWRA, 2001). ABARES records show that soil testing was used by more than 60 per cent of dairy farms in a given year from 2000 (Lubulwa and Shafron, 2007).

There is evidence that despite considerable improvements in understanding, excessive fertiliser application remains an issue.

- Phelps et al (2010) reports that ‘to ensure nutrients are not a limiting factor, farmers often apply more fertiliser than soil and tissue tests suggest is needed’.
- A 2001 audit shows dairy farms were applying fertiliser inputs of nitrogen, phosphorus, potassium, and sulphur to dairy pastures despite the fact that most farms have been in a net positive balance for all of these nutrients (Gourley et al, 2010).
- Recent work undertaken on nutrient balances, for instance in the Accounting for Nutrients on Australian Dairy Farms program (2010b) also shows that farms remain overwhelmingly in net positive balance for all nutrients. Two-thirds of the farms examined had nutrient balances in excess of European Union compliance standards of 180 kilograms nitrogen per hectare per year and this was ‘a likely reflection of the Australian dairy industry’.

Phelps et al (2010) suggest that farmers are not sufficiently confident that the adoption of new fertilizer and nutrient management principles will not adversely impact pasture production. Excess application of fertilisers could also reflect the belief that fertiliser application provides insurance against possible reductions in pasture production due to deficiencies (DAFWA, 2010).

ABARES expenditure data implies that phosphorous applications have been declining over the past decade, particularly over the past five years.

Evidence of farm practice change in effluent management is supported by more clear unambiguous evidence. ABARES survey data shows that in Victoria from 1991–92 to 1999–2000 the percentage of farms running off dairy shed effluent directly into the paddock fell from 45.2 per cent to 14.2 per cent whilst the number of farms with one or two pond systems increased from 36.4 per cent to 71.1 per cent (Rodriguez and Riley, 2001). Throughout the 2000s, the share of farms with effluent runoff directly into the paddock fell to 5 per cent in 2008–09 (MacKinnon et al, 2010).

Significant changes with regard to the use of water have taken place over the past ten years as farmers respond and adapt to low water allocations and low rainfall (Phelps et al, 2010):

- most dairy farmers have made changes in fodder crop and pasture types or to the sourcing of fodder requirements off farm in response to changes in water availability;
irrigation is now mostly supplementary and there is increased attention on alternatives to traditional flood/border check irrigation systems, including centre pivot or lateral move overhead sprays, and sub surface drip systems whilst there is also increased interest in alternative irrigation storage and delivery systems; and

the use of irrigation scheduling varies widely — from calendar based to those with objective measures of soil moisture and knowledge of crop growth stage specific water requirement to schedule irrigation.

There is limited information on water use in Australian dairy farms over the 30 year evaluation period. A recent report produced by CSIRO on water use on Australian dairy farms identified that the irrigated dairy industry currently produces between 600 and 2000 litres of milk per megalitre of irrigation water (Khan et al, 2010). This is equivalent to around 500 to 1666 litres of water to produce a litre of milk or between 2.5 and 8.5 million litres of water to sustain pasture growth and other operations per cow per year (Khan et al, 2010).

The report suggests that ‘significant infrastructure change is needed to convert delivery systems from border check to sprinkler systems’ whilst ‘on farm infrastructure costs restrict the capacity to fully benefit from a pressurised delivery system’ (Khan et al, 2010).

In addition the report concludes ‘there still remains a need for effective integration of dairy effluent with irrigation systems’ (Khan et al, 2010).

Evidence of gains due to RD&E

There has been considerable cross-industry investment in natural resource management in the Australian dairy industry. Whilst the industry is still grappling with issues associated with nutrient and water management, it is clear that the industry has been proactively trying to improve its efficiency in the management of natural resources and integrate NRM into management plans. Industry knowledge appears to have been considerably expanded over the period despite frank admissions of areas of ‘gaps’.

Industry investment in the development of environmental self assessment tools such as DairySAT (see box 8.1) and Farm Nutrient Loss Index is seen as a critical investment to ensuring the industry has strong environmental credentials.

The industry has also heavily invested over the evaluation period in building knowledge about on and off farm nutrient management (Phelps et al, 2010).

From around the 1960s there has been significant local R&D in the potential benefits of applying phosphorous to Australian pastures and forages. Over multiple decades the R&D showed that application of phosphorous increased the efficiency of pastures. There is some suggestion that farms and consultants drove phosphorous
8.1 DairySAT

The development of DairySAT is regarded by industry experts as an important success. The proactive approach of the industry in DfT attracted considerable investment from government and Catchment Management Authorities. The Dairying for Tomorrow: On the Ground (DfT) program, which incorporated DairySAT, was developed in response to the federal government’s request to develop an environmental management system for the dairy industry (BDA Group, 2007). One of the key aims of the project was to ‘develop a set of processes to deal with natural resource issues common to dairy farmers across the country’ (BDA Group, 2007). As well as ‘DairySAT’\textsuperscript{11}, the program incorporated Better PRAC\textsuperscript{12} and the piloting of BizLink.

DairySAT is considered by industry to be a code of practice, used widely by companies, catchment management authorities and agencies, incorporating the NRM R&D over the past 20 years. Approximately 1400 farmers are estimated to have completed DairySAT by July 2007 (BDA Group, 2007). An evaluation in 2009 reviewing DfT suggested a relatively modest benefit cost project return of approximately 4 to 1 (BDA Group, 2007).

Benefits include gains in water quality and biodiversity resulting in the improvement of land, better effluent and nutrient budgeting leading to a reduction in fertiliser and water savings. The report suggests that participants on average are expected to have reduced application of fertilisers by approximately 25 per cent and water savings of approximately 10 ML for each participating farm or 5.6 GL across all farms (BDA Group, 2007) representing around 0.3 per cent of current dairy water use. These are based on a number of assumptions based on expectations of the benefits likely to have been achieved; the potential for the benefits to be overstated or understated in this report is possibly significant.

But industry experts that attended the industry workshop reported the significant benefits delivered through DfT including the DairySAT tool were in its’ impact on the dairy industry psyche and environmental reputation, as well as a large attitudinal shift in what was deemed acceptable practice. Such benefits are measured by the ability of an industry to continue to operate using the existing resources including land.

\textsuperscript{11} DairySAT was a farm based self assessment tool that farmers could use to assess the environmental risks associated with their own operations to identify and prioritise issues and develop appropriate action plans (BDA Group, 2009).

\textsuperscript{12} BetterPRAC involved the development, evaluation and implementation of tools and processes for achieving targeted change identified through farm level action plans.
use to levels above that recommended in the published research. However, the
fertiliser industry has played a large role in fertiliser use practice change, with all
fertiliser accreditation now based on the use of research results. All local R&D is now
incorporated in uniform soil tests and fertiliser provision recommendation processes.

Significant R&D investment has been made to understanding phosphorus runoff,
ahead of the regulation and DairySAT. Industry R&D provided an important base for
understanding the impact of fertiliser use on the environment and providing
industry with management tools (such as the P Buffering Index). Extension has been
very visible and rapid in this area.

Without the industry and regulator contributions to the development of the
necessary drivers for improvements in effluent management practice, such as codes
of practice, state guidelines, statutory planning, regulatory framework, and quality
assurance links through the milk companies, the extension in this area was expected
to have achieved only limited results (Phelps et al, 2010).

- But industry contributed heavily to the development of a code of practice,
  statutory planning systems and nutrients and an industry-based QA audit system
  and communication and implementation plans. The Effluent and Manure
  Management Database for the Australian Dairy Industry, for example, provides
  reliable and scientifically validated technical information on dairy effluent
  management for all dairying regions in Australia.

The Better Fertiliser Decisions extension program has suffered from a lack of
confidence in soil nutrient targets among some advisers (Phelps et al, 2010). This may
be affiliated with the plethora of different nutrient advisory, diagnostic and decision
support tools developed by consultants, DPI/State Departments of Agriculture and
milk companies including paddock scale nutrient mapping, nutrient budgeting tools,
nutrient loss calculators and fertiliser rate calculators (Phelps et al, 2010).

There has been significant investment in catchment studies and the development of
dairy catchment models (Phelps et al, 2010). According to industry experts in a recent
review, this has assisted in building a better understanding of off farm impacts of
dairy practices on water quality although significant ‘knowledge gaps’ in nutrient
process remain (Phelps et al, 2010). These gaps in knowledge affect the ability of the
industry to quantify whether excess N is being lost as di-nitrogen, ammonia, nitric or
nitrous-oxide of ending up in surface and ground water as nitrate (Phelps et al, 2010).

There is no overall evaluation of the benefits of improving the industries
environmental credentials. However, in an ex ante evaluation by TheCIE in 2000 of
the potential consequence of failing to deal with rising environmental pressure and
assessment was made of what might occur from a contraction in the land available to
the industry as a result of:

- land being deemed too vulnerable to farm;
- the price of water rising prohibitively for some producers;
- land being set aside to prevent nutrient and effluent runoffs; and/or
- land being set aside to meet biodiversity targets.

The CIE estimated the potential cost of a reduction in the land available or put in other terms, the benefit of avoiding a reduction in the land available to farm.\(^\text{13}\) Potential benefits from avoiding a 10 per cent reduction in land were estimated to be valued at $404 million (net present value terms) excluding any potential environmental benefits. Based on an investment of $23 million a year over 10 years a benefit-cost ratio of 2.2:1 could be achieved, excluding any potential environmental benefits (CIE, 2001).

---

\(^{13}\) The analysis assumes a probability of forced set-aside land occurring would increase to 80 per cent of eight years.
9 Contributions of RD&E to the dairy industry growth and lessons learned

The evidence presented in chapters 6, 7 and 8 is consistent with the findings of the workshop that RD&E has played an important role in all the industry’s major growth areas over the past three decades. Exactly how important that contribution is, is not easily determined or quantified. Nonetheless the various indicators point toward a sizeable contribution.

Contribution to RD&E to the dairy industry

Chart 9.1 summarises an attempt to quantify (and triangulate) the contribution from three different sources.

- The first is based on RD&E’s share of total on-farm investment over the period, 35 per cent as discussed in chapter 5. Essentially, this assumes that the rate of return from each dollar invested, whether RD&E or other, is the same for each dollar invested.
- The second, 46 per cent, comes from a quantification of the collective opinion from the industry workshop. Industry participants offered a breakdown of how much they thought RD&E contributed to each major area of change relative to the contribution from other factors such as farmers own investments and initiatives.
- The third, at 56 per cent, takes the contributions suggested during the workshop and weights them according to the quantitatively determined importance of each major area of change determined in chapter 4.

A simple average of these estimates is the mid-point estimate 46 per cent.

Based on the estimates of increased profit reported in chapter 4 of $10 billion, 46 per cent would suggest benefits to farmers of around $4.6 billion. This compares with an estimated total investment by Victoria in RD&E in 2010 dollar terms of $1.24 billion over the period.

- In present value terms (using a discount rate of 5 per cent) these figures convert to $7.7 billion for benefits and $2.3 billion for costs, giving a benefit to cost ratio of 3.3:1.\(^\text{14}\)

---

\(^{14}\) Readers should use these figures with care as they are based on some subjective estimates.
Moreover, many of these benefits will be ongoing into the future potentially raising the benefit cost ratio further and the benefits to processors from the greatly increased volume are not included.

For farmers, the benefit to cost ratio maybe more than double this based on investment dollars they contributed through research levies. Matching funding from other sources has allowed farmers to leverage up their returns.

A sensitivity analysis of the benefit cost outcome was conducted around using a higher discount rate of 7 per cent that better reflects the requirement of state treasury departments.

- At a 7 per cent discount rate, the headline analysis changes to $6.2 billion for benefits and $2.98 billion for costs, giving a benefit to cost ratio of 2.0:1.

**Benefits of RD&E outside of the dairy industry**

In addition to the benefits to the Victorian dairy industry from investments in RD&E, there have also been spillover and other benefits to the state and the wider community including consumers of dairy products.
**Environmental and social benefits**

The RD&E described in this evaluation has also had spillover benefits beyond the drivers of profitability within the industry. As already identified in chapter 8, the ongoing investments made in NRM and related areas continue to provide a stream of benefits in two ways by maintaining:

- the industry’s social licence to operate by proactively identifying and managing issues of emerging community concerns around environmental and animal welfare issues;
  - a good example of improving NRM outcomes at farm level, such as addressing effluent run-off into water courses, provides benefits to both industry and to users downstream as a result of improved water quality and sustainability of the resource.

- industries and communities in regional Victoria depend on dairying and other agricultural enterprises to sustain income and employment opportunities where otherwise there would be few alternative economic activities:
  - this impact extends beyond the farm gate and also includes the flow-on economic benefits from milk distribution and processing centres in regional Victoria;
  - ABARE estimates the regional economic multiplier effect for the dairy industry workforce to be around 2.5 from the dairy industry (DA, 2010, page 9);
  - that is, for every one job in the dairy value chain, up to 2.5 other jobs are created in the region.

**Benefits to consumers**

The benefits to the Victorian dairy industry have also flowed onto consumers both within Victoria, and other states of Australia, and export markets. This benefit is in terms of the greater availability of milk products and at lower prices, than would have been the case without the RD&E.

While beyond the scope of this evaluation, the total benefits to consumers are in practice very difficult to quantify in dollar terms because of the relative contribution of the farm and processing sectors.

- For example, while the farm sector has increased production strongly over the past 30 years, Harris (2011) noted the structural change and other developments that occurred in the processing sector that have contributed to the outcomes observed today.

- Consolidation and internationalisation of the processing sector has lead not only to cost efficiencies in processing but also to the development of a wide range of new products for consumers that are available through retail and food service outlets.
Dairy cabinets in supermarkets now contain many more consumer lines that include new products, different portion sizes and more functional packaging.

For consumers, there should have been also substantial benefit from the increased penetration of generic or homebrands in-store at lower price points.

Overall, these benefits have been substantial and sustained, especially since deregulation of the industry, and are expected to be ongoing beyond the timeframe of this evaluation.

Lessons learned
A number of lessons have emerged from this mega evaluation.

Improvements are greater than they may at first appear
Without the major internal industry driven output improvements that occurred, output of the Victorian dairy industry would have declined by an estimated 23 per cent over the past three decades due to a cost price squeeze and depreciation and obsolescence of technology.

- Instead, industry production expanded by around 90 per cent.
- Relative to an estimated decrease in output of 23 per cent, the 90 per cent expansion represents an estimated 146 per cent expansion of output due to major production improvements.
- The extension and adoption of output improvements, while recognising the increased use of purchased inputs, appear to be considerably greater than the 90 per cent observed increase in production.

Capacity to adapt foreign technology is vital
Much of the improvement achieved has been based on imported technology and practices, but its successful uptake has been due to:

- having the scientific and extension capacity to understand and adapt the technologies and practices to Australian, Victorian and regional conditions;
- having competitive international and domestic trading conditions to place pressure on the need for widespread uptake and having domestic policy conditions that allow constant rationalisation and structural change in the industry;

It is essential for industry to be able to adapt overseas technologies and practices to local situations.

- All major technologies and practices adopted from overseas required substantial modification to suit the Australian, Victorian and region climates, soils, resource availability and economic conditions reflecting unique geographic factors.
Victoria has developed the most diverse set of dairy feeding systems found anywhere in the world. These extend from the all pasture system used in New Zealand, through pasture-based bail feeding systems, partial mixed ration and hybrid systems, to the zero grazing total mixed ration (TMR) system used in the northern hemisphere. It is likely to remain so that optimal management approach will be different in the Australian context.

- Australia is part of a huge global dairy industry and most broad technological changes will arise elsewhere. Australian and Victorian industries need to strategically position themselves to take advantage of this.
  - Reliance on technology spill-in will require continued strong capacity to take up the technology.
  - Excellence and world leadership in some areas of RD&E is likely to continue to be required to ensure Australia keeps a seat at the international table for dairy RD&E, to ensure it can keep up with cutting edge developments.

- Local research and development has played a critical role in demonstrating the viability of technologies in an Australian and regional context.

**Autonomous farmer/industry improvement is probably as important as RD&E**

It is difficult to be precise about the split in contribution between industry’s own efforts to increase production and that arising from RD&E. However, all indicators point to RD&E being likely to have contributed between a third and a half of the gain. It is difficult to see that RD&E’s contribution would have been less than a third, but it is also difficult to argue that industry’s own contributions would have been much less than half. Support from others in the supply chain (input suppliers and processors) is also likely to have played an important role in autonomous improvement. Moreover, without industry cooperation high rates of improvement and change are unlikely to have been achieved.

**Extension is at least as important as R&D**

Extension appears to be as important as research and development. Extension is required to support farmers to manage the system as a whole, particularly where concepts are not easily applied. For example, shorter milking times required more time and resources to get the research findings out to farmers.

- A significant role of this extension is to gather and filter information, ground truth it for Australian conditions, and package it so that for more accessible for farmers for decision making.
- What this does is effectively bring forward the adoption that otherwise would have occurred over a longer timeframe.
Understanding interdependencies of farming and biological systems is important

It is difficult to clearly distinguish the individual role of genetics, feeding systems and pasture improvements, but there does appear to be an important causality of improvement running from pastures to supplements to genetics.

- Understanding the complex scientific and economic interdependencies and causalities between drivers is important to devise optimal management systems.
- Analysis needs to be undertaken on a per hectare and per farm basis not simply on a per cow basis. Production improvements per hectare can be very different to production improvements per cow.
- Research and development that accounts for returns at the margin as opposed to average returns has been very important. That said, not all farms have managed feeding inputs based on payoffs at the margin perhaps due to a risk averse approach to feeding associated with the drought. More extensive measurement of feed conversion efficiency among dairy farmers may be a key to unlocking future returns from management at the margin.

Spinoff benefits may have been overlooked

Many benefits of production improvements are indirect and oftentimes not visible.

- The large increase in production achieved has underpinned the achievement of substantial economies of scale, but these gains are commonly attributed to the scaling up of infrastructure by farmers themselves. Whilst this is true to a large extent, it is also true that it would not have occurred to the extent it did without the major output advances.
- Economies of scale and the use of supplements may have provided farmers with more options and flexibility to reduce risk and make better lifestyle choices especially as they relate to milking, labour requirements and use and climatic variability. These need to be accounted for.

Natural resource management focus may help counter technological obsolescence

Quantifying the benefits from natural resource management RD&E is not easy, but the rationale for investing in this area is strong. It helps to prevent technological depreciation and obsolescence brought about by changing (adverse) community and political opinion and tightening regulatory constraints. It may be important insurance to maintain the right to farm.

- Often also improving the management of the natural resources has significant spill over benefits to the sustainability of production.
Significant benefits from RD&E still to be derived in future years

Significant capacity has been built to understand the farm as a whole-of-system: the interactions between pastures, supplements, genetics and animal health and welfare over the past 10 years. This knowledge base is likely to deliver future gains in production and profitability resulting from follow-up research.
References

Australian Bureau of Agricultural and Resource Economics and Sciences (ABARES), 2011, Farm survey data, provided to TheCIE by data request.


Appendices
A CIE model of the Australian dairy industry

The CIE dairy model is a partial equilibrium, non-linear, representation of the Australian dairy industry. The model is programmed in GEMPACK and accounts for interactions between primary producers, processors, manufacturers and consumers. Production is modelled across the six states.

The model used here is a static representation of the Australian dairy industry and is built around a value chain database. The database is augmented with a number of equations which specify how each of the various participants in the industry react as various changes (‘exogenous shocks’) are imposed on the model by the modeller. These equations describe:

- the production of raw, processed and manufactured milk products;
- domestic and export demands for these products;
- pricing relationships; and
- market clearing conditions.

The model is currently being further developed into a dynamic framework. In addition, a rest of the world closure is being added by incorporating detail on competing suppliers and customers in the rest of the world and the trade flows between suppliers and customers.

Structure and detail of the model

Chart A.1 illustrates the broad structure of the CIE model. Its key features are:

- for each state, a farm sector;
- a single raw milk product;
- for each state, three processing sectors — fresh milk processing, UHT milk processing, and manufactured product production;
- single Australia-wide domestic markets for liquid milk (fresh and UHT) and manufactured products;
- UHT and manufactured products are also sold on export markets;
- the domestically produced manufactured products competes with an imported product; and
A.1 CIE model structure

Farm sector (by state)
- Inputs:
  - Hired labour
  - Primary factors
    - Feed
    - Land
    - Capital
  - Other inputs
- (Fixed proportions) Substitution between factors

Total supply of milk

Fresh milk processing (by state)
- Inputs:
  - Other inputs
  - Primary factors (labour, capital)

Total supply of fresh milk

Dairy goods (by state)
- Inputs:
  - Milk
  - Other inputs
  - Primary factors

Total supply of UHT milk

Domestic market for liquid milk

Export market for UHT

Export market for manufactured products

Domestic market for manufactured markets

Imports

Interaction between supply and demand determines farm gate prices

Interaction between supply and demand determines ex-factory prices

Demand
Supply
Demand
Supply
Demand
Supply

Interaction between supply and demand determines farm gate prices

Interaction between supply and demand determines ex-factory prices

Source: TheCIE.
transport margins between the farm and the processing sectors and transport and wholesale and retail margins between the factory and the point of sale (not shown in chart B.1.)

**Key parameters**

The demand of raw milk is determined by the demand for downstream processors as an input to production (this ‘derived demand’ is ultimately determined by final consumers’ demands for the processed product). The supply of raw milk is determined by the farm supply elasticity — set at 0.5 in the base case (table A.2). The interaction of supply and demand for raw milk determines the farm gate price of milk.

### A.2 Key parameter values

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supply elasticities</td>
<td></td>
</tr>
<tr>
<td>Farm</td>
<td>0.5</td>
</tr>
<tr>
<td>Processing industries</td>
<td>1.5</td>
</tr>
<tr>
<td>Demand</td>
<td></td>
</tr>
<tr>
<td>Liquid milk (fresh, UHT)</td>
<td>-0.15</td>
</tr>
<tr>
<td>Manufactured products</td>
<td>-0.25</td>
</tr>
<tr>
<td>Export demand</td>
<td>-10</td>
</tr>
</tbody>
</table>

*Data source: TheCIE model.*

The demand for liquid milk assumes that fresh milk and UHT milk are substitutes. Consumers choose their overall level of liquid milk consumption and then allocate this between fresh milk and UHT milk on the basis of relative prices. The model assumes that these products are imperfect substitutes so the consumer will typically choose a mixture of these products rather than just the cheapest product (as would be the case with perfect substitutes). The overall demand for liquid milk is assumed to be relative price inelastic (elasticity of -0.15) — that is, relatively unresponsive to price changes.

The model also assumes that domestic and imported manufactured products are imperfect substitutes. As with liquid milk, consumers determine the overall demand for manufactured products and then allocate between domestic and imported products. The overall demand for manufactured products is assumed to be relative inelastic (elasticity of -0.25).

Downstream processors of UHT milk and manufactured products are able to export their products into the world market. The model assumes that domestic producers are largely price takers with limited ability to influence price. This is reflected in a relatively flat (elastic) demand curve with an elasticity of -10. Basically, in principle,
Australian producers could divert a large quantity of product to the world market with limited impact on price. This is the ‘small country’ assumption.

The supply of processed products is assumed to be relatively responsive to price (elasticity of 1.5 for each product). The interaction of total demand (domestic and export) and supply of each product from the processors determines the ex-factory prices for the processed products. Transport and retail/wholesale margins are added to the ex-factory price to determine the price to consumers and the export FOB price.

**Model database and key parameters**

The model currently incorporates available 2009–10 data, based on data drawn from a range of sources primarily Australian Dairy Corporation (ADC) for:

- milk production volumes and prices by states;
- production volumes for fluid and manufactured milk products by the processing sector; and
- export and import volumes and values.

Average or indicative cost structures for dairying were also updated from a number of sources including gross margin data supplied by respective state departments and survey data from the ADC.

**Key sensitivities to parameters used in this analysis**

In terms of the economic model, the results are most sensitive to a number of key relationships including:

- the on-farm supply response for unprocessed milk;
- the level of capacity utilisation within the milk processing sector, this is a significant determinant of the relationship between the farm price of milk and the export price of processed products; and
- the export demand elasticity faced by Australian manufacturers of processed milk products.

In this model, while the price demand elasticity for products sold on the domestic markets is important, it is the export price that effectively sets the farm gate price for milk. This is because of the key relationships that:

- exports remain the most important market segment where product can be sold without impacting significantly on the ex-factory price; and
- economies of scale and significant investment has lead the processing sector to demand more milk throughput which results in many of the price signals from the world market are translated back to the farm gate;
  - this is reflected in the high supply elasticity for the processing industry.
B Contribution to dairy performance

This appendix attempts to explain the drivers behind increase in milk yield per cow and per hectare observed for Victoria over the past 30 years.

- The purpose of this analysis is to better inform the relative contribution of increased use of inputs, RD&E and other factors to this success.
- Over this period average yield per cow increased by 94 per cent or 2.2 per cent each year for 30 years.

**Deriving the contribution of pastures**

Given the comparative advantage of the Victorian pasture system, and the limited amount of land suitable for dairying, a better way of looking at production would be the increase in output is in terms of milk production on a per hectare basis (chart B.1).

Over the past 30 years, milk production per hectare has increased by over 190 per cent or a trend rate of growth of 3.4 per cent each year.

**B.1 Average yield per cow and per hectare for Victoria**

(Data source: ABARES.)
Energy requirements over time

To identify the contribution of each of the factors to the total outcomes in chart 2.1, a simple framework was developed around the energy requirement of an average cow over the past 30 years.

This framework ‘add-ups’ the components that contribute to cow nutrition and yield with consumption of pasture (including grazing, hay and silage) growth as the balancing item. The required nutrition for a milker is a function of maintenance needs (including energy required while dry and allowances made for walking etc), which is a function of liveweight, and energy requirements per litre of milk produced.

Chart B.2 shows that over the past 30 years:
- average live weights increased by over 31 per cent to around 550 kilograms; and
- energy requirements increased by 46 per cent from 63 000 to 80 000 megajoules.

This increase is the result of two factors:
- lower energy maintenance costs per litre; but
- more energy required as a result of higher average production.

Total growth in feed consumption per cow and implied improvements in feed conversion efficiency are shown in chart B.3. From 1980 to 2010:
- consumption of dry matter on a per cow basis increased by 44 per cent; and
- feed conversion efficiency improved by 34 per cent (litres of milk per kilogram of total dry matter fed).

B.2 Increase in live weights and energy requirements

Data source: CIE calculations.
 Increase use of supplementary feeds

During the period, the increase in energy requirements was met from both an increased consumption of supplementary feeds and from pastures.

- It is important to note that supplementary feed includes all non-pasture based feedstuffs including grains and meals, concentrates and by-products and maize silage.
- We define pasture to be equal to pasture grazed or consumed through hay or silage which has been harvested and fed out at a later point.

The increase in supplementary feeds is a contributing factor that we have the best evidence on. Key sources for the 2000s are ADC and ABARES surveys which were conducted on a regional basis. Doyle et al (2000) was used on supplementary feed use for information on per cow consumption from 1980 to 1999.

Chart B.4 shows the estimated trajectory of supplementary feeds for Victoria on average. Dairying has gone from exclusively a pasture only system to more intensive feeding systems. On average, average use of supplements is around 1.5 tonnes of dry matter per cow each year.

Chart B.5 shows this transition from across the five feeding systems identified by the 2011 DA National Dairy Farm Survey data, plus unpublished data on feed intakes and FCE’s of five systems.
B.4 Use of supplementary feed per cow, Victoria

![Graph showing the use of supplementary feed per cow in Victoria from 1980-81 to 2008-09.](image)

a Includes grains and meals, concentrates and by-products and maize silage.

*Data source:* DA National Dairy Farm Survey and ABARES survey, Doyle (2000), and CIE calculations.

- Using available industry and ABARES data, a time profile was constructed for the transition from pasture-based systems to more intensive feeding systems.\(^{15}\)
- As shown, there was a relatively swift transition towards low bail systems (from pasture only systems) in the 1980s which remained dominant until the 2000s. There was also a more gradual transition toward partial mixed rations, hybrid systems and TMRs throughout the 2000s.

B.5 Feeding systems change over time

![Diagram showing the percentage contribution of each feeding system from 1980-81 to 2008-09.](image)

*Data source:* DA National Dairy Farm Survey and CIE calculations.

\(^{15}\) Live weight averages for each breed are estimated using an annual growth rate of 0.85 per cent for Holsteins and 0.4 per cent for other breeds.
The statewide data of use of supplementary feed was then run back to 1980 on the basis of data on the basis of the relative intensity of purchased feed in each of the Victorian regions from the Farm Monitor survey (chart B.6).

- Gippsland and the South West have closely tracked each other due to the similarity of their production systems.
- The North is a more intensive feeding system and is the hardest hit when there were shortages of water for irrigation, which then required proportionally more use of supplementary feeds.

**B.6 Use of purchased feed per cow, by Victorian region**

*Includes grains and meals, concentrates and by-products and maize silage.*

Data source: Doyle (2000), ABARES survey, DPIV Farm monitor and CIE calculations.

**Increased pasture consumption per cow**

From 1980 to 2010, on average the total requirement of dry matter per cow has increased from 4.1 to 6 tonnes.

- In 1980, the average cow consumed around 4 tonnes of dry matter, all from pasture that was either grazed or fed as hay and silage.
- By 2010, this has increased marginally to 4.5 tonnes while average consumption of supplements had increased from virtually a zero base to 1.5 tonnes in 2010 (chart B.7).

This has reduced the relative contribution of pasture to overall nutrition levels.

- By 2010, the contribution of pasture to total energy requirements was around 75 per cent compared to 100 per cent in 1980.
B.7  Implied increase in consumption of pasture per cow, Victoria\(^a\)

![Graph showing the increase in consumption of pasture per cow for Victoria over the last 30 years.](image)

\(^a\) Pasture includes grazing, conserved hay and silage.

Data source: ABARES survey, VDDPI Farm monitor and CIE calculations.

Chart B.8 calculates implied pasture consumption by region which largely is a function of each region’s use intensity of supplementary feeds.

B.8  Increase in consumption of pasture per cow by region\(^a\)

![Graph showing the increase in consumption of pasture per cow for different regions in Victoria over the last 30 years.](image)

\(^a\) Pasture includes grazing, conserved hay and silage.

Data source: ABARES survey, VDDPI Farm monitor and CIE calculations.

**Stocking rates**

The next step is to transform apparent per cow consumption of pasture to a per hectare basis. A reliable time series on stocking rates for Victoria and for each of the regions is problematic.

* A series was put together from the DPIV Farm Monitor and ABARE survey data.
Stocking rates are represented by the number of milkers on effective grazing land, that is, land that is not being used for cropping. ABARE data indicates that cropping is only other major enterprise conducted on dairy land, in addition to the grazing of milking cows and maintenance of dry dairy stock.

Chart B.9 shows that over the past 30 years, average stocking rates have increased by around 40 per cent.

- Chart B.9 also shows the impact of seasonal conditions on stocking rates. For example, a significant reduction on cow numbers following the 2002-03 drought lead to a temporary fall in stocking rates.
- Changes also reflect a combination of increased pasture efficiency but also better use of feeding systems based on non-pasture ingredients.

**B.9 Statewide stocking rates for Victoria**

![Graph showing statewide stocking rates for Victoria from 1980-81 to 2008-09](image)

*Data source: ABARE and CIE calculations.*

Chart B.10 shows calculated stocking rates by region in Victoria that are calculated to move in line with the statewide average and the intensity of use of non-pasture feeds in each region. This series also highlights the impact of seasonality around an upward trend towards high stocking densities.

Given average consumption by each cow and higher stocking rates, chart B.11 shows that pasture utilisation per hectare has increased especially through the second part of the 1990’s.

- We note that the maximum grazing consumption of pasture by an individual cow is around 4 tonnes of dry matter each year (at current liveweights).
- Survey data indicates a clear downward trend towards reducing average effective grazing area as a percentage of total dairy farm area.
This reduction in grazing area for milkers reflects the increase in the importance of cropping or running increasing numbers of dry dairy cattle.

This change may also provide dairy farmers with increased flexibility in managing their dairy enterprise and managing risk.

**Increased pasture consumption per hectare**

Combining apparent consumption per cow of dry matter and higher stocking densities results in apparent pasture utilisation per hectare (see chart B.11).

**B.11 Apparent statewide utilisation of pastures for Victoria**

Data source: TheCIE calculations.
From 1980 to 2010, apparent utilisation of pasture increased from 4 to just over 6 tonnes per hectare.

Chart B.11 shows that the majority of this increase is likely to have happened in the twenty years up to 2000 after which it plateaus off. Again the impact of seasonal changes can be observed, but the trend is clear.

The next step is to translate these trends back for each Victorian region (see chart B.12) using stocking rates by region.

The level and the rate of change of pasture utilisation in the North stands out as being significantly different to Gippsland and the South West.

**B.12 Apparent pasture utilisation, by Victorian region**

*Pasture includes grazing, conserved hay and silage.*

Data source: CIE calculations.

**Summary of findings to this point**

Table B.13 summarises the average annual change in key variables that drive cow performance, nutrition and feed consumption. In terms of yield per cow and per hectare, a significant proportion of the total change took place in the 1980s that resulted from increases in feed conversion efficiencies (32 per cent) from increased levels of supplementary feeding. Overall the energy use of cows increased 49 per cent as a result of larger cows and greater availability of mostly supplements but also increased pasture per cow.
**B.13 Summary of changes in performance of the average dairy cow**

<table>
<thead>
<tr>
<th>Period</th>
<th>Yield and stocking rates</th>
<th>Energy requirements</th>
<th>Feed conversion</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Yield per cow</td>
<td>Cows per ha</td>
<td>Megajoules per litre</td>
</tr>
<tr>
<td></td>
<td>%</td>
<td>%</td>
<td>%</td>
</tr>
<tr>
<td>1980-89</td>
<td>3.2</td>
<td>3.4</td>
<td>-1.5</td>
</tr>
<tr>
<td>1990-99</td>
<td>2.3</td>
<td>2.0</td>
<td>-1.3</td>
</tr>
<tr>
<td>2000-09</td>
<td>1.9</td>
<td>2.8</td>
<td>-1.0</td>
</tr>
<tr>
<td>1980-81 to 2009-10</td>
<td>2.3</td>
<td>1.0</td>
<td>-0.9</td>
</tr>
<tr>
<td>Cumulative</td>
<td>96.9</td>
<td>36.6</td>
<td>-32.0</td>
</tr>
</tbody>
</table>

*Average annual change for each period.*  
*b Megajoules of energy required per cow per litre of milk yield.* 
*Source: TheCIE calculations.*

Table B.14 summarises how the apparent consumption of supplementary feeds and pasture by region and the state.

- The 1980s was a period of significant increase in the use of both supplementary feeds and utilisation of pastures, which both slowed in the 1990s.
- In the 2000s, the rate of increase of supplementary feeds increased again while pasture utilisation slowed. Both of these outcomes can be attributed to seasonal conditions (the drought).

Over the past 30 years, pasture utilisation increased by nearly 47 per cent, or a trend annual rate of 1.3 per cent over the past 30 years. This level of increase is certainly significant when compared to production per hectare for other pasture based livestock industries.

**Contribution to performance — a more complete perspective**

In addition to the introduction and increased role of concentrates to supplement dietary requirements; and increased utilisation of pastures, other possible factors contributing to the observed increases in milk yield from 1980 to 2010 include:

- genetic change, including:
  - selection of higher yielding cows given the similar live weight;
  - structural change in the breed composition of the herd;
  - the trend toward larger cows resulting from selecting and breeding for higher production and profit; and
- other factors such as herd health and seasonal factors.

Some of these factors are more easily quantified that others but all are inter-related. The approach taken here is to start the factor (which contribution is being investigated) while the levels of all other factors are held at 1980 levels. The outcomes are derived using our simple energy framework.
THE IMPACT OF INNOVATION ON THE DAIRY INDUSTRY OVER THE LAST 30 YEARS

B.14 Increase in supplementary feeds and pasture utilisation by region

<table>
<thead>
<tr>
<th>Region</th>
<th>Supplementary Feed</th>
<th>Pasture Utilisation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>t DM per ha</td>
<td>t DM per ha</td>
</tr>
<tr>
<td></td>
<td>%</td>
<td>%</td>
</tr>
<tr>
<td>Gippsland</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1980–89</td>
<td>34.7</td>
<td>4.2</td>
</tr>
<tr>
<td>1990–99</td>
<td>9.7</td>
<td>2.5</td>
</tr>
<tr>
<td>2000–09</td>
<td>7.0</td>
<td>2.5</td>
</tr>
<tr>
<td>1980–81 to 2009–10</td>
<td>12.3</td>
<td>1.2</td>
</tr>
<tr>
<td>Cumulative</td>
<td>3 146.8</td>
<td>44.4</td>
</tr>
<tr>
<td>South West</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1980–89</td>
<td>34.7</td>
<td>4.5</td>
</tr>
<tr>
<td>1990–99</td>
<td>13.9</td>
<td>2.1</td>
</tr>
<tr>
<td>2000–09</td>
<td>3.2</td>
<td>0.3</td>
</tr>
<tr>
<td>1980–81 to 2009–10</td>
<td>13.0</td>
<td>0.9</td>
</tr>
<tr>
<td>Cumulative</td>
<td>3 810.0</td>
<td>32.2</td>
</tr>
<tr>
<td>North</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1980–89</td>
<td>34.7</td>
<td>4.0</td>
</tr>
<tr>
<td>1990–99</td>
<td>9.9</td>
<td>2.3</td>
</tr>
<tr>
<td>2000–09</td>
<td>12.1</td>
<td>4.1</td>
</tr>
<tr>
<td>1980–81 to 2009–10</td>
<td>12.2</td>
<td>1.4</td>
</tr>
<tr>
<td>Cumulative</td>
<td>3 100.4</td>
<td>53.9</td>
</tr>
<tr>
<td>Statewide</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1980–89</td>
<td>34.7</td>
<td>4.2</td>
</tr>
<tr>
<td>1990–99</td>
<td>11.1</td>
<td>2.3</td>
</tr>
<tr>
<td>2000–09</td>
<td>7.5</td>
<td>2.8</td>
</tr>
<tr>
<td>1980–81 to 2009–10</td>
<td>12.5</td>
<td>1.3</td>
</tr>
<tr>
<td>Cumulative</td>
<td>3 289.7</td>
<td>46.6</td>
</tr>
</tbody>
</table>

*a* Average annual change for each period.

Data source: TheCIE calculations.

**Structural change in feeding systems**

We have already identified that the increased use of supplementary feeding has had a significant impact on overall production levels. Using available industry and ABARES data, a time profile was constructed for the transition from pasture-based systems to more intensive feeding systems (see chart B.5). These feeding systems are categorised by the DA Grains2Milk program as follows:

- **pasture only** — including grazed pasture and other forages;
- **low bail** — grazed pasture and other forages and up to 1.0 tonne cereal grain/concentrates fed in the parlour;
- **moderate to high bail** — grazed pasture and other forages plus more than one tonne of cereal grain/concentrates fed in the parlour;
- **partial mixed ration** — pasture is grazed for most or all of the year and cows consume a partial mixed ration on the feed pad and potentially cereal grain/concentrates are fed in the parlour;
hybrid — pasture is grazed for less than nine months of the year and cows are fed a partial mixed ration on the feed pad and potentially cereal grain/concentrates fed in the parlour; and

total mixed ration — cows do not graze, they are housed and fed a total ration.

To better understand the impact of greater use of supplementary feeds for the 1980s cow, it is instructive to examine the impact of increasing feed intensity across the current dairy industry.

- The more the intensive feeding system, the higher the milk yields and better feed conversion.
- Table B.15 presents the data developed as part of the DA Grains2Milk program.

### B.15 Impact of feeding systems for the modern cow 2009–10

<table>
<thead>
<tr>
<th>Feeding system</th>
<th>Live weight</th>
<th>Yield</th>
<th>Dry matter consumed</th>
<th>Feed efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pasture only</td>
<td>550</td>
<td>5 011</td>
<td>5.1</td>
<td>0.98</td>
</tr>
<tr>
<td>Low bail</td>
<td>550</td>
<td>5 301</td>
<td>5.3</td>
<td>1.00</td>
</tr>
<tr>
<td>Moderate to high bail</td>
<td>550</td>
<td>6 310</td>
<td>5.5</td>
<td>1.14</td>
</tr>
<tr>
<td>Partial mixed rations</td>
<td>550</td>
<td>6 483</td>
<td>5.6</td>
<td>1.17</td>
</tr>
<tr>
<td>Hybrid</td>
<td>550</td>
<td>6 828</td>
<td>5.6</td>
<td>1.21</td>
</tr>
<tr>
<td>Total mixed rations</td>
<td>550</td>
<td>7 671</td>
<td>5.8</td>
<td>1.33</td>
</tr>
<tr>
<td>Weighted average all systems</td>
<td></td>
<td>6 187</td>
<td>5.5</td>
<td>1.13</td>
</tr>
<tr>
<td>Benchmark - Colin Holmes</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Friesian total mixed ration</td>
<td>700</td>
<td>9 000</td>
<td>7.0</td>
<td>1.29</td>
</tr>
<tr>
<td>Friesian Jersey cross - pasture</td>
<td>450</td>
<td>3 800</td>
<td>4.2</td>
<td>0.90</td>
</tr>
</tbody>
</table>

Data source: Personal communication with Steve Little, 12 August 2011 and Colin Holmes presentation.

These outcomes for Australia can be compared with the benchmark results, at each of the feeding spectrum, for a New Zealand pasture only system using a Friesian Jersey cross and a US TMR system using Friesian/Holstein.

- The NZ system demonstrates the maximum amount of dry matter that can be consumed from 100 per cent grazing system at current liveweight range. Our pasture system may have a slightly higher feed efficiency than that of New Zealand because we are likely to include consumption of up to a tonne of hay or silage (which improves feed efficiency).

Table B.16 compares the each of the feeding systems identified with the case of pasture only.

- Data from the survey shows that cows in intensive systems do not eat dramatically more dry matter at the same average body weight:
B.16 Increase in each feed efficiency compared to pasture only 2009–10

<table>
<thead>
<tr>
<th>Feeding system</th>
<th>Yield</th>
<th>Dry matter consumed</th>
<th>Feed efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low bail</td>
<td>5.8%</td>
<td>3.4%</td>
<td>2.3%</td>
</tr>
<tr>
<td>Moderate to high bail</td>
<td>25.9%</td>
<td>8.3%</td>
<td>16.2%</td>
</tr>
<tr>
<td>Partial mixed rations</td>
<td>29.4%</td>
<td>8.8%</td>
<td>18.9%</td>
</tr>
<tr>
<td>Hybrid</td>
<td>36.3%</td>
<td>10.3%</td>
<td>23.5%</td>
</tr>
<tr>
<td>Total mixed rations</td>
<td>53.1%</td>
<td>13.2%</td>
<td>35.2%</td>
</tr>
</tbody>
</table>

Data source: ADC feeding survey.

- A cow in a TMR system will consume only 13 per cent more dry matter while producing 53 per cent more milk compared to a pasture only system.
  - It would be reasonable to expect these cows to be heavier than in a less intensive system.
  - As a result feed efficiency increases by 35 per cent accounts compared to pasture only. But currently, this system only accounts for less than 2 per cent of cows in production. Still 95 per cent of farms access pastures.

- Around half of cows are still fed in the moderate to high bail systems which results in yields 26 per cent higher than pasture only and consumption of dry matter that is only 8 per cent higher.

Table B.17 shows how the combination of pasture and non-pasture feeds changes with the intensity of the system in Australia.

B.17 Composition of pasture and supplements by feeding system 2009–10

<table>
<thead>
<tr>
<th>Feeding system</th>
<th>Pasture(^a)</th>
<th>Supplements</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>t DM per cow</td>
<td>t DM per cow</td>
<td>t DM per cow</td>
</tr>
<tr>
<td>Low bail</td>
<td>4.3</td>
<td>1.0</td>
<td>5.3</td>
</tr>
<tr>
<td>Moderate to high bail</td>
<td>4.0</td>
<td>1.5</td>
<td>5.5</td>
</tr>
<tr>
<td>Partial mixed rations</td>
<td>3.6</td>
<td>2.0</td>
<td>5.6</td>
</tr>
<tr>
<td>Hybrid</td>
<td>3.2</td>
<td>2.5</td>
<td>5.6</td>
</tr>
<tr>
<td>Total mixed rations</td>
<td>1.8</td>
<td>4.0</td>
<td>5.8</td>
</tr>
<tr>
<td>All</td>
<td>3.9</td>
<td>1.6</td>
<td>5.5</td>
</tr>
</tbody>
</table>

\(^a\) Including pasture grazed, hay and silage.

Data source: ADC feeding survey.

Drivers of feed conversion efficiency for supplemental feeding

Increases in milk yield and feed efficiency in table B.15 are a result of a number of factors, the most significant being the capacity of the cow to consume more dry matter per day through increased use of supplementary feeds and better pasture utilisation. Other factors include use of nutritionally balanced diets, maintaining good rumen function, minimising feed gaps throughout the year, minimising feed wastage and energy losses associated with excessive walking, body condition change, heat stress etc.
In contrast to New Zealand, the pasture-based systems of Victoria are dominated by strong pasture growth in spring which then ‘dries-off’ around Christmas. This leads to lower pasture availability during the mid to late lactation, especially for seasonal dairy farms. Lower nutrition levels then result in significantly lower yields per cow over the year.

Rather than the total amount being fed, the introduction of supplementary feeds, and the use of hay and silage, allows farms to address the shortfall in mid to late lactation to maintain yield. This approach has two benefits.

- The maintenance of yield over these periods will dramatically improve average yields by 25 per cent and total feed use efficiency, by 15 per cent in the case of a moderate to high bail system (compared to pasture only systems).
- Supplementary feeds also allow higher levels of pasture utilisation during the spring growth period by permitting higher stocking rates and more effective use of the feed base. This higher stocking rate is sustained after the spring growth period by feeding hay, silage and non-pasture inputs.

Movement from predominantly pasture to the current structure could alone account for between 15 and 30 per cent increase in yield per cow with other factors held constant.

To simulate the impact of increased use of supplemental feeds, we use our simple energy framework to simulate the impact on a 1980s cow with all other factors held at 1980 levels including pasture efficiency. This is illustrated later.

**Genetics**

There has been considerable increase in output per cow. This is due to genetic improvements resulting from selection and breeding. The process of genetic improvement across the Australian and Victorian herds is complicated and addresses a number of objectives and criteria. Whether intended or not, selecting and breeding for increased production and profit have had two consequences: a trend toward larger framed cows and cows that produce more milk per kilogram of liveweight.

- That said, both smaller and larger breeds both produce more per year now than they did in 1980, but larger cows produce proportionally more on average as they appear to have an advantage in converting feed to milk, especially if high levels of feed are available.

**Breed composition and larger framed cows**

Over the past 30 years the Australian dairy herd has changed markedly in terms of breed composition.

- In 1980, Jersey cows comprised approximately 38 per cent of the herd compared to just 13 per cent in 2010.
Holstein cows became increasingly dominant in the Australian dairy herd; comprising approximately 43 per cent of the herd in 1980 and just less than 80 per cent of the current herd in 2010.

Average liveweight of dairy cattle has also increased dramatically over the period increasing from an average of around 400 kilograms in 1980 to 550 kilograms.

Larger framed cows typically have better feed efficiency than smaller cows, if fed at high levels, because with their higher feed intake, a larger proportion of the diet is available for milk production. That is, maintenance feed requirements are ‘diluted’ by the increased total feed intake.

The shift towards higher yielding breeds (structural shift) and higher yielding animals (via genetic improvement) has resulted in an increase in energy requirement for the average cow. This has been a key driver of the increase in the intensity of Australian dairy feeding systems over the period.

In practice, breed composition also matters because of the composition of the milk produced and target market for that milk. Larger-framed Holstein cows have higher milk yields with lower milk solids than Jerseys and so have a lower energy requirement per litre of milk than Jerseys.

In 1980 a Holstein cow is estimated to have weighed approximately 450 kilograms, around 17 per cent heavier than the Jersey cow in 1980 which are estimated to have weighed approximately 385 kilograms on average.

In 2010 a Holstein cow weighs approximately 575 kilograms, an additional 125 kilograms from the 1980 Holstein. At the same point, a Jersey cow weighed around 425 kilograms, an additional 40 kilograms from the 1980 Jersey.16

Even without genetic gain focusing on increased yield per cow, simply changing breeds and moving to large framed animals will impact on total production milk on a litres basis. But this impact would be significantly different if we were trying to explain the impact on the production of milk solids rather than fluid milk.

In 1980, the average Holstein cow is estimated to have produced approximately 3238 litres of milk per cow, approximately 468 litres more than Jerseys (which produced approximately 2770 litres) in the same year. Remaining cross breeds produced around 2878 per cow (360 less than Holsteins).

If milk yield per cow would have increased in line with liveweight over the period to 2010, then there would be a significant increase in average yields of:

- 28 per cent, to 4139 litres for Holsteins;

16 Live weight averages for each breed are estimated using an annual growth rate of 0.85 per cent for Holsteins and 0.4 per cent for other breeds. These rates are required to achieve average weights reported today.
around 12 per cent for other breeds to around 3170 litres.

To investigate the impact of genetic change in modern cows, starting with the 1980’s cow, the average liveweights of dairy cows were increased in line with trends observed while keeping all other factors at 1980 levels including, critically, pasture availability and the use of supplementary feeds — see later.

**Increases in milk yield per cow**

Genetic improvement has obviously resulted in increases in yield per cow over and beyond that achieved from changing breed.

Experience from other livestock industries suggests that the output gains from such genetic change could be in the order of 1 per cent each year. That is, a 1 per cent increase in milk yield for the same liveweight and feed consumption. To simulate this contribution, we start with the 1980s cow and maintain cow liveweight, pasture availability and the use of supplementary feeds at 1980 levels for the next 30 years.

**Other factors**

In addition to the above, there are the following key factors which contribute to dairy production gains:

- improvement in herd health (reduction in mortality, morbidity and mastitis); and
- seasonal variations (that result in dry matter consumption that is above or below trend on a per cow basis).

These are very difficult to quantify and so will be the ‘residual’ between observed yields per cow and per hectare and the contribution from other factors.

**Contributions to milk yield improvement: conclusions**

Here we vary each factor separately while holding others constant to determine the individual influence of each factor in turn.

**Feeds**

**Supplementary feeds**

Chart B.18 shows observed yields per cow and how much of that yield is explained by supplementary feeds alone. It can be seen that supplementary feeding has significantly increased the nutritional level of the 1980s cow which has resulted in higher yields, up to 1994. As already noted, the most significant factor would be filling in seasonal gaps in nutrition resulting in an increase in feed conversion efficiency. However, the increase in yield plateaus when the 1980s cow reaches its
capacity to consume additional supplementary feed (in addition to 1980s level of pasture utilisation).

A critical assumption here is the additional dry matter that can be consumed by the 1980s cow. We have assumed that this cow can increase consumption by 10 per cent overall. But overall, with supplementary feeds the yield per cow increases by around 33 per cent, 4000 litres in 2010 compared with 3000 litres in 1980. In addition to eating more, supplementary feeds contain more easily digestible and utilisable energy which is converted to more milk.

Supplementary feeds have also made it possible to increase stocking rates. As a result of higher use of supplementary feeds, but with pasture utilisation held constant at 1980s levels, stocking rates can be increased over 1980 levels. From the mid-90s onward they explain a large proportion of the increase in stocking rate (see chart B.19). This means supplements have also made it possible to increase milk per hectare. They allow higher feeding all year round, which allows more pasture to be eaten when it is available, but the animals can be maintained with supplements when pasture gaps occur.

*Increased pasture consumption and utilisation*

Under this scenario, we attempt to increase the level of consumption of pasture by the 1980s cow.

- A cow of this liveweight is not capable of using the higher pasture availability under this scenario, because the maximum amount of pasture that the cow can physically consume is limited (see chart B.20).
- This maximum has been assumed to be around 4.15 tonnes, taking the experience from New Zealand benchmark pasture only system.
B.19 **Impact of supplementary feeding only on stocking rates**

![Graph showing the impact of supplementary feeding on stocking rates with observed yield and yield with supplementary feeding over time.]

*Data source: TheCIE calculations*

B.20 **Impact of greater pasture consumption on per cow yields**

![Graph showing the impact of greater pasture consumption on per cow yields with observed yield and yield with pasture productivity over time.]

*Data source: TheCIE calculations.*

But without supplementary feeding and the 1980s cow, improved pasture permits a higher stocking density around 10 per cent higher than the observed case (the black line is 10 per cent higher than the red line), as shown in chart B.21.

- The bottom line here is that increasing pasture availability or utilisation, on its own, will permit a higher stocking rate and more milk production per hectare, this releasing a land constraint.
- Alternatively, with the same number of cows, it effectively releases land to other uses such as cropping.
B.21 Impact of greater pasture utilisation on stocking rates

Data source: TheCIE calculations.

Genetics

Chart B.22 shows the impact on yield of modern larger cows with higher milk yields, in line with liveweights observed over time, with milk yields growing over the period at around 1 per cent each year (for the same liveweight), yield per cow increases by around 33 per cent between 1980 and 2010.

- With pasture constrained at 1980 levels, higher yielding cows without complementary increases in nutrition would not be able to achieve their genetic potential.
- This is consistent with the experience in the 1980s where larger framed cows and without increases in pasture availability, resulted in poor performing cows.
- This supports the logic why the New Zealand industry with pasture only systems has remained with smaller framed Jersey and Jersey cross genetic stock.

The higher nutritional requirement of modern larger cows without an increase in feed base then requires stocking rates to be reduced. Because stocking rates decline by about 33 per cent, they almost totally offset the increase in output per cow, so reducing milk yield per hectare (chart B.23).
**B.22 Impact of improved genetics only**

![Graph showing the impact of improved genetics on yield per cow.](image)

*Data source: TheCIE calculations.*

**B.23 Impact of genetics on stocking rates**

![Graph showing the impact of improved genetics on stocking rates.](image)

*Data source: TheCIE calculations.*

**Summary of results**

Table B.24 summaries the findings of the attribution exercise. The first point is that the contribution of each factor is critically different between yield per cow and yield per hectare.

- Increased use of supplementary feeds has had the largest single impact on both yield measures.
  - As mentioned before the maximum amount of dry matter that could be consumed by a 1980s cow is a critical assumption.
B.24 Contribution of key factors to observed growth in milk yield

<table>
<thead>
<tr>
<th></th>
<th>Yield per cow</th>
<th></th>
<th>Yield per hectare</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Litres per cow</td>
<td>%</td>
<td>Litres per ha</td>
<td>%</td>
</tr>
<tr>
<td>Feeding</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Increased supplementary feeding</td>
<td>950</td>
<td>33.8</td>
<td>2 233</td>
<td>40.3</td>
</tr>
<tr>
<td>only</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Increased pastures only</td>
<td>40</td>
<td>1.4</td>
<td>1 871</td>
<td>33.8</td>
</tr>
<tr>
<td>Genetics</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Higher yielding cows</td>
<td>958</td>
<td>34.1</td>
<td>176</td>
<td>3.2</td>
</tr>
<tr>
<td>Other factors</td>
<td>866</td>
<td>30.8</td>
<td>1 261</td>
<td>22.8</td>
</tr>
<tr>
<td>Total</td>
<td>2 814</td>
<td>100.0</td>
<td>5 541</td>
<td>100.0</td>
</tr>
</tbody>
</table>

Data source: TheCIE calculations.

- Increasing this parameter from 10 to a 15 per cent increase over pasture only consumption, increases the contribution for supplementary feeds from 34 to 50 per cent.
- While increased utilisation of pastures has had minimal impact on yield per cow, it has probably contributed around one third of the gains to yield per hectare.
- Genetics has potentially a very large contribution to observed increase in yields per cow (around 35 per cent) but a significantly smaller impact on yield per hectare as a result of greater pressure on stocking rates.

The final category as the residual or unexplained proportion represents around one third of the total improvement in yield per cow and one fifth of yield per hectare. Other factors may contain a mix of positive and negative factors including:

- the synergies between genetics and intensive feed systems;
- improved animal health outcomes; and
- higher levels of infertility and associated problems that may have reduced output below levels that could otherwise be expected.

Key sensitivities to variables used in this analysis

Much of the data and analysis presented in this appendix is based on data which has been triangulated from a number of sources and expert industry opinion. The discussion of data sources has indicated that a consistent time series is not complete for many key variables requiring some judgment and opinion. The outcomes of this appendix are most sensitive to data and assumptions regarding the level and time path of:

- average stocking rates on a per hectare basis across the Victorian herd;
- liveweights for cattle by breed across the Victorian herd — which are critical in determining energy demands; and related;
- the compositional shift away from pasture only systems through the 1980s and the 1990s towards the current profile of feeding systems as reflect by recent survey results.