THE CENTRE FOR INTERNATIONAL ECONOMICS

PREPARED FOR HORT INNOVATION JULY 2025

Factors driving horticulture productivity

TECHNICAL REPORT

Hort Innovation

The Centre for International Economics is a private economic research agency that provides professional, independent and timely analysis of international and domestic events and policies.

The CIE's professional staff arrange, undertake and publish commissioned economic research and analysis for industry, corporations, governments, international agencies and individuals.

CANBERRA

Centre for International Economics
Ground Floor, 6 Brindabella Cct South
Canberra Airport ACT 2609

Telephone +61 2 9250 0800
Email cie@TheCIE.com.au

Website www.TheCIE.com.au

SYDNEY

Centre for International Economics
Level 7, 8 Spring Street
Sydney NSW 2000

Telephone +61 2 9250 0800
Email ciesyd@TheCIE.com.au

Website www.TheCIE.com.au

Contents

BOXES, CHARTS AND TABLES

Executive summary

- **The potential for new technologies to unlock an additional $37 billion in value for the horticulture industry is significant. This report presents a forward-looking economic framework to help the industry understand and analyse the key factors driving productivity growth and quantify what is at stake.**

The issue

- **Sustained productivity growth is the primary lever for horticultural enterprises to enhance profitability and competitiveness in response to ongoing challenges in both domestic and global markets.**
- **To help understand and analyse the underlying factors driving productivity within the industry, Hort Innovation commissioned the Centre for International Economics (CIE) to build a tool that incorporated the drivers of productivity.**
- **The purpose of the research presented here is to develop an economic modelling framework that allows users to:**
  - **Understand the relative importance of different drivers with a view to address them through targeted industry actions.**
  - **Quantify different productivity scenarios to create an understanding of what is at stake.**
  - **Examine productivity within industries under unique circumstances.**

Key findings

- **While difficult to measure, historically horticulture productivity has likely grown at between 0.5 and 1.5 per cent a year over the past three decades.**
- **Looking to the future, drivers of productivity can be incorporated within an economic modelling framework that quantifies four key areas of innovation. They are:**
  1. **Production cost analysis: Building the skills and capability to understand cost drivers and profitability. This allows enterprises to modify operations and discontinue unproductive activities or practices.**
  2. **Automated farm data collection: Using digital technologies to support real-time management decisions. This involves capturing, processing, and operationalising data and information to inform farm practices and enable more data-driven farm management.**
  3. **Machine learning (ML) and artificial intelligence (AI): Using advanced analytics to support better decision-making. ML and AI enable enterprises to interrogate**

data, uncover patterns, and understand the detailed dynamics of enterprise performance. This opens up new possibilities for agronomic and related practices.

4. **Mechanisation and automation:** Applying physical automation in farm-based production (picking and spraying, for example), packing and transport. While this overlaps with data collection and AI, this group focuses on the physical implementation and other forms of automated interaction with the relevant crop.

- To demonstrate how this framework can be used, we modelled three innovation adoption scenarios.
  - In each case, this is adoption of innovation over and above 'baseline' productivity driven by factors such as compositional change in the industry.
  - For these scenarios, we report the effect on industry value added as an appropriate measure to assess the effect of productivity changes. Industry value added in the model database in 2025 is estimated to be $8 billion.
- Under the *High* scenario, which assumes relatively rapid adoption of the four innovation elements, productivity growth averages 1.3 per cent a year to 2040. In this case, total horticulture industry value added reaches $22 billion by 2040. Under the *High* scenario, value added in 2040 is 78 per cent higher than it would have been without the innovation adoption.
- Under the *Low* scenario, which assumes a slower adoption rate, productivity growth averages 0.7 per cent a year to 2040. Here, total horticulture industry value added only reaches $17 billion by 2040. This equates to an industry value added 30 per cent higher in 2040 than it would be without the innovation adoption.
- The difference between the two scenarios (added up over time and expressed in today's dollars) comes to $37 billion.
- Analysis of a further *incremental* scenario indicates that, even a small change (a ten-percentage point increase in the maximum adoption rate and a two-year acceleration in adoption) can translate to a $10 billion benefit for the industry.

Conclusion

- Our simulations with the model demonstrate that there is a lot at stake. The difference between faster and slower adoption of productivity enhancing innovations could mean as much as $37 billion (in present value terms) for the entire horticulture industry.
- The modelling developed for this report provides a common language for productivity analysis across different horticulture industries, with the tool offering a practical way to further examine the underlying productivity drivers for the Australian horticulture sector.

Report roadmap

1. Background
Productivity, underpinned by innovation, is the main means by which the horticulture industry can respond to various challenges.

2. What is productivity?
How is it defined and measured, and what are the high-level drivers of productivity within the overall innovation system?

3. Measuring horticulture productivity
What does currently available information tell us about productivity growth in horticulture?

4. Productivity drivers: lessons from growers
Comparing ABS data on productivity drivers with horticulture grower experience.

5. Market dynamics of productivity
A simulation analysis of how on-farm productivity interacts with the market.

6. A grouping of innovation options
Drawing information together to provide a practical grouping of innovation options and their economic impacts as a framework for understanding productivity in horticulture.

7. An economic framework for projecting productivity growth
Using empirical information to develop a modelling framework for projecting productivity growth and economic outcomes in horticultural industries.

8. Horticulture scenarios
Using the economic framework to simulate outcomes of various horticulture scenarios and understand the potential economic value and risks.

9. Conclusion

10. Key focus areas

1 Background

Productivity and economic outcomes

The importance of productivity for economic outcomes is well recognised in recent analyses of Australia's economic performance. As the Productivity Commission has observed 'productivity is the key to long-term prosperity':

> It is the process by which people get more from less: more and better products to meet human needs produced with fewer hours of work and fewer resources. In many cases this growth occurs with lighter environmental impact. (Productivity Commission 2023, p. 1).

In the long-term, productivity growth is the major means through which horticultural enterprises can continue to grow and be profitable in an increasingly competitive domestic and global environment. While short-term profitability can sometimes be achieved by using *more* resources (labour, capital, materials and the natural environment); enduring competitiveness relies on making more efficient and effective use of available resources to maintain resilient and responsive to changes in the external environment.

This is particularly true in an environment where horticulture is increasingly competing with other industries across the wider economy for access to resources such as labour and capital. Industry consultations undertaken for this project reiterate that labour is a key cost and that many producers face labour shortages — at least in some key points of their production cycle. This is consistent with survey data indicating that around one third of horticulture producers have difficulty in recruiting workers (Slatter 2024) along with estimates of seasonal workforce gaps (KPMG 2020).

Productivity growth (and the closely associated idea of innovation) is how the industry can reduce its overall requirements and offer competitive wages to attract labour away from other uses.

At its core, productivity is about the efficient use of available resources: labour, capital, materials, and the environment. Without continual improvements — that is, without productivity growth — any industry is less able to adapt to ongoing challenges and changes in the world. All industries compete for resources, particularly labour. Those that are more productive are better able to compete.

For some enterprises, profitability can be maintained through the development of unique or branded products. But even this needs to be underpinned through productivity. Over time, product premiums are subject to competition from elsewhere in the industry, reinforcing the need for ongoing productivity improvement as the foundation for sustainable industry growth.

This view is widely recognised across the horticulture sector. Industry consultations undertaken as part of this project suggest that many producers are proactively seeking profitable innovations that they can adopt to enhance profitability at the enterprise level. However, the availability of suitable innovations and likelihood of their successful adoption, remains uncertain.

The need to understand productivity drivers

Productivity is fundamental to economic outcomes. Understanding the drivers of productivity — and being able to quantitatively model them — enables the horticulture sector, and the individual industries within it, to undertake analyses and support industry development, including:

- Developing scenarios for future strategic planning.
- Modelling the impact of key drivers (such as policy, R&D, and other drivers on productivity) on productivity and overall economic outcomes for the industry.
- Understanding the adoption level of productivity-enhancing innovations needed to achieve specific productivity growth.

Given the diversity of horticulture industries, this understanding must be flexible and able to be tailored to the specific circumstances of each industry.

This report

This report, produced as part of research project *HA24004 Factors Driving Horticulture Productivity* examines the factors (drivers) that influence productivity within the Australian horticulture industry. It is designed as a companion to the economic modelling research developed under MT21010 Economic contribution of Australian Horticulture.

The *Economic contribution* report used a general equilibrium modelling framework to assess the contribution of horticulture to the broader economy. It used the:

- *FP model* – a general equilibrium model of the Australian economies with a detailed identification of farming and food processing industries; and
- *HI_LINK model* – a detailed horticulture value chain model which identifies 42 horticulture growing (farming) sectors and 6 horticulture processing sectors.

While the *Economic contribution* report developed future scenarios for the value of horticultural production, and used productivity as one input into those scenarios, this report considers the productivity variable in more detail and considers the potential for innovation driven productivity over and above that previously modelled. Specifically, this report explores whether the key drivers of productivity can be systematically understood over the long term.

The report is structured as follows:

- Chapter 2 outlines the key concepts around productivity.
- Chapter 3 considers historical approaches to measuring productivity and compares the information base for all agriculture, including available sources on horticulture.

- Chapter 4 explores the range of factors that influence innovation and, by extension, productivity. Here we compare broader economic and agricultural data with insights drawn from industry consultations.
- Chapter 5 summarises some specific modelling simulations from the horticulture productivity models and compares the findings with insights from our industry consultations.
- Chapter 6 proposes a grouping of innovation options and uses some broad evidence to understand the potential magnitude of productivity gains from each of the productivity types.
- Chapter 7 sets out a modelling framework for projecting productivity by horticulture industry. This framework is implemented using a spreadsheet model which is a companion to this report.
- Chapter 8 reports model simulations to indicate the importance of different productivity scenarios to the horticulture industry.
- Chapter 9 provides a conclusion.
- Chapter 10 suggests some areas for future focus.

Overall methodology

The overall research methodology for this report consisted of three main components:

- **Theoretical analysis** of the underlying factors that drive the adoption of new technologies and practices, and consequently, increases in productivity. This analysis was used to enhance the modelling capability that underpins the models applied in the *Economic Contribution* report.
- **Literature and data set reviews** to assess relevant existing information.
- **Industry consultations**, including one on one interviews and a series of four mini-workshops (see Appendix B).

Box 1.1 summarises some key resources that support the examination of productivity in horticulture.

1.1 Key resources

Productivity in its broadest sense has been the subject of extensive researchers by institutions and academics over many years.

At an economywide level, the Australian Productivity Commission has a broad mandate to study, analyse, and make policy recommendations to help enhance productivity. Its five yearly reviews (most recently Advancing Prosperity) provide a detailed picture of productivity in Australia.

Within agriculture, including horticulture, the Australia Bureau of Agricultural and Resource Economics (ABARES) has a long history of analysing agricultural productivity. ABARES provides regular updates and publishes detailed research reports (see: https://www.agriculture.gov.au/abares/research-topics/productivity).

The Australian Government Department of Industry Science and Resources, provides data and analysis to track Australia's innovations system. This work is done in conjunction with the Australian Bureau of Statistics (ABS), which produces data for Innovation in Australian Business.

The analysis of how new technologies and techniques are diffused and adopted is central to productivity growth in agriculture and other sectors, a topic that has been subject to considerable study since at least the 1950s. A key reference in this field is the seminal *Diffusion of Innovations* by Everett Rogers, first published in 1965 and now in its fifth edition.

The work of Kuehne et al (*Predicting farmer uptake of new agricultural practices: A tool for research, extension and policy*) which led to the ADOPT model provided by CSIRO has drawn on this literature to develop a quantitative tool incorporating a wide set of underlying factors.

Within horticulture, the 2015 report for Hort Innovation project AI13011 *Transformational Innovation Performance Analysis* by Dr Damian Hine presents key survey results examining innovation in horticulture enterprises. This work serves as a complementary resource to the ABS innovation survey data.

2 *What is productivity?*

Productivity is fundamentally about how efficiently we turn inputs—such as labour, land, capital (technology), and materials—into outputs. It measures how much value or product is generated for every unit of resource used.

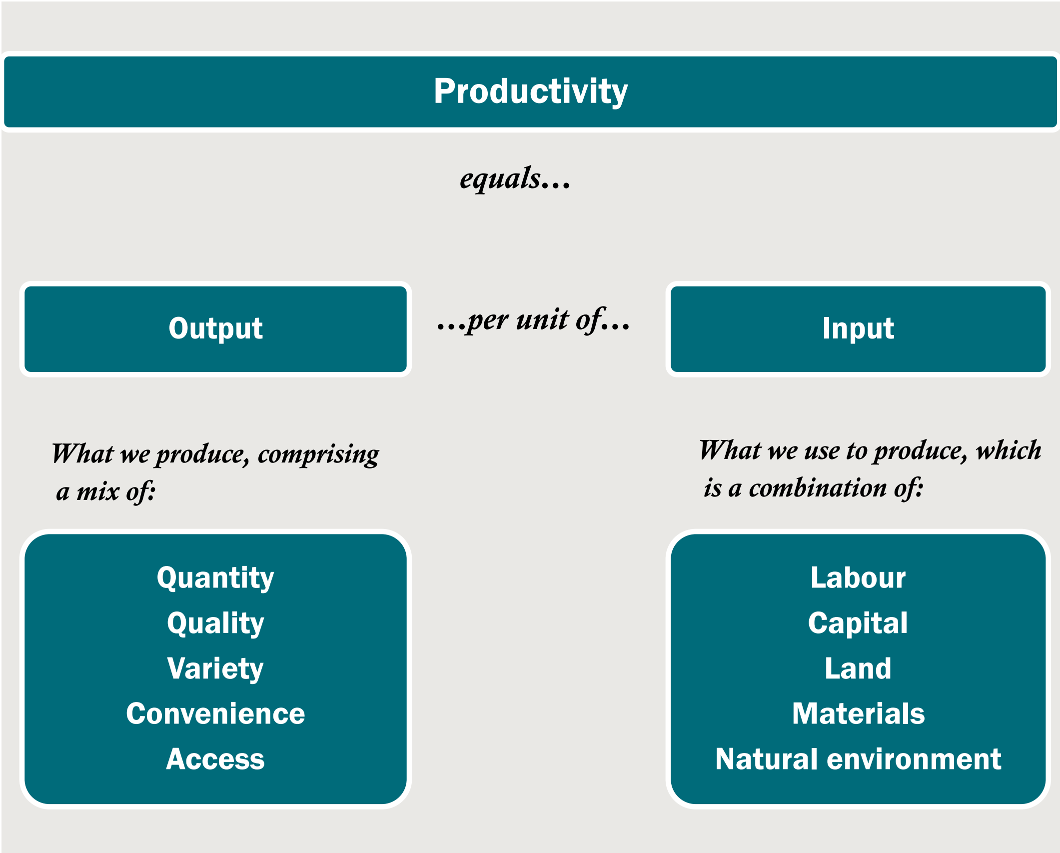
Productivity is about getting more from less…

Australia's Productivity Commission defines productivity as follows:

> It is the process by which we learn how to get more from less: more and better products — new solutions to meet human needs — produced with less hours of work, fewer resources and a lighter environmental impact.
>
> In essence, productivity growth is about working smarter. The extraordinary rise in average living standards over the past 200 years has come about through the ongoing discovery and spread of new, useful ideas. Some took the form of new technology — like electricity or antibiotics. Others were new business models like mass production or ride sharing. While others were institutional innovations like accounting standards, capital markets or free trade. (Productivity Commission *Advancing Prosperity: 5-year Productivity Inquiry Report*).

Sometimes productivity is confused with production: someone is productive if they produce more. But this common use misses the other part of the equation, that it is about producing more but with less effort.

2.1 Defining productivity



Data source: CIE

…it's about outputs from inputs…

Productivity is defined as the ratio of a measure of output relative to a measure of inputs. Using this definition, there are a variety of productivity measures that are commonly used including:

- Yield: Output relative to the quantity of land input (hectares, for example).
- Labour productivity: Output relative to labour input (hours worked or FTE workers, for example).
- Multifactor productivity (MFP), sometimes called total factor productivity (TFP): Output relative to a combined index of all inputs. This includes labour, land, materials (such as chemicals, fuel etc) and capital (long-lived assets that deliver benefits over time).

While each of these measures can be useful for specific purposes, it is important to note that partial productivity measures (such as yield and labour productivity, that look at output relative to one input) can be misleading as they do not capture the full set of inputs. For example, yield may increase due to higher labour and material use, but if those additional inputs outweigh the gains in output, MFP may decline.

…and it is more than the 'quantity' of output

Productivity growth is not just about increases in the 'quantity' of production. Other dimensions of output, including the quality or variety of goods (and services), are also a crucial part of the productivity story.

Recent research by ABARES indicates very clearly that while looking only at the quantity of output in the vegetable industry, productivity appears to have declined. However, when changes in product quality were accounted for, the data suggested the possibility of much stronger productivity growth (See Valle et al *Total factor productivity of Australian Vegetable farms*, April 2024).

In its most general sense, growth in productivity means generating an increase ***in something of value*** without using additional resources – and ideally, freeing up resources to create additional value elsewhere. That value can take different forms, including:

- Increased product quality.
- Greater product variety.
- Improved social outcomes.
- Better environmental outcomes (or reduced environmental impact).
- Increased profitability through lower costs or higher revenue.

For some horticulture industries, opportunities to increase the total quantity of sales may be limited. In these cases, productivity gains are more likely to come from improving product quality, expanding product variety, or delivering better outcomes for the environment or communities – rather than simply producing more.

Three levels of productivity

Productivity can be thought about and measured at three levels:

1. Economywide.
2. Industry.
3. Individual enterprise.

While productivity ultimately stems from decisions of individual enterprises, there are sources of productivity gain at the industry and economy-wide levels that emerge from changes in the composition of production — either the size and nature of firms, or the mix of products produced by the industry.

A compositional shift within an industry from smaller to larger firms — that is, an increase in scale — tends to improve measured productivity when economies of scale enable efficiencies in overall production. According to ABARES, 'farm size has proven to be a core driver of productivity growth by spreading fixed costs such as management skill and machinery ownership, to generate more output' (ABARES 2025).

A reallocation of resources away from lower yielding options and products to higher yielding or more profitable product lines will also tend to increase aggregate productivity.

In both cases, aggregate productivity can increase even if the productivity of individual entities does not increase — as long as there is a compositional change that results in improved resource allocation efficiency. These types of productivity gains depend on the flexibility and efficiency of markets.

Conversely, barriers to market flexibility (eg. regulatory barriers or poor information flow) can restrict and limit both aggregate and individual productivity growth.

Productivity growth

An organisation cannot raise its productivity without change — whether through doing new things or doing old *things better. In this sense, productivity is virtually synonymous with innovation. (**Gary Banks**, former Chair, Productivity Commission)*

Long run productivity growth is determined by the innovation and diffusion (or adoption) of a series of new technologies, practices and products that deliver greater value and higher net returns.

The technologies and practices can be viewed in general terms and cover a broad range of approaches and techniques including:

- Specific new machinery or new plant varieties.
- New techniques for pest and environmental management.
- New management approaches.
- New ways in which new markets are found and developed.

Moving to the frontier, and moving the frontier

Over time there are two fundamental and closely related processes that lead to improvements in productivity. These reflect the distinction between how enterprises within an industry adopt existing best practices and how entirely new technologies or practices are developed which extend productivity beyond what was previously possible.

Productivity growth occurs through two complementary processes:

- Adoption or diffusion of existing best practices by individual enterprises. In effect, these businesses improve their productivity by catching up to, or being at the frontier of, the productivity that is possible with existing technologies and practices – ***moving toward the productivity frontier***.
- New ideas or new knowledge being used to create innovations that elevate performance for the whole industry beyond current best practice - ***shifting the productivity frontier.***

The diffusion or adoption processes for these are very closely related. Sometimes moving the frontier is about diffusion of ideas from outside the industry or outside the country. Sometimes it is about creating new ideas that are themselves the result of diffusion or a combination of ideas from different fields.

Clear incentives and an enabling environment

There is a long-standing body of research exploring the drivers of innovation, diffusion and hence productivity. The simplest summary of what emerges is that sustained productivity gains requires two core conditions:

1 **Clear incentives** to increase productivity.

2 **An enabling environment** that allows those incentives to be realised.

A clear historical presentation of this can be seen in the Australian Productivity Commission publication *Sources of Australia's Productivity Revival*. This report considered the reasons for Australia's boost in productivity growth in the 1990s (never since repeated). The research found that some of the immediate causes were:

- Increased openness (in domestic markets and openness to international trade).
- Increased domestic R&D.
- Spillovers from adoption of outcomes from international R&D, including developments in information and communications technologies.

Crucially, each of these factors were underpinned by specific policy reforms. These included:

- Competition-enhancing policies that strengthened incentives to improve productivity.
- Targeted support for R&D.
- Enhanced flexibility in product, labour, and capital markets - together forming a more enabling environment.

An innovation system framework

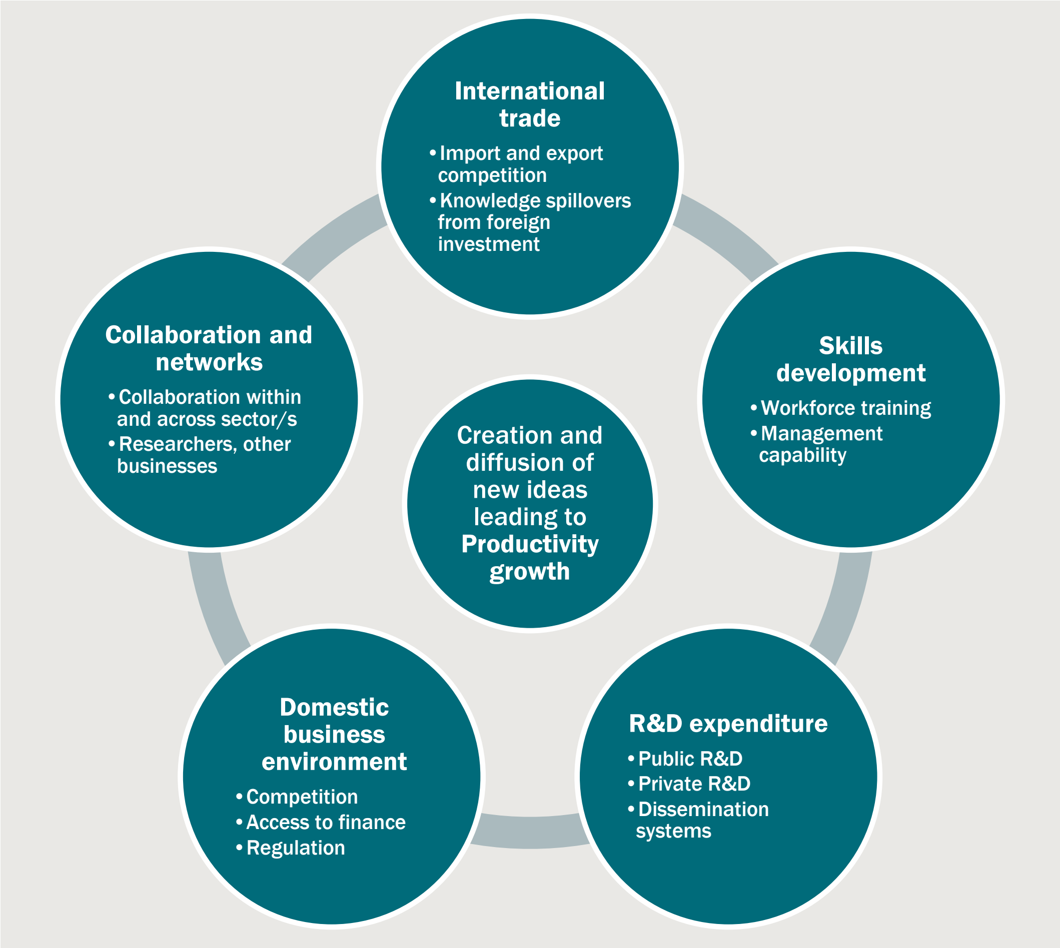
The Australian Government, through the Department of Industry Science and Resources and Industry and Innovation and Science Australia, sets out a broad classification for the enabling environment that supports innovation in Australia (chart 2.2). This framework consists of 5 key factors:

- **International trade and technology spillovers**. International trade and linkages with foreign investment encourage the exchange and adoption of globally competitive innovations. For Australia – especially in horticulture – international linkages are a particularly important mechanism for finding and implementing new innovations. Chapter 4 explores this in more detail.
- **Skills development**. In many contexts, skilled workers play a critical role in both adopting and adapting the adoption of innovations, as well as ensuring they are effectively implemented and customised for Australian conditions. In horticulture, it is likely that new types of skills will become increasingly important as new production technologies (including artificial intelligence, AI, and automation) become more important.
- **R&D expenditure**. R&D expenditure both by governments and individual enterprises is an essential precursor for innovation. Australia's domestic R&D complements the

broader global innovation ecosystem, contributing to both local advancements and the ability to adapt international technologies.

- **The domestic business environment**. There are many factors that combine to make up the Australia domestic business environment. Of particular importance is the extent of competition in markets and the availability of finance to fund innovation activities. Competitive industries are generally more productive (monopolies do not need to innovate to remain profitable), and competition also creates incentives for innovation. The domestic business environment is also influenced by the nature and type of government regulatory actions.
- **Collaboration and networks**. Innovations diffuse through both formal collaborations and informal networks - between growers, researchers, and other stakeholders. These connections support knowledge exchange and the evolution of the innovation.

2.2 The enabling environment



Data source: Based on Department of Industry, Science and Resources.

2.3 Economic theory and productivity

Economic theory provides several complementary frameworks to explain how productivity increases over time.

One major strand of theory focuses on the **creation and spread of new ideas.** Innovations — such as research into better crop varieties, more efficient irrigation, or improved pest management techniques — are forms of knowledge that, once generated, can be widely adopted by all growers. (See, for example, Romer 1990).

Another strand focuses on the role of **human capital** - the skills and experience of farm managers and workers. Just as formal education raises a worker's effectiveness in a factory, on-farm training and hands-on learning raise the capacity to adopt and adapt new technologies on the farm. (see, for example, Sorensen 1993).

A third family of models conceptualises productivity growth as a series of **stepwise quality improvements**. Innovations are conceptualised as moving growers to higher 'rungs on the ladder' of productivity. Over time, old methods are replaced in a process of 'creative destruction' as successful new ideas replace older ones. (Grossman and Helpman 1989 and Aghion and Howitt 1992).

Finally, models of **directed technical change** explore why some innovations are pursued over others. These theories suggest that innovation responds to relative scarcity. For example, when labour is expensive, researchers and equipment makers focus on labour-saving techniques; or when land is scarce, they prioritise ways to grow more fruit per hectare. (Acemoglu 2002).

Example: labour productivity

Table 2.4 outlines three broad ways by which an individual enterprise could increase labour productivity. A key idea is that labour productivity can be increased either through the application of additional capital (eg. new machinery or new technology designed to improve worker efficient) or through increasing human capital (that is, increasing the skills and capability of workers e.g. through training).

Automation represents a specific form of capital investment where activities can be redesigned to reduce reliance on labour. Each of these strategies can strengthen enterprise-level performance which when adopted while also have wider implications for the enterprise and the overall industry.

2.4 Paths to increase labour productivity

Option	Nature of improvement	Wider implications
Increase worker 'human capital'	On the job or other formal training that enables workers to perform more efficiently throughout the enterprise.	Increased skills make the worker more valuable across the industry. Individual enterprises may not be able to retain the gains.

Option	Nature of improvement	Wider implications
Apply new capital to support workers	Deployment of technology to directly improve productivity of workers. For example, AI glasses to assist with harvesting increases worker efficiency.	Expertise will be required to train, customise and maintain the system. AI expertise will become a crucial factor for enterprises.
Reduce worker reliance through automation	The use of machinery or robot-based capital items to reduce worker reliance within a particular operation.	Enterprises will require access to specific expertise for both training and problem solving on a day-to-day basis. Likely to alter relationships within the production chain. Robotics expertise may become a limiting factor, rather than labour per se.

Source: CIE.

Implications for drivers and modelling strategy

Table 2.5 summarises the implications of this discussion for the modelling of productivity drivers.

2.5 Implications for drivers and modelling strategy

Driver	Comment	Modelling strategy
Scale change, or changes in the mix of products within the industry	Industry productivity may change over time due to a change in the composition of the industry (as reflected either in the size of firms), or through the mix of products produced by the overall industry (each of which will have different cost structures).	The modelling framework does not explicitly recognise different sized firms within an overall horticulture industry. The potential effect of compositional change is modelled through an exogenous small annual increase in the productivity of each industry. The model recognises 42 different growing horticultural industries, so the overall composition of the horticulture sector is determined within the model in response to the circumstances of each individual industry within horticulture.
Incentives	All change requires incentives. By far the most important incentive is to maintain profitability of the overall enterprise. Within this, specific labour issues create targeted incentive for improved labour productivity.	The modelling framework assumes that profitability is the main objective within each horticulture industry (and indeed, for all industries outside of horticulture). This means that within each industry, inputs are reallocated to maximise profitability (given the technical constraints faced by the industry).
Enabling environment	The overall research and regulatory environments have a key influence on the adoption of innovations.	As discussed further in chapter 7, drivers related to the enabling environment are built into the modelling of individual adoption factors.
Types of productivity	Productivity is related to each of the individual factors of production and productivity can increase because of factors applying to any of these.	The modelling framework recognises four broad factors of production: land, labour, capital and material inputs (comprise of the many materials used in production).

Driver	Comment	Modelling strategy
		The modelling framework provided within the spreadsheet distinguishes between labour productivity and MFP, which also includes labour.

Source: CIE.

3 Measuring horticulture productivity

Aggregate Australian estimates

The two major sources of information about productivity in the Australian economy are:

- The Australian Bureau of Statistics (ABS) which regularly publishes Estimates of Industry Multifactor Productivity, which include a range of productivity estimates and their components for major industry groups. ABS's most detailed published estimates refer to the sector Agriculture, Forestry and Fishing. However, the ABS do not produce specific productivity estimates for horticulture. The data reveals that agricultural productivity growth is considerably higher than the economy-wide average (table 3.1).
- The Australian Bureau of Agricultural and Resource Economics and Sciences (ABARES) which presents systematic analysis of productivity in Australian broadacre agriculture and dairy (Table 3.1). ABARES do not routinely report horticulture productivity, however a 2024 ABARES study looked at productivity within Australian vegetable farms. While productivity appeared to be declining in this study, it noted that this is likely to be an underestimate of actual productivity growth because changes in product quality are difficult to capture in the data (table 3.1).

3.1 Summary of historical productivity growth estimates

Source and coverage	Productivity measure	Growth rate
		Per cent per year
ABS		
Agriculture, forestry and fisheries	Value added based (1994-95 to 2023-24)	2.25
Agriculture, forestry and fisheries	Output based (1994-95 to 2023-24)	0.88
All sectors	Value added based (1994-95 to 2023-24)	0.27
ABARES		
All broadacre	Output based (1994-95 to 2023-24)	0.5 to 0.6 (depending on climate adjustment)
Dairy	Output based (1994-95 to 2023-24)	0.5
Vegetables	Output based (2007-08 to 2015-16)	-1.08 to 2.13 (depending on quality adjustment)

Note: Productivity can be estimated on both a value added or total output basis. ABS reports value added estimates as their main area of focus. ABARES estimates are consistent with an output-based focus. Generally, value added based estimates imply higher growth than output-based estimates. The two can be reconciled by considering the share of value added in total output.

Source: ABS and ABARES

Top-down estimates for horticulture

One way of getting a sense of productivity growth for horticulture is to use the aggregate agricultural estimates, combined with the components for broadacre, to estimate horticulture productivity growth.

As set out in Appendix A, such an analysis implies horticulture productivity growth (on an output basis) of between 0.5 and 1.5 per cent a year.

3.2 Limited horticulture productivity estimates

There are very few statistical productivity series for horticulture published for any country in the world (in contrast with broadacre agricultural productivity). The reasons for this relate to fundamental challenges in undertaking systematic analysis for a sector as diverse as horticulture.

- Horticulture covers a diverse array of crops with different characteristics. These cannot easily be aggregated into a single output index, considering horticulture outputs vary in unit and quality. From price data to weight measurements, these outputs are often sparse or hard to compare. A shift from low-value to high-value crops (or improvements in quality) might raise farm income and arguably productivity, but those gains aren't fully captured by simple quantity indices.
- In Australia, there is not sufficiently detailed or long enough time series data to allow long-term productivity analysis.
- Horticulture is generally more labour-intensive and has multiple harvests or continuous production cycles compared with broadacre cropping. This complexity means input–output relationships are harder to quantify. For instance, an orchard's output may be influenced by tree age cycles or pruning practices that don't have clear 'input' values.
- Horticulture industries often focus on improving quality, shelf-life, or variety of produce rather than just quantity. While these improvements (e.g. a sweeter mango variety or packaged salad greens) increase value, they may not increase the overall quantity of output. Standard productivity indexes based on quantity can thus undervalue progress in horticulture.

Implied productivity

While the benchmarking reports set out in Appendix A are not specifically intended to measure productivity growth over time, they do provide some basis for drawing inferences about productivity growth within those sectors.

Table 3.3 summarises productivity estimates derived from these benchmarking reports. As expected, the results are varied - reflecting the different industry contexts, challenges, and productions systems - and range from periods of strong productivity (yield) growth to periods of highly variable growth.

3.3 Productivity growth implied by benchmarking reports

Industry	Productivity measure	Period	Productivity growth
			% per year
Nursery	MFP proxy	2017-18 to 2020-21	2 to 4
	MFP proxy	2020-21 to 2023-24	–4 to –6
Almonds	Yield	2011 to 2023	1.3
Macadamias	Yield	2009 to 2023	1.1 to 2.5
Bananas	MFP proxy	2011 to 2024	–1.6

Source: See Appendix A.

Table 3.4 presents productivity comparisons between the highest and lowest profitability enterprises in the avocado and vegetable industries. The data shows that the lowest 25 per cent of enterprises (by profitability) have around half the productivity of the highest 25 per cent, with this difference consistent across all inputs.

3.4 Productivity differences highest and lowest performing enterprises

Industry	Productivity measure	Period	Lowest 25% (Productivity Index)	Highest 25% (Productivity Index)
Avocado	MFP	2022	100	192
	MFP	2023	100	206
Vegetables	MFP	2023	100	177
	Labour	2023	100	197
	Fertiliser	2023	100	180

Note: Productivity for the lowest 25% set at 100.

Source: See Appendix A.

Analysis of these reports indicates that if the lowest profit enterprises were able to lift their productivity to the sample average, overall industry productivity would increase by between 7 and 10 per cent. This magnitude of potential gain is demonstrated in chapter 6 and chapter 8 when examining potential productivity improvements in horticulture.

Do horticultural enterprises measure their own productivity?

Industry consultations indicate that individual growers or enterprises in horticulture do pay attention to productivity, though primarily through 'partial' productivity measures—such as labour harvest rates, pack-out rates, and other similar estimates that can be generated daily.

These productivity estimates are used primarily to support operational decision-making, helping identify issues and maintain throughput in areas such as packing and transport. Although profit margins remain the key performance metric for most businesses, productivity metrics play a supporting role in maintaining overall profitability.

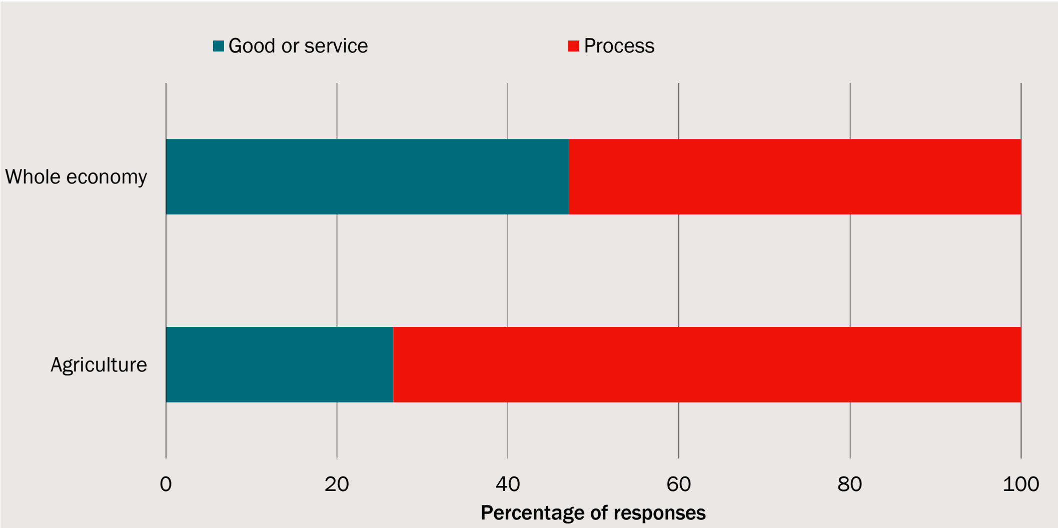
4 Productivity drivers: lessons from growers

This chapter draws on ABS innovation data as a vehicle for considering key factors underlying innovation in Australian horticulture. For each area of innovation, we consider relevant economic and agricultural information and compare them with findings of practical grower experience that emerged from industry consultations.

Product or process innovation

Innovations can occur in either goods and services (product innovation) or in underlying production and business processes (process innovation). For the overall economy, product and process innovation occur at roughly similar rates. However, in agriculture, there is considerably more focus on process innovation (chart 4.1).

4.1 Product and process innovation



Data source: ABS *Innovation in Australian Business*.

For horticulture, it is also true that process innovation is the major focus. Table 4.2 summarises the types of innovation in horticulture that have been identified in previous studies.

4.2 Examples of process innovations in horticulture

Typical innovations
Approaches to labour use or other farm management practices
Marketing approaches
Transport, storage and logistics processes
Equipment
Fertiliser application practices
Multi-site farming
Multi-cropping
Irrigation and water management practices
Soil management practices
Pest management practices
Weed management practices

Source: Hine 2015 *Transformational Innovation Performance Analysis*.

It is important to note, however, that there is a significant amount of product innovation in horticulture, whether that is through new varieties or finding new ways of presenting produce to consumers. For example:

- New varieties, such as Bravo apples, represent a new product, introducing a unique set of characteristics within an existing product category.
- New specifications, such as the red-tipped eco-banana, offers a new variant to consumers that reflects a different underlying production process, combining both product and process innovation.
- New processes embedded in recognisable products, such as the Mulgowie green beans, are another example of product innovations that seek to provide the consumer with a better overall experience.

Novelty of the innovation

Innovations taking place within a business can have various levels of novelty; they may be new to the world, new to the country (Australia), new to the industry, or they may be new to the business only.

In Australian agriculture, most innovations are new to the business only, a similar trend to the overall Australian economy (chart 4.3). Very few of the innovations are new to the industry or to Australia. Diffusion of existing ideas and practices is a key mechanism underlying productivity for agriculture. This, in part, reflects the large amount of international research taking place.

4.3 Novelty of the innovation

Data source: ABS Innovation in Australian Business.

This pattern is also broadly true for horticulture. While there are some growers that have self-initiated developments, industry consultations indicated that many growers actively seek new information and ideas from overseas, often with regular visits to South Africa, the Netherlands, Israel and the United States (depending on the industry). That is, these growers are seeking information that is new to them but not to the world. The countries visited are generally recognised as the technical leaders within product groups or technical practices.

Further, some enterprises are individually cultivating relationships with key international machinery and technology companies to find out about, and in some cases, test new products. At the same time, international suppliers appear to be seeking broader industry-wide options to introduce new, innovation-led products into the Australian market.

Industry consultations highlighted that growers draw on a diverse range of sources for new technology and processes suitable for horticulture. Table 4.4 provides an illustrative list of technology suppliers that regularly featured in the consultations. The presence of these suppliers — often on the cutting edge of technical developments — reflects the simple fact that there are many innovations available that are new to the enterprise, but not to the industry, and in many cases also not new to Australia.

4.4 Sample of tech suppliers and providers identified in industry consultations

Supplier	Nature of service and industry use
Multikraft Probiotic Solutions https://multikraft.com.au/	Fertilisation
GlobalGap https://www.globalgap.org/	Automated certification
Farmable https://farmable.tech/	AI supported farm management.
Oxbo https://www.oxbo.com/	Harvest technology
Fieldin https://fieldin.com/	Real time data
GUSS https://gussag.com/	Autonomous sprayer
Aerobotics https://www.aerobotics.com/	Fruit sizing technology
Burro https://burro.ai/	Autonomous vehicles
Swarmfarm https://www.swarmfarm.com/	Autonomous vehicles
CeresAI https://ceres.ai/	Farm management
RapidAIM https://rapidaim.io/what-we-do/	Digital pest management
GreenAtlas https://greenatlas.com/	Crop load management
Fieldwork Robotics https://fieldworkrobotics.com/	Raspberry harvesting
Ripe Robotics https://www.riperobotics.com/	Automated apple and stone fruit picking
Smart Apply https://smartapply.com/	Spray control system

Source: Industry consultations.

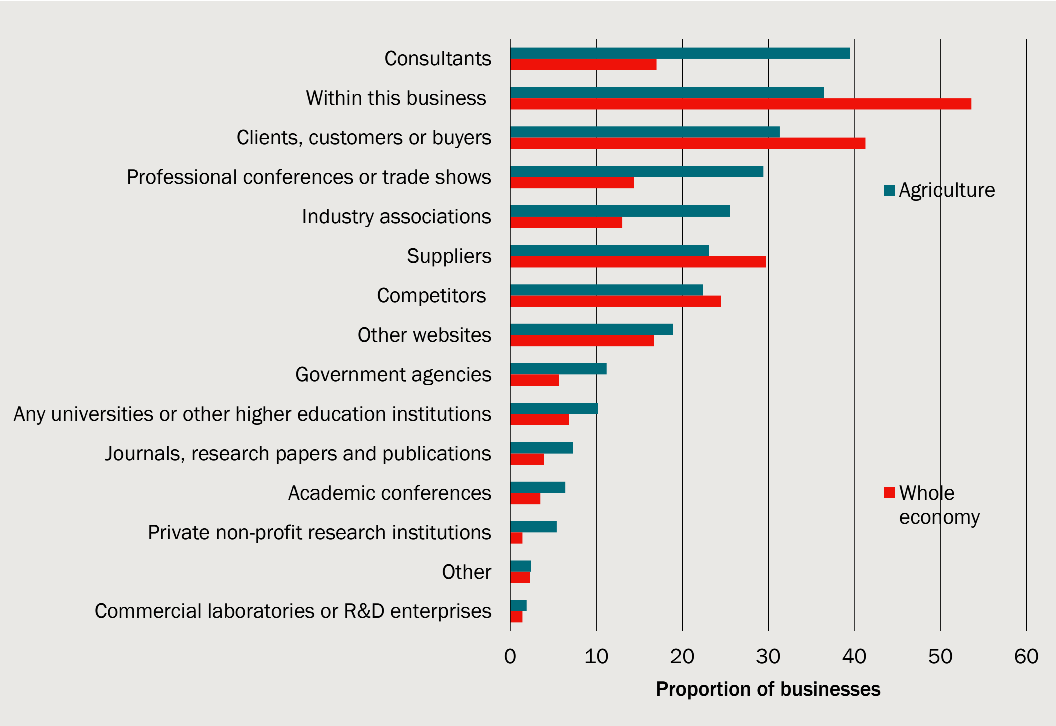
Where do ideas come from?

The source of ideas for innovation indicates the ways in which information is transmitted throughout the industry. Strengthening these information flows can be a major contributor to the adoption of new practices or technologies.

In agriculture, the most frequent response given to '*where ideas come from*?' is *consultants*. This category broadly includes a range of paid farm advisors such as agronomists and business consultants (refer to chart 4.5). According to ABS Innovation in Australian Business, consultants play a significantly larger role in transmitting ideas within the agriculture sector compared to the overall economy.

The second most cited source of ideas is *within the business*, followed by *professional conferences and trade shows* and then *industry associates*. Notably, both conferences and trade shows and industry associates are considerably more influential sources of ideas in agriculture than in the overall economy.

4.5 Where do ideas come from?



Data source: ABS Innovation in Australian Business.

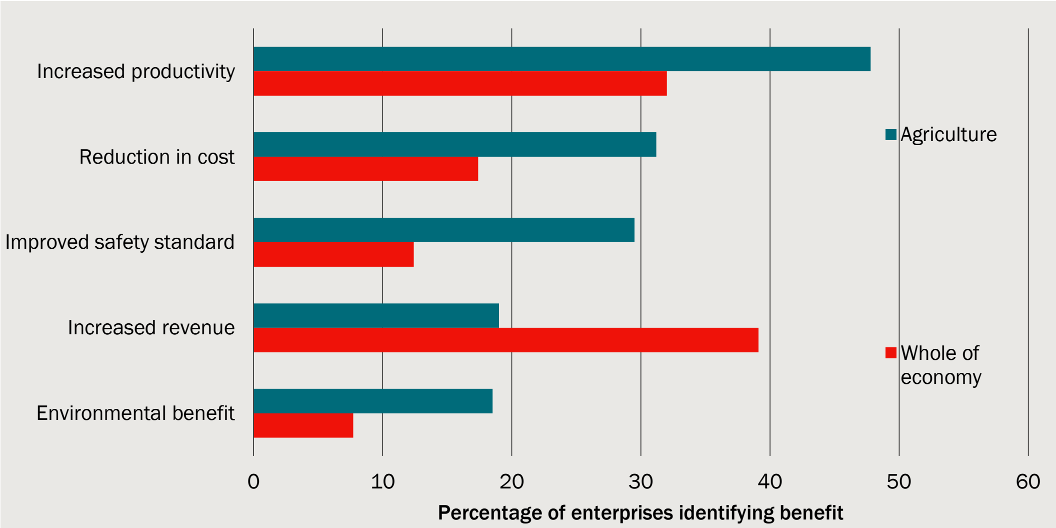
Within horticulture, a slightly different picture emerged. Technology suppliers, or potential suppliers, are evidently a very important source of information for innovation.

As noted above, there is a large body of potential technical developments in horticulture, many of which are already in use in international markets. Knowledge of this within horticultural enterprise seems to depend less on domestic networks within the industry (conferences and so on) and more on proactive, targeted search activities undertaken by the enterprises themselves.

Benefits and barriers to innovation

When considering the benefits of innovation, increased productivity and reduced costs emerge as major factors for agriculture — more so than across the broader economy (refer to chart 4.6). Additionally, both safety standards and environmental benefits are more prominent priorities in agriculture compared to the overall economy. This likely reflects the nature of agricultural work practices and the heightened awareness of environmental impacts in rural industries.

4.6 Key benefits of innovation

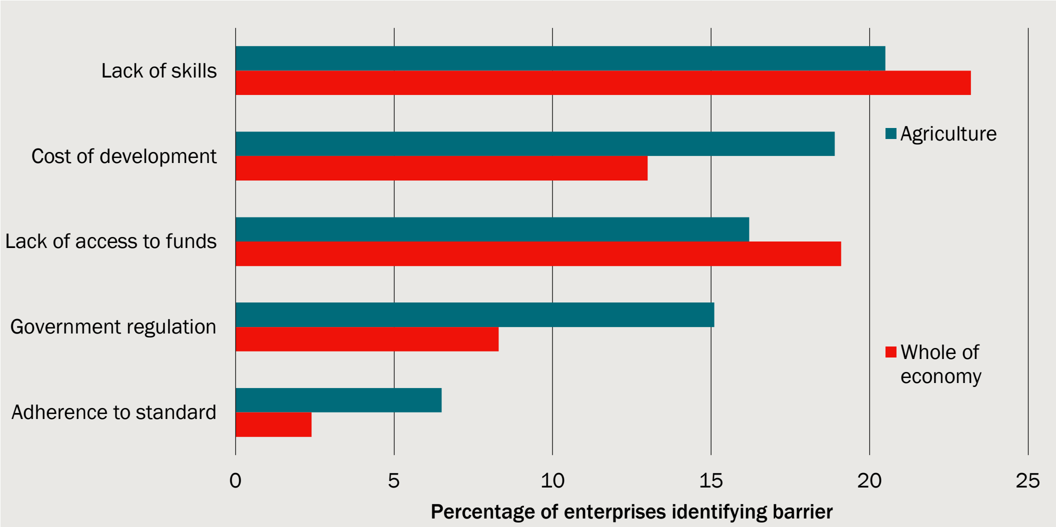


Data source: ABS Innovation in Australian Business.

These same broad benefits of innovation were also reflected in the horticulture consultations. Productivity gains — particularly in response to competitive pressures— and cost reduction (especially labour costs), were consistently cited as key benefits of innovation adoption.

Barriers to innovation in agriculture include lack of skills, cost of product and process development, and lack of funds. These barriers are broadly consistent with the barriers faced by the whole economy (refer to chart 4.7). However, the ABS survey highlights that government regulation and compliance with standards are notably more significant as a barrier to innovation in agriculture than it is for the wider economy.

4.7 Key barriers to innovation



Data source: ABS Innovation in Australian Business.

These same broad findings also hold true for horticulture. Many horticulture enterprises cited capital constraints as a key limitation to adopting new technologies, particularly where there is uncertainty about the potential impact of the technology. Some enterprises also expressed uncertainty about how to assess or evaluate new technologies, contributing to uncertainty around the true costs of adoption.

Regulatory constraints were also raised as barriers, including rules around the use of drones for spraying and chemical operations, as well as constraints on the use of autonomous vehicles at the interface between private and public property.

Workshop outcomes

A complementary framing of these benefits and barriers is presented in table 4.8, which summarises the findings from four mini workshops that were conducted as part of the industry consultation process.

4.8 Summary of workshop responses

What is your biggest productivity challenge?
Labour costs
Pricing transparency
Lack of full understanding of costs of production; knowledge, and finance to make business decisions
Supermarket quality parameters
Regulations and compliance, especially around biosecurity (fruit fly zones), chemical registration and related certification
Other regulations (e.g. solar panels, netting, drones)
What can you do to address this?
Collaboration and supply chain transparency

Consumer engagement
Assessment and adoption of automation products
What would help you implement a response?
Shelf-life extension research
Communication of product health attributes to consumers
Easy to use costing app or software
Analytical tools for assessing new technologies, to help determine profitability and ROI
Integrated management tools to allow work on key growth parameters
What is hindering you from implementing a response?
Cost and profitability of new tech. Current technology seems to be very high cost
Capital cost and applicability of new tech, especially automation
Not all production steps are currently susceptible to automation

Source: CIE/HI online workshops, April 2025.

Implications for drivers and modelling strategy

Table 4.9 summarises the implications of the above discussion for the modelling of productivity drivers.

4.9 Implications for drivers and modelling strategy

Driver	Comment	Modelling strategy
Availability of technical options and strategies	Industry discussions and the broader literature indicate substantial volume of technical development is taking place- both within Australia and, more notably, internationally.	The modelling approach assumes a wide availability of technical options and focuses primarily on the economics of adoption. The modelling framework is deliberately 'technology agnostic' and flexible, allowing for the incorporation of a broad range of innovations.
Dissemination of ideas	Knowing about and understanding an innovation is key to being able to consider implementing it. Enterprises appear to be largely proactive in finding information about the options available.	The core strategy is to incorporate parameters for dissemination within the adoption framework set out in chapter 7.
Constraints and barriers	Key barriers to adoption include capital constraints, the availability of sufficient skills to implement and potential regulatory limitations.	The existence of these barriers is explicitly included in the adoption framework set out in chapter 7.

Source: CIE.

5 Market dynamics of productivity

The implications of productivity change within agriculture markets have been subject to considerable empirical and modelling analysis. The work of Borrell et al (2014) illustrates how to use a model of the food production chain to analyse productivity changes induced by R&D. One of the key findings is that productivity developments along the whole production chain bring benefits to growers.

This chapter uses the FP and HI_LINK models to illustrate the implications of productivity change specifically within the horticulture value chain.

These models incorporate a number of different productivity levers and can be used to simulate and compare the impacts of different types of productivity improvements. They allow the analysis of changes in:

- Labour productivity.
- Capital productivity.
- Land productivity (yield).
- Water use productivity.
- Efficiency in the use of other inputs (such as chemicals, fertilisers, etc).

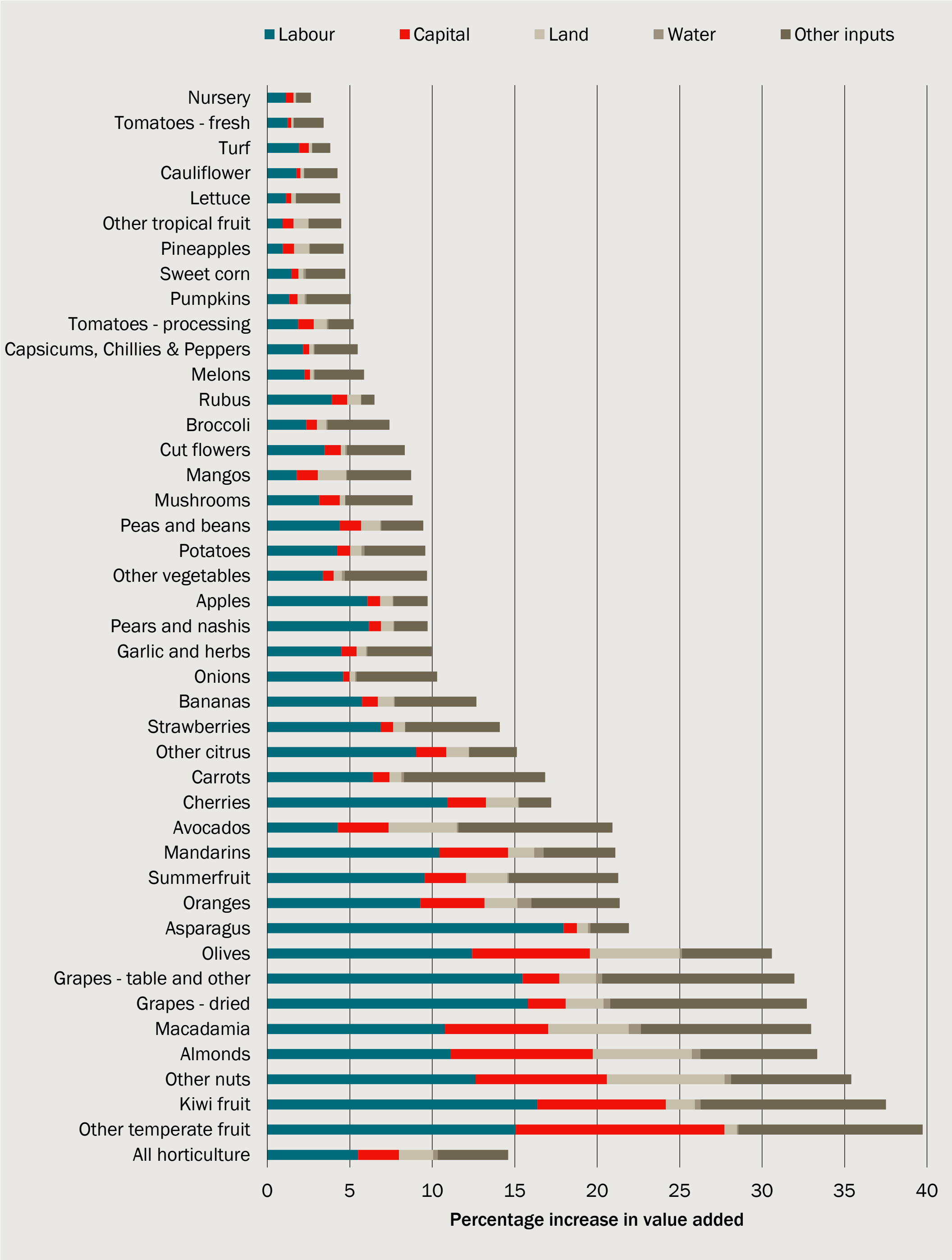
Diverse responses to productivity changes

Chart 5.1 shows the effect on industry value added resulting from an illustrative 10 per cent increase in productivity in each of land, labour, capital, water and other inputs. Each horizontal bar represents a different industry, and the stacked bars show the effect of each input productivity change on industry value added. The total of the stacked bars represents multifactor productivity. The results represent the final modelled productivity outcomes after all subsequent market effects have worked their way through.

Several key insights are illustrated from this chart:

- The responses across industries are diverse, with some achieving a very large increase in value added in response to the productivity shocks, while others see more modest improvements.
- The extent of the response depends on overall industry circumstances. Industries selling to the domestic market have a smaller scope to increase output compared to those selling into export markets.
- Related to this, the response also depends on the competition faced by the individual industry. Many fruit and vegetable products, for example, compete with each other for consumer demand, which in turn limits the ability to confidently increase output.

5.1 Illustrative effects of a 10 per cent productivity increase for each input

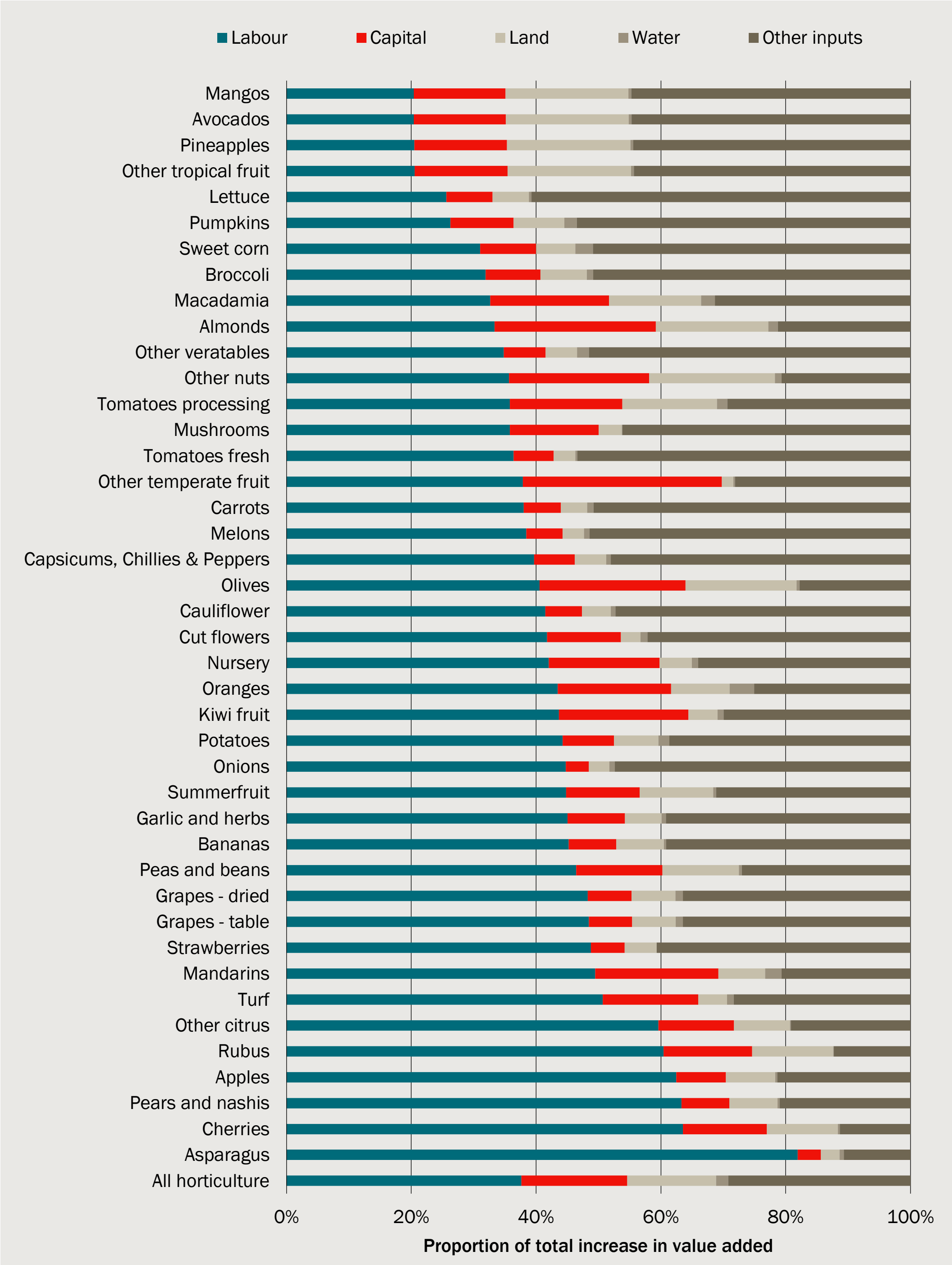


Data source: CIE simulations.

Relative importance of factors varies

Chart 5.2 presents the productivity impacts from a slightly differently perspective. Here, each horizontal bar (one for each industry) shows the proportional contribution of the productivity change across the different input categories, with the proportions summing to 100 per cent for each industry. This highlights the relative importance of productivity changes in different factors of production to different industries. Industries in this chart are ranked according to the relative importance of labour productivity.

5.2 Composition of productivity improvement



Data source: CIE simulations.

Chart 5.2 highlights several key patterns:

- In some industries, labour productivity accounts for more than 60 per cent of the total improvement effect.
- In others, labour productivity accounts for a smaller but still significant 40 to 50 per cent.
- For the remaining industries, productivity gains from other factors of production are more dominant.
- For total horticulture, labour productivity accounts for 38 per cent, with other inputs accounting for 30 per cent.

These modelling results are consistent with industry consultations. For most horticulture industries, labour represents the single largest input cost, although the combination of other costs may be larger than labour. The HI_LINK model database indicates that the share of labour in total costs ranges from 20 to 80 per cent, with an overall farm average of around 40 per cent. This is very high by Australian standards and makes horticulture very similar to labour intensive service industries. As a result, a great deal of focus is on finding technologies that will reduce the dependence on labour as an input. This, in turn, is a response to competition for labour across the whole economy.

Industry feedback also points to historical shifts in labour demand and supply. For example, several producers noted that in the 1970s and 1980s, migrants from Southeast Asia (particularly Vietnam in some cases) provided a ready workforce in horticultural enterprises. Today, however, migrants from these same regions — as well as from countries such as India and China — have access to a wider range of employment opportunities, meaning the horticulture sector must compete with other sectors to attract and retain migrant labour.

A key response to the importance of low-cost labour to horticulture (and agriculture in general) has been to develop temporary migrant guestworker schemes (working holiday visas and the Pacific Australia Labour Mobility Scheme). These programs offer regionally based labour support. However, as employment alternatives continue to expand for migrant workers, the challenge of securing a reliable horticultural workforce is likely to grow.

Links between sectors

Outcomes for the horticulture industry are not determined solely by productivity within the growing sector itself. Productivity improvements elsewhere in the economy can also have a substantial effect on grower-level horticulture outcomes.

Chart 5.3 shows the effect on growing industry (farm-level) value added for two aggregate sectors - fruit and nuts, and vegetables – resulting from an illustrative 10 per cent increase in productivity in:

- The growing sectors themselves (capturing the *direct* or '*own*' effect of grower-level productivity improvements).

- Other parts of the value chain, including wholesale trade, retail trade, services, and further processing of horticulture products (capturing the *indirect* or '*flow-on'* effects from productivity gains beyond the farm gate).

These results indicate that:

- In terms of own effects, a 10 per cent productivity improvement within the growing sector leads to an increase in value added of 9 and 7 per cent (for fruit and nuts, and vegetables, respectively).
- Productivity improvements in wholesale and retail trade also increase value added for growers by around 1 per cent in each case. This indicates that as wholesale and retail trade become more efficient, some of the gains are passed back through the supply chain to growers.
- Productivity improvement in the services sector (which includes scientific and technical services, as well as finance) also benefit growers. There are two broad mechanisms for this.
- Services are an input cost for growing, meaning that some of the productivity improvement is passed back to the growing sector.
- Services are a large part of the economy, meaning that productivity growth in services increases general income in the economy, some of which flows back to horticulture through a demand effect.
- Productivity improvements in horticultural product processing can lead to lower consumer prices, which in turn leads to higher demand and increases value added for the growing sector.

5.3 Effects on growing industry value added of productivity improvements along the value chain (illustrative 10 per cent)

Data source: CIE simulations

Productivity and product prices

Chart 5.4 shows the effects of productivity improvements across the value chain on grower-level output prices (farmgate prices).

5.4 Effect on grower farmgate prices of productivity improvements along the value chain (illustrative 10 per cent)

Data source: CIE simulations

Farm level productivity improvements

A key finding from these simulations is that a farm-level (grower) productivity increase, assuming all other factors remain equal, tends to lead to a reduction in farm gate prices. To sell the additional production arising from the productivity increases, prices must adjust downward to incentivise consumers to purchase the increased supply. Despite the downward price effect on farmgate prices, with a lift in grower-level productivity overall farm-level value added still increases a result of higher total output and improved efficiency.

In a competitive market such as horticulture, some of the benefits of the productivity improvement at the farm level are passed down the chain, particularly to final consumers in the form of lower prices. Lower prices (all other things equal) are necessary to provide the incentive to consumers to consume the increased supply from the productivity increase. This finding is consistent with broader productivity research (see Borrell et al 2014).

For some growers, productivity gains can be converted to improved quality rather than an increase in output. This approach — recognised in sectors such as turf, bananas and select vegetables — can yield better margins in the short term. However, over the longer term, widespread quality productivity improvements tend to erode price premiums for quality and reintroduce downward price pressure.

In a competitive market, productivity becomes a major tool for producers to maintain margins, increase quality and offset cost increases.

Productivity improvements elsewhere in the value chain

In contrast to the farm-level dynamic, productivity improvements in the other sectors (wholesale and retail trade, services, and processing) all lead to higher farmgate prices and value added for growers. As noted above considering the results for value added, some of the benefits downstream of the farm gate led to benefits back at the farm level. As these downstream value chain sectors become more efficient, cost savings and productivity gains flow back up the chain, improving returns at the grower-level. This occurs because greater efficiency in wholesale, retail, and processing enhances the overall profitability and competitiveness of the supply chain, creating more value that can be shared with growers.

Labour productivity and real wages

An increase in labour productivity — modelled as a reduction in the labour required per unit of output – not only increases output of the relevant sectors but also leads to an increase in real economywide wages. This has two important implications:

- On the positive side, for horticulture, any improvement in labour productivity allows enterprises to pay higher wages and to continue to attract labour. Put another way, it allows horticulture enterprises to remain competitive in the labour market and to deal with real wage cost pressures.
- On the challenging side, productivity improvements elsewhere in the economy tend to drive up real wages. Without corresponding improvements in its own productivity, the industry risks exacerbating labour shortages and increasing cost pressures.

Implications for drivers and modelling strategy

Table 5.5 summarises some implications for productivity drivers and the modelling strategy.

5.5 Implication for drivers and modelling strategy

Driver	Comment	Modelling strategy
Productivity in other industries	Productivity developments in other industries flow through to outcomes for horticulture.	We account for this through the implementation of exogenous productivity growth in industries outside agriculture. In the model, this automatically feeds through to the horticulture sector.
Price effects	Price effects are integral to changes in productivity.	The modelling framework adopted endogenously solves for price changes required to clear export and domestic markets (that is, to ensure that all product is sold). These price effects then feed through to all industries and affect subsequent changes.

Driver	Comment	Modelling strategy
Labour and MFP	While labour is often the single biggest cost item for many enterprises, other factors combined are also significant. The potential benefits of other sources of productivity should also be considered.	The modelling framework used here distinguishes different types of productivity and allows the choice of changes in labour productivity or changes in multifactor productivity

Source: CIE.

6 A grouping of innovation options

A grouping of innovation options

A review of the wide range of potential innovations available to horticultural producers — together with insights from a series of industry consultations — suggests that a useful way to organise and analyse innovation is through a four-level grouping. This grouping of options reflects the progression many enterprises follow, where the adoption of certain innovations enables or supports others.

These groups are designed to be general enough to capture the common experience of all horticultural industries. However, their relevance and application to specific industries will vary — both in principle and in practice. The structure of the groupings is designed to support analysis without being completely prescriptive for individual industries.

The four groupings of innovation are as follows.

- **Production cost analysis:** Building the skills and capability to understand cost drivers and profitability. This allows enterprises to modify operations and discontinue unproductive activities or practices.
- **Automated farm data collection:** Using digital technologies to support real-time management decisions. This involves capturing, processing, and operationalising data and information to inform farm practices and enable more data-driven farm management.
- **Machine learning (ML) and artificial intelligence (AI):** Using advanced analytics to support better decision-making. ML and AI enable enterprises to interrogate data, uncover patterns, and understand the detailed dynamics of enterprise performance. This opens up new possibilities for agronomic and related practices.
- **Mechanisation and automation:** Applying physical automation in farm-based production (picking and spraying, for example), packing and transport. While this overlaps with data collection and AI, this group focuses on the physical implementation and other forms of automated interaction with the relevant crop.

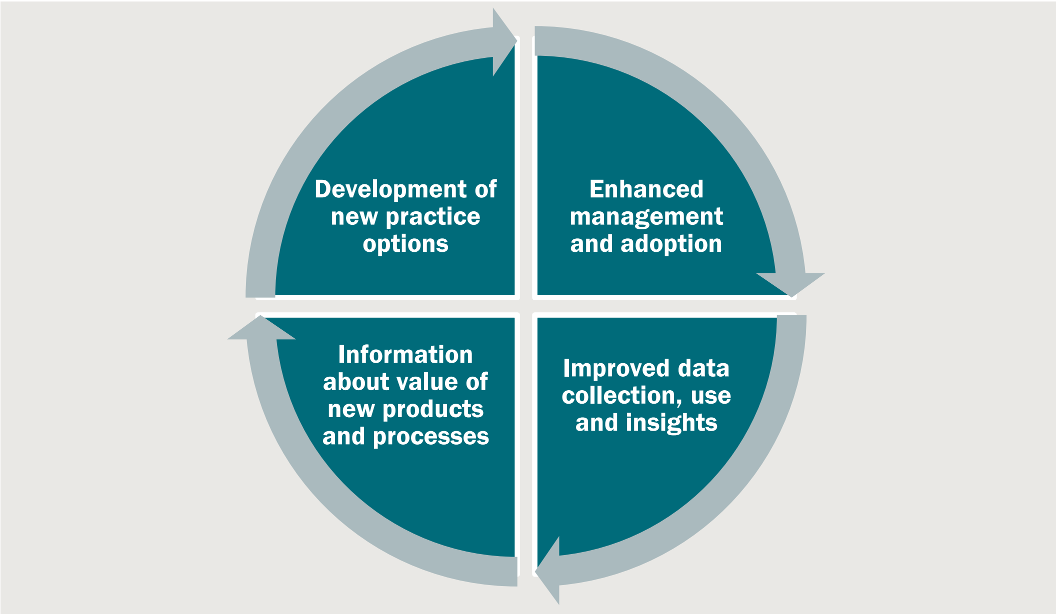
These four groups encompass not only technologies but also the enhanced farm practices and production management systems they enable. The various technologies (data collection tools, advanced analytics etc.) are valuable in that they enable the development and application of a range of better practices related to, but not limited to, labour management and allocation of effort, pest control, fertiliser use and specific treatment of different areas of the farm. In essence, this framework of innovation groupings represents the ongoing development of the sorts of process innovations set out in table 4.2.

Importantly, adoption of new technologies often also implies (and in some cases requires) behavioural change. In many cases, the various technologies reveal options for both new practice change and reduced cost or complexity of implementing those changes.

Further, these groupings are not intended to represent a hierarchy. Any individual enterprise may be working on more than one front simultaneously, and from an industry-wide perspective, the levels of adoption across each of the four groups may vary significantly over time.

In practice, innovation within these groups often follows an iterative cycle (chart 6.1). Improved management and adoption of new practices and techniques may lead to improved data collection, which generates richer information about the value of new products and processes. This, in turn, informs further new practice options – reinforcing a continuous cycle of improvement.

6.1 Cycle of improvement



Data source: CIE.

Production cost analysis

During industry consultation, a number of growers indicated that a foundational source of productivity gain lies in the combination of farm management training with detailed cost structure analysis. This allowed the enterprise to accurately identify their cost structures so that they could adjust input and product mixes to minimise costs and eliminate unprofitable activities.

Overall productivity gains from this are in the order of 5 to 10 per cent, based on a range of benchmarking programs supported by Hort Innovation (see the benchmarking reports referred to in chapter 3).

Automated farm data collection

Industry consultations indicated that many enterprises are increasing their capabilities for automated data collection. Growers indicated that this ability has been significantly enhanced in recent years with 'low code' or 'no code' programming options, and more recently with AI-assisted programming (Box 6.2).

This enables low-cost customisation of management systems for a variety of enterprises. Smaller enterprises — previously limited by the high cost or complexity of digital tools — can now adopt solutions that were once only accessible to larger operations. Low code platforms also allow the customisation of data collection to accurately represent the needs of the enterprise. Other forms of low-cost customisation are likely to continue to emerge as technologies develop.

6.2 Low code and AI assisted coding

No code and low code platforms allow enterprises to build functional software by manipulating visual building blocks instead of writing extensive code. A drag-and-drop interface assembles pre-built components, while a behind-the-scenes engine turns those choices into the actual code. These tools could considerably lower development costs for farm management and data systems.

AI-assisted coding (sometimes called 'vibe coding') takes this one step further — instead of dragging blocks onto a canvas, the user describes the *intent* of the program in conversational language, and an AI assistant generates the full codebase. (This is concerned with an initial step of generating code rather than the later step of using ML and AI enhanced analytics as part of farm management).

Low code options are already adopted in a variety of contexts within Australian agriculture, as well as horticulture specifically. For example:

- Kobuta Australia are retiring a variety of legacy apps, to be replaced with low code options (see Business process automation with power apps).
- Keates (2023) notes the importance of low code options in implementing modern business processes in Australian horticulture.
- In consultations, Hillwood Berries indicated they had used low code development to implement a labour productivity package.

These tools help reduce *data entropy* - transforming previously unstructured or inaccessible information into actionable insights that can be used in regular management decisions.

Table 6.3 provides some examples of yield and related gains from the automated collection and use of data in Australian horticulture.

6.3 Examples of gains from sensors and better data use

Production system	Data tool used	Outcome
Open-field vegetables (carrot, sweet-corn, beans)	Multi sensor mapping for variable rate inputs and drainage redesign	Yield gaps of 22 to 33 per cent identified in under-performing zones. See: Adoption of precisions system technology in vegetable production
Green beans (East Gippsland)	Strip tillage with site specific soil and moisture data	26 per cent increase in bean yield and lower fuel and labour costs. See Hort Innovation Impact Update May 2023.
Smart production nursery (Golden Grove Wholesale Nursery, Queensland)	Substrate moisture probes for automated irrigation	30 per cent reduction in irrigation water applied, along with energy and labour savings (no need for manual water quality checks. See: *Smart Farming Guide for Horticulture*.

Source: As noted.

Industry consultations echoed similar results to those in table 6.3, indicating that the use of data and related tools may be associated with:

- Water and energy savings of 20-35 per cent.
- Fertiliser savings in the order of 10-30 per cent.
- Increases in yield of 5-30 per cent.
- Labour productivity gains of around 10-15 per cent.

ML and AI

While still emerging through research and initial applications by some growers, AI and ML applications offer promising gains when applied to enterprise-specific data in the horticulture industry. Based on a variety of sources and industry consultations, table 6.4 summarises potential gains from AI tools applied to data collected within the horticulture industry.

6.4 Potential gains from ML and AI applied to data

Area of gain	Potential additional gain	Key source of gain
Yield (or pack out)	3 to 10 per cent increase	Harvest timing, disease protection, targeted and predictive fertigation
Input use efficiency	5 to 15 per cent increase	Forecast driven spraying, AI pathway planning for key machinery
Labour use (per tonne)	10 to 25 per cent reduction	Tighter harvest schedule, automated quality control
Working capital use	5 to 12 per cent lower	More accurate supply forecasts and better pack house utilisation

Source: Industry discussion and indications from ongoing projects, including: Robotics-Ready AI in Viticulture, Predicting Green Bean Harvest and Yield, AI Powered Weather Forecasting, Driving on-farm productivity with augmented technologies for fruit growers.

Mechanisation and automation

There are mixed views across the horticulture industry regarding the potential gains from advanced mechanisation and automation.

- In some operations, the gains are potentially very large. For example, with automated pollination in greenhouse tomatoes, labour savings are estimated to be up to 90 per cent. (See *Industry Spearheads Adoption of Labour Saving Tech*).
- Similarly, in select automated harvest applications, automation is expected to deliver labour savings of up to 50 per cent in some fruit applications. (See, for example, *Fieldwork Robotics*).

However, the practical experience of automation varies widely. Importantly, some forms of automation require significant changes in the organisation of an operation, such as modification to the physical layout of the farm or adjustments to workflows across each production process. For some early adopters, the time required to realise the expected benefits has been considerably longer than anticipated.

7 A framework for projecting productivity growth

This chapter brings together the multiple strands of research into a model of productivity growth in Australia's horticultural industries. The framework is operationalised through a companion spreadsheet to this report, which allows users to simulate future productivity outcomes for 42 different horticulture industries.

Drawing on input assumptions and data from the HI_LINK model of Australian horticulture (developed as part of MT21010 Economic contribution of Australian Horticulture), the tool produces estimates of future industry *value added*. This approach supports for the quantitative analysis of different productivity growth scenarios.

To address the diversity across the horticultural industries the framework applies an approach that is conceptually general across all industries but allows for customisation of specific settings for individual industries.

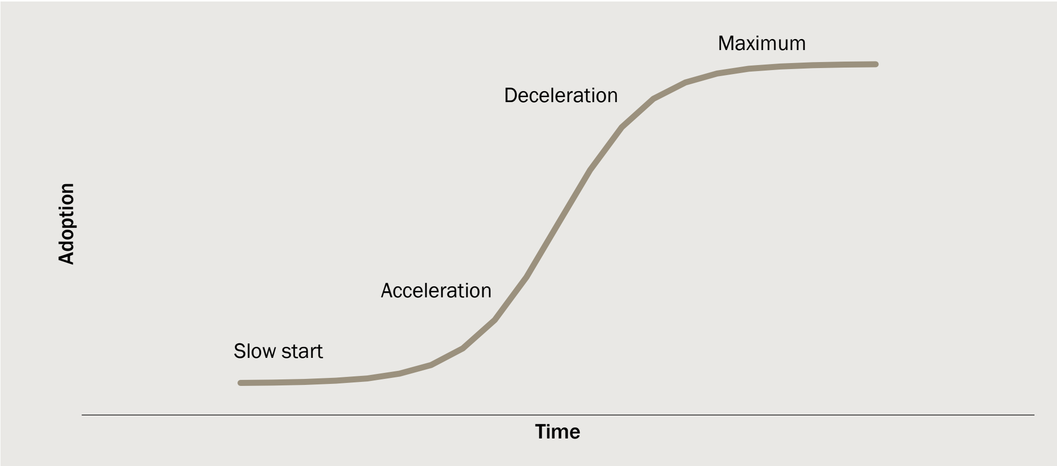
First, we adopt the four groups of productivity enhancing innovation, outlined in chapter 6:

- Production cost analysis.
- Automated farm data collection.
- ML and AI.
- Mechanisation and automation.

While these four innovation groupings are general across all horticulture industries, their application requires specific assumptions – particularly regarding the expected productivity gains associated with each group of innovation for different industries. Throughout the modelling below, we use broad averages from the available evidence discussed in chapter 6.

Second, we propose that the model assumes that the adoption of innovations follows a typical S-curve pattern - consisting of initial period of slow growth, followed by accelerated adoption, and finally a deceleration towards the maximum adoption rate (chart 7.1). Explanation of the use of S-curves is set out in the Box 7.3.

7.1 Standard S-curve adoption profile

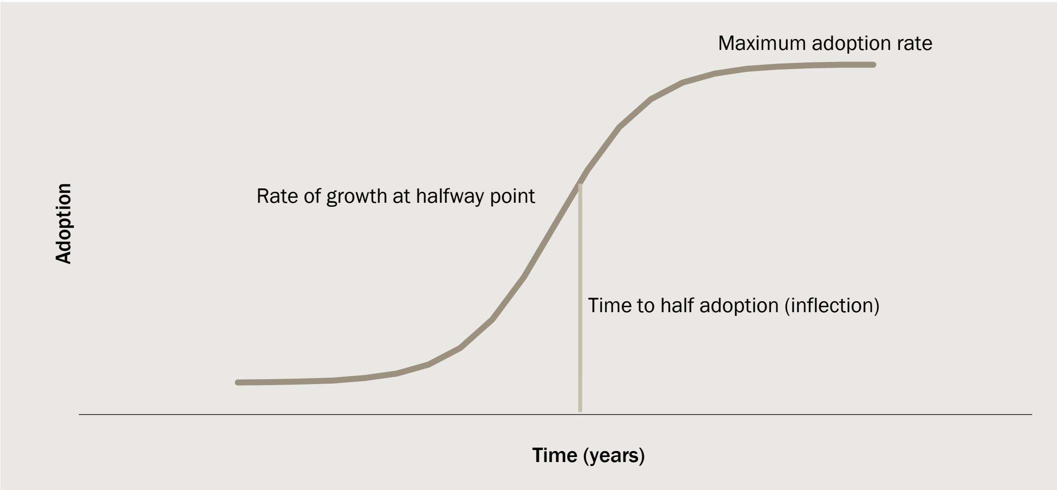


Data source: CIE.

The adoption of innovation is modelled using a three parameter S-curve (chart 7.2). The three parameters are:

- Maximum adoption rate. This is the upper limit of adoption across the industry. While the theoretical maximum is 1.0 (100 per cent), full adoption across the entire industry is rarely achieved in practice.
- Time to half maximum adoption. For example, if the adoption process starts in 2025, the time to half maximum adoption can be set at a specific year (eg. 2035) to reflect expectations around how quickly the technology will diffuse through the industry.
- Growth rate at the halfway point. This defines how steep the curve is at the midpoint of adoption. A steeper curve has a more pronounced ‘S’, indicating rapid adoption around the midpoint. A flatter curve suggests a slower, more linear uptake, resembling a straight line.

7.2 Parameters of a standard S-curve



Data source: CIE.

7.3 S-curves for adoption modelling

Everett Rogers' *Diffusion of Innovations* (2003) laid the conceptual groundwork for thinking about adoption as an S-shaped process. He demonstrated that successful innovations go through three stages: slow experimentation by 'innovators', followed by rapid take-up by early adopters and then the majority adopt as the innovation proves successful, and finally, a tapering phase as the remaining population adopts more cautiously – or not at all. Rogers also identified five attributes that speed or slow this process - relative advantage, compatibility, complexity, trialability, observability - and highlighted the critical role of communication channels in the diffusion process.

Building on Rogers, the Bass model (1969) provides the most widely used equation for implementing an S curve. The Bass curve resembles the classic logistic shape and can be fitted with three parameters: timing, speed, and maximum adoption. These models are widely used because they are easy to estimate and can be extended to handle multiple product generations or heterogeneous grower segments.

In horticulture, this framework maps neatly onto real world diffusion channels, such as demonstration orchards, supplier networks, and regional grower communities. These mechanisms amplify the imitation dynamic, while factors such as high capital costs or skill barriers often limit the eventual maximum adoption rate.

Indicative productivity settings

Table 7.4 illustrates a sample configuration of input settings for a hypothetical horticulture industry.

7.4 Indicative settings for productivity model

Productivity factor	Productivity Gain	Year of half full adoption	Speed at half adoption	Maximum adoption
Innovation element				
Production cost analysis	10%	2026	0.6	100%
Automated farm data collection	12%	2028	0.4	90%
ML and AI	7%	2030	0.4	80%
Mechanisation and automation	8%	2034	0.7	70%

Source: CIE.

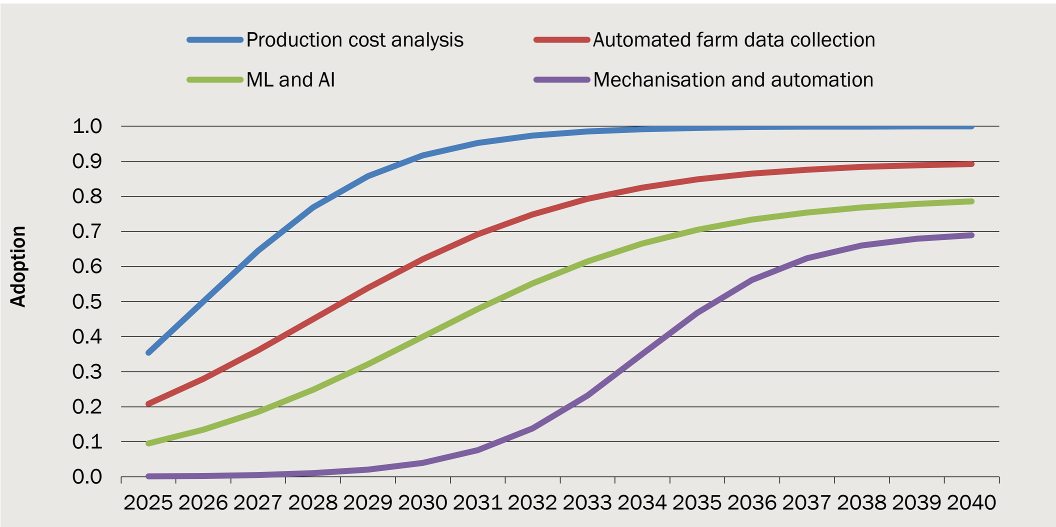
Expanding on the three parameters of an S-Curve, the productivity model also defines the expected productivity gain associated with each innovation element. This parameter captures the extent of the productivity improvement expected once the innovation element is fully adopted by an enterprise. For example, in table 7.4, the productivity gain of 10 per cent for production cost analysis reflects the assumption that, once implemented, this innovation will increase enterprise productivity by 10 per cent. The extent to which this leads to industry-wide productivity depends on adoption of the innovation across enterprises. If adopted by 50 per cent of enterprises, then the industry productivity improvement would be 5 per cent in this case.

Altogether, there are 16 parameters that can be chosen to represent specific horticultural industries.

- The total improvement associated with each of the four groups of innovation.
- The maximum adoption for each type of innovation.
- The year of half adoption for each type of innovation.
- The rate of growth at the halfway year for each type of innovation.

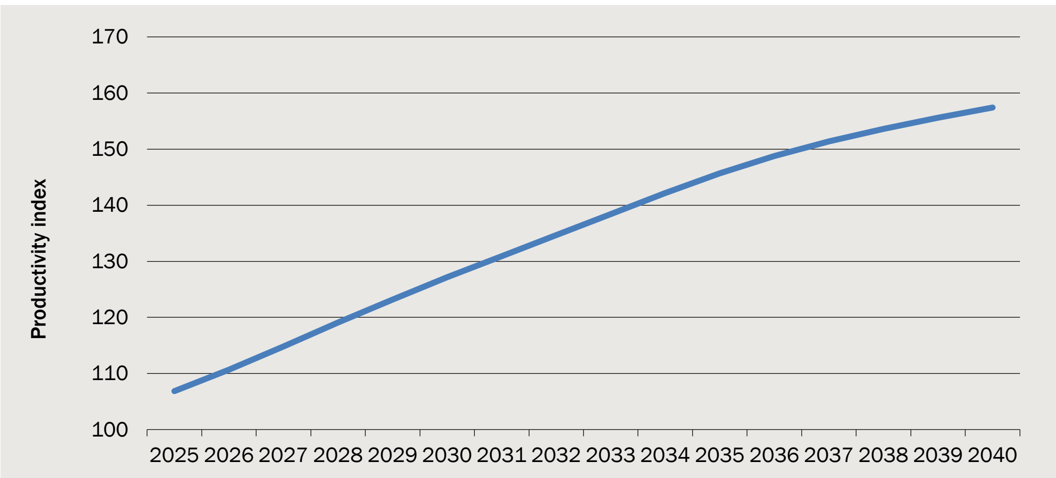
Based on the sample configuration, chart 7.5 illustrates the adoption profiles associated with these assumptions and chart 7.6 shows the productivity index that results from all these assumptions combined.

7.5 Adoption profiles



Data source: CIE.

7.6 Productivity index



Data source: CIE.

Several points should be noted in relation to the productivity settings used in this model:

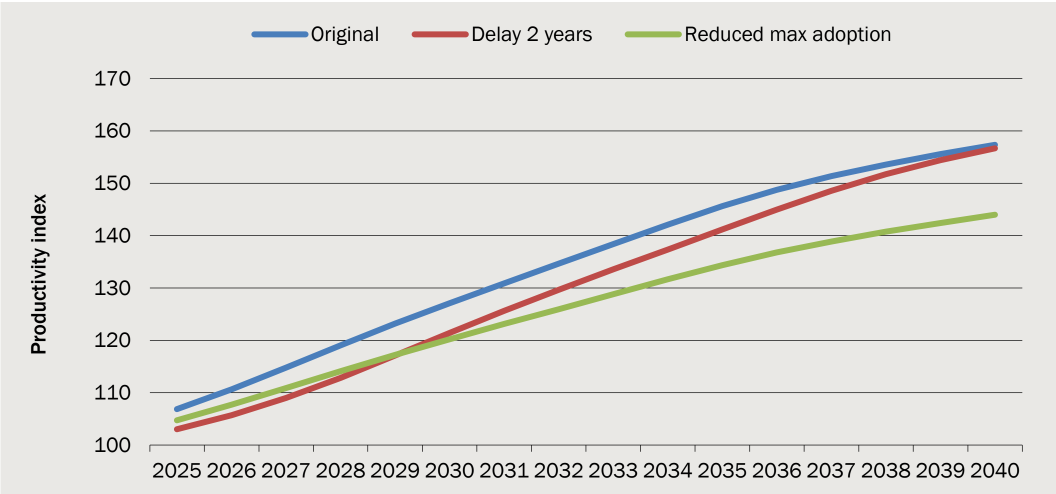
- **Industry level adoption can overlap**. As shown in chart 7.5, different innovations are adopted concurrently but maturing at different times. For instance, by 2030, all four innovation types are in various stages of adoption, but each at different rates. For individual enterprises, adoption is more likely to be sequential.
- **The overall productivity index is determined by the cumulative effect of multiple innovations**. Each year's index value reflects the incremental, steady adoption of a mix of technologies — each contributing its own potential productivity effect. Importantly, the productivity index directly influences total industry value added production, which is calculated in the underlying horticulture economic contribution spreadsheet model.

Changes in the underlying parameters will clearly lead to different values for the productivity index. This is where the richness of the model lies.

The model is also systemic, in that the set of innovations can be customised based on specific industry information. While the above simulation uses a generic set of parameters, different sets can easily be applied using available industry data or expert input.

Changes to these assumptions can substantively change productivity outcomes. Chart 7.7 illustrates the effect of either delaying adoption by two years or a 30 per cent reduction in the maximum adoption rate on the resulting productivity index.

7.7 Effect of varying assumptions; productivity index



Data source: CIE

There are several ways this modelling approach can be applied:

- **Scenario generation:** The model can be used directly to develop scenarios of potential productivity growth and corresponding industry value over time.
- **Comparative analysis:** Comparing different scenarios to estimate the incremental value associated with different adoption outcomes. These insights can support decision-making related to R&D, extension activities, policy and other strategic activities.

- **Reverse modelling:** The model can also be used in reverse to estimate the levels of adoption required to achieve a specific productivity outcome. For example, if an industry sets a future productivity target, the model can estimate the adoption parameters needed to meet it.

Factors affecting adoption parameters

The factors that determine the adoption parameters used in the model represent the final set of ultimate productivity drivers. These are the key factors that determine the actual uptake of innovation options by industry.

These drivers have been the subject of extensive research and vary depending on the characteristics of each industry. Table 7.8 summaries some key elements as noted in the ADOPT model.

7.8 A way of organising drivers of adoption

	Net advantages of the innovation	Ease of understanding and implementation
The nature of the innovation itself	What are the benefits of the innovation (increased profits, for example) relative to the costs of adopting it? Costs include up-front investment costs and ongoing incremental maintenance costs. What are the risks of the innovation, and is it reversible if things don't work out? Does the innovation require particular skill sets? Is the innovation likely to be subject to regulatory interventions?	Is the innovation complex and hard to implement? Does it require a particular specific skill set? Can it be trialled within an enterprise on a small scale? Can the effects be seen quickly or slowly? Can other enterprises easily observe the benefits by looking to those that have already adopted?
The nature of the population (industry, region) that may adopt the innovation	Does the population have a clear focus on profit, or do other factors such as environmental outcomes play a big role? Is the population subject to financial constraints? Does management take a long run perspective? Is the population risk averse? Does the population consist of mostly large or small enterprises?	Does the population have the relevant skills and knowledge? Can these be acquired? Are there extension or other advisory services readily available? What are the knowledge dissemination options available (farmer groups, field days etc)?

Source: Modified from Kuehne et al (*Predicting farmer uptake of new agricultural practices: A tool for research, extension and policy*).

Table 7.9 sets out the factors determining the adoption of parameter values in more detail. As this table indicates, each of the three S-curve parameters (maximum adoption, year of half adoption and speed at half adoption) is determined by six underlying factors as set out in the 'key determinants' column.

7.9 Drivers of S-curve parameters – and therefore adoption

S curve parameter	Key determinants	Typical indications
Maximum adoption	▪ Technical fit (crop/soil compatibility, equipment interface standards) ▪ Capital intensity vs. farm size ▪ Complementary infrastructure required (cold-chain, broadband, service technicians) ▪ Regulation & certification (biosafety rules, water licences) ▪ Strategic substitutes (viable alternative technologies) ▪ End-user heterogeneity (skill, risk tolerance, land tenure)	Maximum adoption approaches 100 % only when the innovation is (i) modular, (ii) low-cost relative to revenue, and (iii) free of structural exclusions. Maximum adoption of around 70 % is common.
Year of half adoption	▪ Cost-decline trajectory & pay-back period (learning curves, scale economies) ▪ Capital replacement cycle (tractor life, greenhouse retrofit schedule) ▪ Visibility of demonstrators (extension trials, peer examples) ▪ Supply-chain ramp-up (manufacturing capacity, distribution reach) ▪ Policy or price shocks (subsidy start, carbon price) ▪ Macroeconomic conditions (credit cost, commodity prices)	Short t_{50} (≤ 5 yrs) occurs when installation can piggy-back on annual operating decisions and payback < 3 yrs. Long t_{50} (15-30 yrs) occurs where adoption waits for asset turnover or major policy moves.
Speed at half adoption	▪ Strength of social contagion/network density ▪ Marketing & extension intensity ▪ Modularity & ease-of-trial (plug-and-play kits vs full-farm conversion) ▪ Competitive pressure (price premiums, cost penalties for slow adopters) ▪ Supply-chain elasticity (ability to meet surging demand) ▪ Risk & complexity (bio-security, data skills)	Faster adoption occurs where word-of-mouth is strong, technology is modular, and capital suppliers can scale. Shallow slopes (< 0.3 yr^{-1}) occurs where learning or finance bottlenecks dominate.

Source: CIE analysis.

In the spreadsheet model accompanying this report, the selection of these parameters is guided by a structured questionnaire. Users can input responses based on their knowledge of an industry, and the model then generates estimated adoption parameters accordingly.

8 Horticulture scenarios

To explore how productivity in the horticulture industry might evolve, two scenarios—*High* and *Low* adoption—were developed using the productivity modelling framework described above. These scenarios represent different potential rates of productivity growth. The simulations were generated using the HI_LINK model and the results illustrate possible future outcomes and the practical application of the modelling framework.

These two scenarios are built on specific rates of adoption of the innovation technologies. This is in addition to the slow, underlying productivity growth used in the *Central* scenario of the report MT21010 Economic contribution of Australian Horticulture. For the current report, the *Central* scenario has been extended to 2040. The slow productivity growth in the *Central* scenario can be thought of as productivity taking place as a result of steady compositional change in the industry. In contrast, the specific scenarios here consider different rates of adoption of the four innovation groupings.

Comparing high and low scenarios

Tables 8.1 and 8.2 present the two adoption scenarios: *High* adoption and *Low* adoption of each of the four innovation groupings. In both scenarios, the potential productivity gain at full adoption of each innovation element has been set to reflect the findings in Chapter 6. However, the patterns of adoption (maximum adoption, year of half adoption and speed to reach maximum) differ between the two scenarios.

In the *High* adoption scenario, each innovation element reaches a higher peak level of use and does so more quickly. This is reflected in both the shorter time to reach 50 per cent adoption and the faster speed to reach maximum adoption.

8.1 Scenario assumptions: *High*

Innovation element	Gain	Maximum adoption	Year of half adoption	Speed to reach maximum
Production cost analysis	10%	90%	2026	Very quick
Automated farm data collection	12%	80%	2028	Quick
ML and AI	7%	70%	2032	Normal
Mechanisation and automation	8%	60%	2036	Slow

Source: CIE.

In contrast, the *Low* scenario has been adjusted to lag by four years and achieves just under half the maximum adoption level seen in the high scenario.

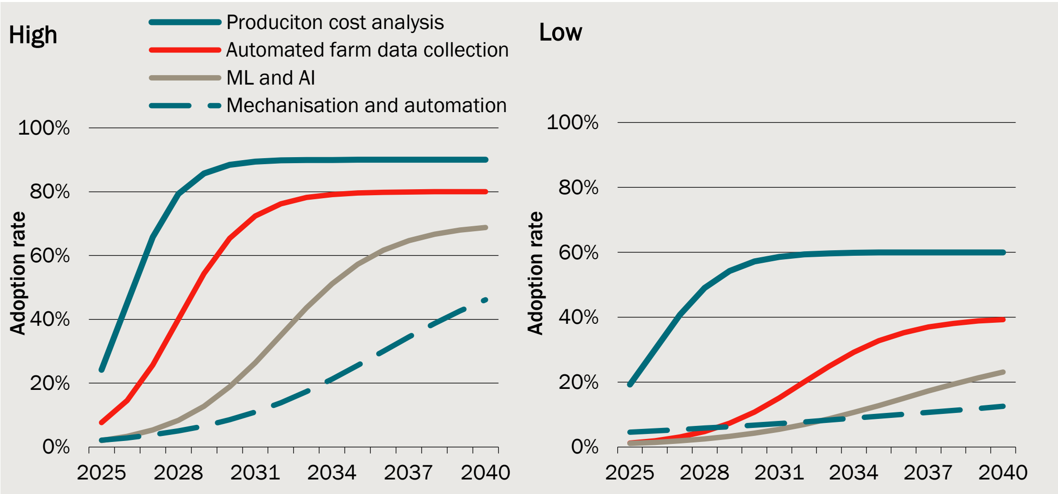
8.2 Scenario assumptions: *Low*

Innovation element	Gain	Maximum adoption	Year of half adoption	Speed to reach maximum
Production cost analysis	10%	60%	2026	Quick
Automated farm data collection	12%	40%	2032	Normal
ML and AI	7%	30%	2036	Slow
Mechanisation and automation	8%	25%	2040	Very slow

Source: CIE.

Chart 8.3 provides a visual comparison of the two adoption scenarios, clearly showing the lower uptake in the low adoption scenario.

8.3 Adoption, *High* and *Low* scenarios



Data source: CIE.

Under these adoption profiles:

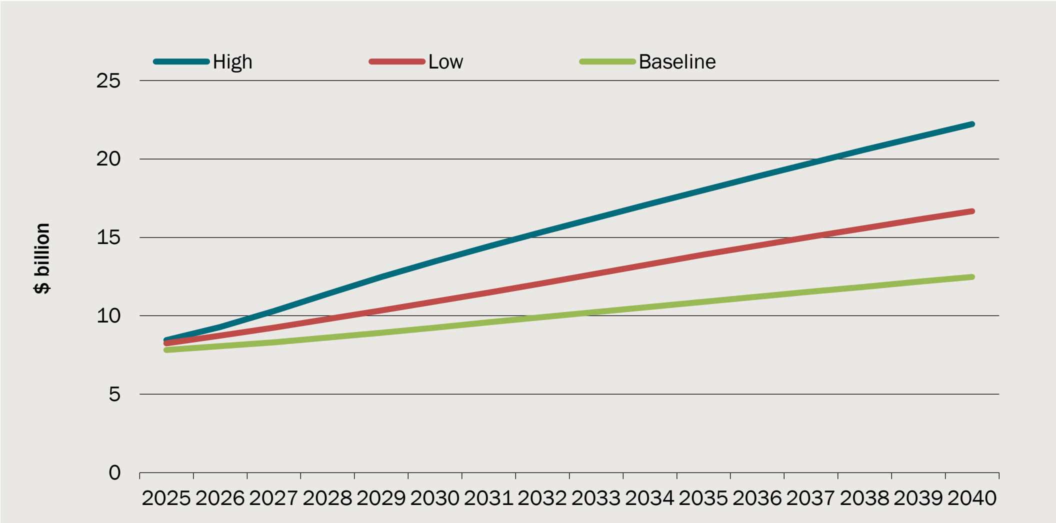
- Productivity growth in the *High* scenario averages 1.3 per cent a year to 2040.
- Productivity growth in the *Low* scenario averages 0.7 per cent a year to 2040.

Chart 8.4 shows the model's estimates of horticulture industry value added under each adoption scenarios.

Value added is used as the comparison metric rather than gross value of production (GVP) because it more accurately reflets the economic gains from productivity improvements. See box 8.5.

It is important to note that these results assume productivity improvements are realised through multifactor productivity – meaning gains across all inputs, not just labour. Results focused on labour productivity alone are discussed later in this chapter.

8.4 Industry value added, *High* and *Low* scenarios



Note: Assumes multifactor productivity increase

Data source: CIE simulations with HI_LINK model.

Under the *High* scenario, total horticulture industry value added reaches $22 billion by 2040, from a starting point of $8 billion in 2025. Also under the high scenario, value added in 2040 is 78 per cent higher than it would have been without the innovation adoption.

Under the *Low* scenario, total horticulture industry value added only reaches $17 billion by 2040 — 30 per cent higher in 2040 than it would have been without the innovation adoption.

As time progresses, the gap between the two scenarios continues to widen. The area between the *High* and *Low* lines represents the cumulative loss in value added resulting from lower productivity in the *Low* adoption scenario. In present value terms, this amounts to $37 billion.

8.5 Gross value of production (GVP) versus value added (VA)

Understanding how we measure the impact of productivity is critical. While GVP measures total output, VA offers a more useful picture of true economic contribution of productivity increases.

By definition:

- **GVP**: The total market value of all products sold. It is made up of the sum of VA and intermediate input costs.

  GVP = (VA) + (intermediate input costs)

  Intermediate inputs are all the goods and services bought from other industries and used up in production (fertiliser, herbicides, power, fuel, office supplies, packaging, irrigation materials, transport costs, etc.).

  On average in horticulture, 36 per cent of GVP is spent on intermediate inputs.

- **VA**: The value created by the industry after accounting for the cost of inputs purchased from other sectors. It represents the net wealth generated by the horticulture industry itself.

  VA = (returns to capital) + (returns to land) + (returns to labour)

  Returns to capital and returns to land combined can be thought of as **profit**.

Why use VA to measure the effect of changes in productivity?

- Isolates true value creation: VA removes external input costs, revealing the wealth created directly by the industry's own efforts.
- Better measures the returns to efficiency: VA directly increases when a farm reduces intermediate costs, even if GVP is stable. This accurately shows efficiency gains (doing more with less). VA will also capture productivity improvements even if GVP declines (ie. where reduced input costs outweigh increases in production).
- Aligns with profit & wages: VA directly indicates funds available for profits and wages. If profits do not increase, growers are unlikely to adopt the productivity measure.

Productivity gains can be hidden if we only look at GVP. Therefore, VA is a better measure of the gains that arise from a productivity increase, reflecting changes in profits plus the change in the industry's ability to pay workers.

Incremental gains

The previous section illustrated the productivity implications of a large difference in adoption scenarios. However, another key question is to consider what could be gained from ***incremental* increases** in adoption.

Table 8.6 presents assumptions for a relatively modest improvement in the *Low* scenario. In this case, the maximum adoption rate is increased by 10 percentage points and the timeline for adoption is brought forward by two years.

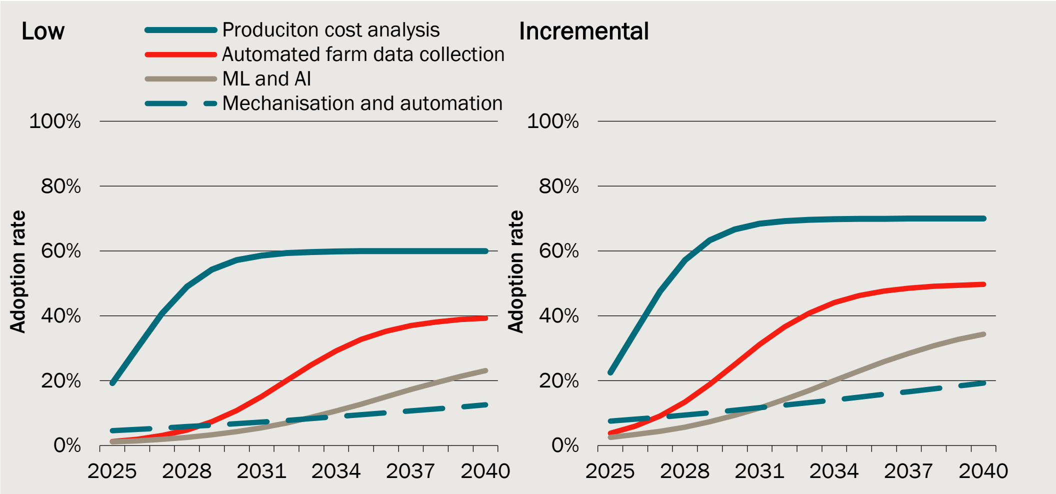
8.6 Scenario assumptions: *Incremental* gain from *Low*

Innovation element	Gain	Maximum adoption	Year of half adoption	Speed to reach maximum
Production cost analysis	10%	70%	2026	Quick
Automated farm data collection	12%	50%	2030	Normal
ML and AI	7%	40%	2034	Slow
Mechanisation and automation	8%	35%	2038	Very slow

Source: CIE.

The *Low* and *Incremental* adoption scenarios are illustrated in chart 8.7.

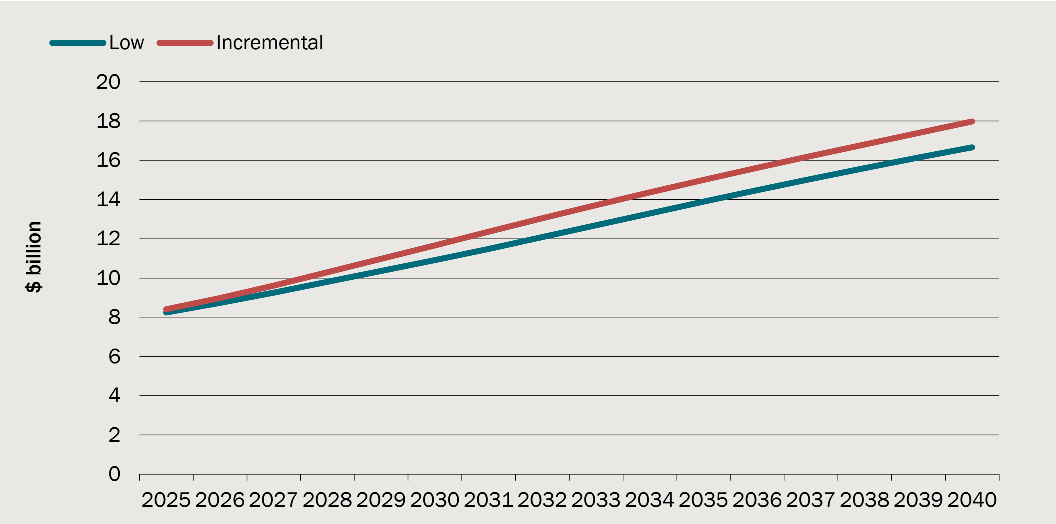
8.7 Adoption, Low and Incremental scenarios



Data source: CIE.

The resulting value added from these two scenarios is shown in chart 8.8.

8.8 Industry value added, Low and Incremental scenarios



Note: Assumes multifactor productivity increase.

Data source: CIE simulations with HI_LINK model.

As shown in chart 8.8, the lines representing the low and incremental adoption scenarios are much closer together, indicating a modest but meaningful difference. In present value terms, the difference equates to approximately $10 billion.

Simulations like this can help evaluate the effectiveness of programs that support research dissemination or undertake extension activities designed to improve adoption. In this context, the $10 billion in incremental benefit serves as a benchmark that can be compared to the costs of these programs, providing a useful measure of return on investment.

Labour versus multifactor productivity

The previous calculations assumed an increase in multifactor productivity. To look at the difference in effects between labour productivity and MFP, table 8.9 presents a calculation showing value added for the *High* and *Low* adoption scenarios compared to the *Central* scenario baseline discussed above.

The table shows the present value of value added for each scenario (out to 2040). Note that the present value of value added for the baseline is the same for each scenario to allow a constant point of comparison.

Results are shown for both:

- Labour productivity (improvements in labour productivity alone), and
- MFP, which captures productivity gains across all inputs, inclusive of labour productivity.

Chart 8.10 illustrates the how these present values are built up from the annual results over time.

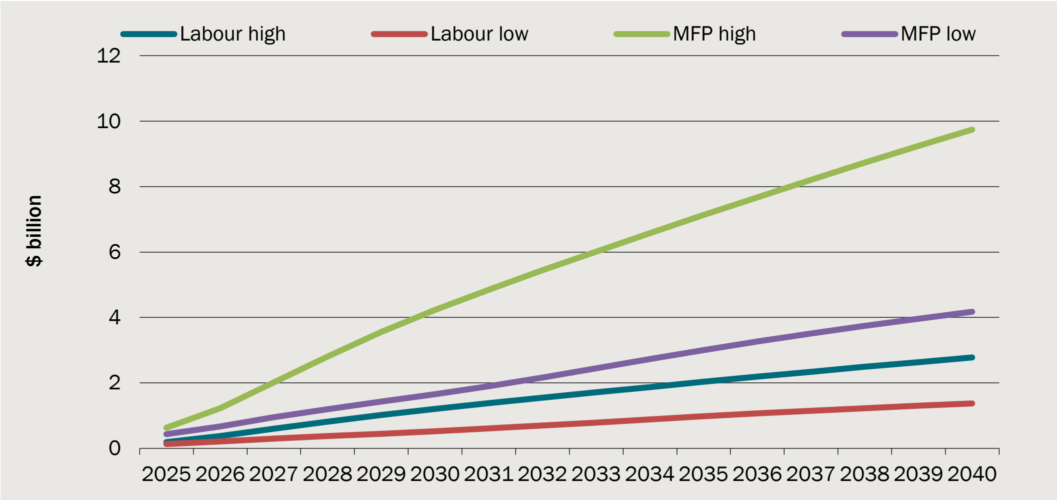
8.9 Present value to 2040, labour and MFP

Scenario	Labour only	MFP
Cumulative value added, $ billion		
High	143	189
Low	133	151
Baseline (no additional productivity growth)	124	124
Difference from baseline, $ billion		
High	18	64
Low	9	27
Difference from baseline, Percent		
High	15	52
Low	7	22

Note: Refers to present value from 2025 to 2040

Source: CIE simulations with HI_LINK model.

8.10 Industry value added, Labour productivity versus MFP, *High* and *Low* scenarios



Note: Measures the present value of the increase in industry value added relative to no productivity change

Data source: CIE simulations with HI_LINK model.

While labour is the single largest cost component for most horticulture industries, there are still significant gains to be made from improving the productivity of other factors of production, such as land, capital and material inputs (including water and fertilisers).

For example, an increase in labour productivity under the high adoption scenario would add $18 billion to the industry. But when improvements are made in other productivity factors (land, capital, etc), an additional $46 billion is gained - bringing the total to $64 billion.

This highlights the point that while labour is the single largest input to most enterprises, improving the productivity of other factors combined will have a critical impact on long-term outcomes for horticultural industries.

Caveats

The results presented here should be interpreted as scenario-based estimates, not forecasts. They are based on reasonable assumptions informed by a range of sources, but these assumptions are subject to change.

The magnitudes of the simulation results also depend on the quality and availability of data and insights, which can vary considerably by industry.

9 Conclusion

The potential for innovation to drive productivity and address the challenges faced by the horticulture industry is significant. As demonstrated in this report, opportunities can be expressed within four broad innovation groups:

- **Production cost analysis:** Building the skills and capability to understand cost drivers and profitability. This allows enterprises to modify operations and discontinue unproductive activities or practices.
- **Automated farm data collection:** Using digital technologies to support real-time management decisions. This involves capturing, processing, and operationalising data and information to inform farm practices and enable more data-driven farm management.
- **Machine learning (ML) and artificial intelligence (AI):** Using advanced analytics to support better decision-making. ML and AI enable enterprises to interrogate data, uncover patterns, and understand the detailed dynamics of enterprise performance. This opens up new possibilities for agronomic and related practices.
- **Mechanisation and automation:** Applying physical automation in farm-based production (picking and spraying, for example), packing and transport. While this overlaps with data collection and AI, this group focuses on the physical implementation and other forms of automated interaction with the relevant crop.

There is sufficient information to incorporate these within an economic model of horticultural industries. The tool provided with this report offers a practical way to further examine the underlying drivers and how adoption of these innovation options drives productivity.

Simulations with the model demonstrate that there is a lot at stake. The difference between faster and slower adoption of productivity enhancing innovations could mean as much as $37 billion (in present value terms) for the entire horticulture industry. Even a small increase in the rate of adoption could translate to an additional $10 billion benefit for the industry.

The model provides a tool to experiment with different productivity drivers. It can be used to:

- Develop scenarios for future planning of industry value added based on assumptions about the uptake of productivity improving technologies.
- Compare the impacts of different productivity developments.
- Test the effect of changes in adoption drivers.
- Assess the incremental effects of improved adoption outcomes.
- Analyse what kinds of productivity assumptions needed to generate ‘targets’ for industry growth.

10 Key focus areas

Following from the analysis undertaken in this report, we have five key areas of future focus.

1. Encourage ongoing productivity discussions within industries

Productivity is a critical area for the whole horticulture sector, not just policymakers. It will be important to encourage ongoing discussions within the horticulture industries about innovation and the activities and practices that are most likely to increase productivity.

The spreadsheet tool provided with this report can be used both as an analytical framework within individual industries and as a way to support and structure these conversations. These discussions should also consider the needs of individual growers in making decisions about whether to adopt new technologies or practices.

2. Create opportunity for productivity conversations across industries

All horticulture industries face similar underlying challenges, even if their form varies from industry to industry. It is likely that at least in principle, solutions found in one industry may be applicable to other industries.

Given this, it is worthwhile to create more opportunities for conversations across industries; conversations that may not otherwise take place in the normal course of business.

It is well known that cross-fertilisation is a major source of innovation. As indicated by the research in chapters 2 and 7, the dissemination and spread of ideas into new settings is an important driver of both productivity and adoption of new innovations. This key focus area seeks to extend the scope for the spread of ideas across industries, as well as within them.

3. Take advantage of benchmarking to understand practices and profitability

Measuring historical productivity in horticulture is difficult (as noted in chapter 3). This makes it difficult to generate lessons about what practices lead to profitable innovations and hence increases in productivity.

One practical approach is to extend the use of benchmarking analysis within horticulture industries to include analysis of the practices adopted by the highest-performing enterprises within an industry.

While benchmarking can be used to generate proxy productivity measures, it also plays an important role in building grower-capability to understand the practices that lead to both productivity and profitability. The underlying idea is that if growers are able to adopt the innovations and practices of the most profitable farms, the overall sector's productivity will rise over time.

4. Seek to further understand 'hidden' productivity

Some productivity changes do not readily appear within standard measured economic accounts, particularly those tied, directly or indirectly, to reduced environmental impacts.

A better understanding of 'hidden' productivity value is important, particularly as industries face potentially increased scrutiny for their environmental footprint. Strengthening the evidence base in this area will also help ensure that the full value of innovation is recognised.

Productivity directly relates to environmental impact. Some of the businesses consulted for this report have explicitly sought to reduce their impact. It is worth further understanding this linkage and understanding the many ways in which the environment could be improved through the ongoing application of innovations to enhance environmental outcomes as well as traditional production measures.

5. Understand how consumer convenience innovations benefit growers

Another area of analysis is to understand how innovations in consumer-facing technologies — the new types of products offered and their new formats — provide benefits to growers through their effects on systemwide productivity.

For domestic facing industries in particular, there may be limited scope to increase the quantity of output, meaning that value growth may increasingly come from innovations that change how products are presented to the consumer. Key questions include:

- To what extent can changes at the farm level contribute to this?
- How do these changes feedback to provide benefits to farmers?

Appendixes

A Top down and benchmarking productivity estimates

Top-down estimates

Given that we have total agriculture, forestry and fisheries productivity growth estimates, along with estimates of some components of this, implied productivity growth for horticulture can be inferred. Table A.1 summarises the available information and the shares of each component.

A.1 Total agricultural productivity and its components

Sectors	Productivity growth	Share of output
	% per year	%
Total Agriculture, forestry and fisheries	0.88	100
Broadacre (average of climate and non-climate adjusted estimates)	0.55	46
Dairy	0.5	6
Forestry and Fisheries (plus other)	?	28
Horticulture	?	20

Source: ABS, ABARES, CIE estimates.

To reconcile the individual productivity growth rates with the overall sector average of 0.88 per cent per year, we can infer the likely productivity growth rates for the forestry and fisheries and horticulture sectors based on their respective output shares.

Given that both broadacre and dairy have lower growth rates than the sector average, the combined productivity of forestry, fisheries, and horticulture must be greater than 0.5 per cent per year to achieve the weighted average of 0.88 per cent.

- Assuming an optimistic value of 1.5 per cent a year for forestry and fisheries, then this implies horticulture productivity growth of around 0.9 per cent a year.
- Assuming the average for forestry and fisheries (0.88 per cent a year), then this implies horticulture productivity growth of 1.7 per cent a year.

There are clearly a number of ways in which errors can arise for this type of comparison. While similar, the ABS and ABARES estimates are not calculated on exactly the same basis. Also, the relevant share of each industry change over time, which will affect a detailed calculation.

However, based on a range of sensitivity analyses on the estimates, it is reasonable to conclude that overall productivity growth for horticulture is positive and likely falls in the range of 0.5 to 1.5 per cent a year. This places it in line with or slightly below cropping, for which ABARES estimates productivity growth of around 1.2 per cent a year.

These estimates are consistent with the broad view that emerged from industry consultations, which emphasised that, given increasing costs and prices received by growers remaining largely the same, enterprises must find ways to continually improve productivity.

This is also consistent with the recent growth of private equity and pension fund ownership in a number of horticulture industries. A major portion of returns for these owners will inevitably need to come from ongoing productivity improvements.

Benchmarking estimates

Table A.2 summarises the outcomes from six benchmarking projects recently undertaken within horticulture.

A.2 Summary of benchmarking reports

Industry	Benchmarking source	Method	Results
Nursery	Nursery Industry Statistics 2020-21 to 2024-25	Using data from the benchmarking report Nursery Industry Statistics 2020-21 to 2024-25 we construct a proxy set of productivity estimates using data on output and labour and land use	These proxy estimates indicated that nursery productivity grew strongly from 2017-18 to 2020-21 (at between 2 and 4 per cent a year). Subsequently (2021-21 to 2023-24) productivity declined (by between 4 and 6 per cent a year).
Almonds	Almond Insights 2023/2024	Examine yield outcomes	Almond Insights 2023/2024 indicates that almond yields have grown at an average of 1.3 per cent a year between 2011 and 2023
Macadamias	Macadamia industry benchmark report 2023	Examination of reported yield outcomes	The Australian Macadamia Society Macadamia industry benchmark report 2023 indicates that macadamia yields grew by between 1.1 and 2.5 per cent a year, between 2009 and 2023, depending on the yield measure used
Bananas	Banana Benchmarking Project Seasons 2023 and 2024 Report	Report sets out detailed information on real output and costs from 2011 to 2024 from which proxy productivity measures can be calculated	We calculate that productivity fell sharply from 2011 to 2024 and then recovered strongly in 2024. Average annual productivity growth over the period was -1.6 per cent.

Industry	Benchmarking source	Method	Results
Avocados and Vegetables	Two reports used: The Avocado Benchmarking National Report — Production season ending 2023; and The National Vegetable and Onion Benchmarks Season 2023	Provide key information on the differences between high and low performing enterprises	
International	*Agricultural Productivity in China* *Total Factor Productivity in Horticultural Crops in Maharashtra* *Productivity Growth in Global Agriculture Shifting to Developing Countries*	Mixed methods used in reports to indicate broad productivity changes	■ In China horticulture TFP has recently growth at 3 to 5 per cent a year ■ Up to 5 per cent growth a year in some states in India ■ California and Florida appear to have had low or stagnant TFP growth in recent years

Source: CIE analysis based on sources cited.

As set out in the future focus findings, benchmarking can provide a major contribution to understanding the key drivers of productivity within an industry.

There are a number of advantages to using benchmarking in this way.

- Profit and loss information is collected during usual business operations so data collection in relatively straightforward.
- Benchmarking is already in use, and working, in several horticulture industries.
- Benchmarking captures many dimensions of business performance, including yield, quality premiums, wastage, labour productivity and risk management.
- This approach avoids the need for complex weighting of inputs and outputs required for traditional productivity measures.

Some caution is needed however to deal with some challenges that arise from benchmarking.

- Some enterprises may be profitable because of very specific circumstances such favourable forward-contract prices, niche branding, or local market dominance—factors which other growers will not be able to adopt directly.
- Benchmarks need to control for location and resource endowment factors which are outside of the control of enterprises. This includes factors such as soils and microclimate.
- Benchmarks require more than just a single year where random factors can influence performance. This includes factors such as exchange rate swings, seasonal price swings and so on.
- Benchmarks need to account for investment cycles. A mechanised farm may look less profitable in the short run (due to depreciation and finance costs) despite higher

physical productivity and improved profitability in the long run. Without accounting for this, benchmarking might discourage long-horizon innovations such as robotics.

- Finally, industry benchmarking itself runs the risk of missing step change technologies that may have major long run benefits not captured in the benchmarks.

B Coverage of industry consultations

Part of the research for this project involved a series of one-on-one industry consultations along with four mini-workshops. Participation was by invitation, with interviews and workshops arranged with individuals and organisations who responded to an invitation from Hort Innovation.

Consultations questions

The structure of questions for the one-on-one consultations is set out below.

B.1 Structure of interview questions

Topic	Line of questions
Company	Company details
Product and enterprise	Details of products, enterprise nature, location etc
Productivity measures	Current productivity measures used
Current productivity growth	Recent productivity growth if measured
Current technology	Technologies currently used in the enterprise
Future developments	Plans for future developments in technology
Information comes from?	Where does information about technologies and innovations come from?
Constraints	Constraints to adoption of new productivity technologies
Other issues 1	Other issues
Other issues 2	Other issues

Source: CIE.

Workshop questions

Workshops were focused around four key questions:

- What is your biggest productivity challenge?
- What can you do to address this?
- What would help you implement a response?
- What is hindering you from implementing a response?

Coverage

B.2 Consultation coverage

Industry	State	Number
Almonds	Queensland	2
Almonds	NSW	1
Apples	NSW	3
Apples	WA	1
Apples	South Australia	1
Avocado	NSW	2
Banana	Queensland	1
Beans	Queensland	1
Berries	Tasmania	1
Citrus	NSW	3
Citrus	South Australia	2
Citrus	Victoria	1
Grapes	NSW	1
Grapes	South Australia	1
Lychees	Queensland	1
Macadamias	Queensland	5
Mixed enterprise	National	1
Mushrooms	Victoria	2
Nursery	South Australia	1
Nursery	WA	1
Nursery	Victoria	1
Olives	South Australia	1
Pecan	Queensland	1
Pineapple	Queensland	1
Service providers	National	2
Stonefruit	Victoria	1
Strawberries	Victoria	1
Turf	Victoria	1
Vegetables	Queensland	1
Vegetables	Victoria	1
Walnut	Queensland	2

Source: CIE.

References

ABARES (Australian Bureau of Agricultural and Research Economics and Science) *Australian Farm Productivity — Broadacre and Dairy Estimates*. https://www.agriculture.gov.au/abares/research-topics/productivity/agricultural-productivity-estimates?utm_source=chatgpt.com#daff-page-main

ABARES 2025 *Productivity drivers* https://www.agriculture.gov.au/abares/research-topics/productivity/productivity-drivers.

ABS (Australian Bureau of Statistics) 2024 *Innovation in Australian Business 2023-24* https://www.abs.gov.au/statistics/industry/technology-and-innovation/innovation-australian-business/latest-release#key-statistics

ABS (Australian Bureau of Statistics) 2025 *Estimates of Industry Multifactor Productivity 2023-24*. https://www.abs.gov.au/statistics/industry/industry-overview/estimates-industry-multifactor-productivity/latest-release

Acemoglu, D 2002 'Directed Technical Change' *The Review of Economic Studies*, Volume 69, Issue 4, Pages 781–809. https://doi.org/10.1111/1467-937X.00226.

Aghion, P and Howitt, P 1992 'A Model of Growth Through Creative Destruction', Econometrica, Vol. 60, No. 2. pp. 323-351. https://web.econ.ku.dk/dalgaard/growth/growth07/AghionHowitt.pdf.

Banks, G 2012 Productivity policies: the 'to do' list. Paper presented at Economic and Social Outlook Conference, Melbourne. https://www.pc.gov.au/media-speeches/speeches/productivity-policies/productivity-policies.pdf

Bass, F 1969. 'A New Product Growth Model for Consumer Durables' *Management Science* 15(5). https://pdodds.w3.uvm.edu/files/papers/others/1969/bass1969a.pdf.

Borrell, B., Jiang, T., Pearce, D. and Gould, I. 2014 'Payoffs from research and development along the Australian food value chain: a general equilibrium analysis'. *Australian Journal of Agricultural and Resource Economics*. Vol 58, Issue 3 pp 409-429. https://doi.org/10.1111/1467-8489.12062.

Carey D et al 2023 *Predicting Green Bean Harvest and Yield*. Foodagility CRC Report. https://cdn.prod.website-files.com/5f4f19737a6ae318c84e362c/649b850d34cde68b756e3447_FA048%20Predicting%20Green%20Bean%20Harvest%20and%20Yield_Final%20Report%202023.pdf.

CIE (Centre for International Economics 2023 *Economic contribution of Australian Horticulture*. https://www.horticulture.com.au/growers/help-your-business-grow/research-reports-publications-fact-sheets-and-more/mt21010/.

Department of Industry Science and Resources 2024 *How is the Australian Innovation System Tracking in 2024?* https://www.industry.gov.au/news/how-australian-innovation-system-tracking-2024

Grossman, G. and Helpman, E 1989, Quality Ladders in the Theory of Growth, NBER Working Paper 3099. https://www.nber.org/papers/w3099.

Hine, D 2015 *Transformational innovation performance analysis.* https://www.horticulture.com.au/growers/help-your-business-grow/research-reports-publications-fact-sheets-and-more/ai13011/

Hort Innovation 2024 *Industry spearheads adoption of labour saving tech*. https://www.horticulture.com.au/hort-innovation/news-events/media-releases/2024/industry-spearheads-adoption-of-labour-saving-tech-with-%2452m-boost/.

Keates, O 2023 'Actionable insights for horticulture supply chains through advanced IoT analysis'. *Procedia Computer Science* Vol 217, pp 1631-1640. https://doi.org/10.1016/j.procs.2022.12.363

KPMG 2020 *Seasonal horticulture labour demand and workforce study*

Kuehne et al 2017 'Predicting farmer uptake of new agricultural practices' *Agricultural Systems*, vol 156, Sept, pp 115-125 https://doi.org/10.1016/j.agsy.2017.06.007

Layden, I and O'Halloran, J n.d *Adoption of precision systems technology in vegetable production. Hort Innovation* VG16009 Final Report. https://www.horticulture.com.au/globalassets/laserfiche/assets/project-reports/vg16009/vg16009-final-report-complete.pdf

Novales, A and Mancha, R 2023 *How Hortilux Used Low-Code to Develop Its IoT Digital Services*. Communications of the Association for Information Systems. Vol 53, paper 38. https://pure.eur.nl/ws/portalfiles/portal/146017521/How_Hortilux_Used_Low-Code_to_Develop_Its_IoT_Digital_Services.pdf

Parham, D 2003 *Sources of Australia's Productivity Revival*. https://www.pc.gov.au/research/supporting/revival

PC (Productivity Commission) 2023 *Advancing Prosperity 5-year Productivity Inquiry Report*. https://www.pc.gov.au/inquiries/completed/productivity/report

Rogers, E 2003 *Diffusion of Innovations* 5th Edition. Simon and Schuster. ISBN 978-0-7432-5823-4.

Romer, P 1990 'Endogenous Technological Change' *Journal of Political Economy* vol. 98, no. 5. https://web.stanford.edu/~klenow/Romer_1990.pdf.

Rootsey et al 2015 Robotics-Ready AI in Viticulture. Foodagility CRC Report. https://cdn.prod.website-files.com/5f4f19737a6ae318c84e362c/67ec9aa713e8cc9dfa2f25f9_FA115%20-%20Final%20Public%20Report%20(Complete).pdf.

Slatter, B 2024, *Labour use in Australian horticulture: Analysis of survey results, 2022–23*, ABARES research report, Australian Bureau of Agricultural and Resource Economics and Sciences, Canberra, November, DOI: https://doi.org/10.25814/pc94-0628 .

Sorensen, P 1993 'Human Capital Investment, Government, and Endogenous Growth', FinanzArchiv / Public Finance Analysis, New Series, Bd. 50, H. 1 (1993), pp. 73-93. https://www.jstor.org/stable/40912529.

Southam-Rogers, L and Hyde, H *Smart Farming Guide for Horticulture*. https://berries.net.au/wp-content/uploads/2024/01/ABJ-AUT-23-IND-Smart-Farming-Guide-for-Horticulture.pdf.

Valle, H et al 2014 *Total factor productivity of Australian vegetable farms* ABARES Working Paper. https://www.agriculture.gov.au/abares/research-topics/working-papers/total-factor-productivity-of-australian-vegetable-farms