Co-designed scoping study
to unlock the power of digital

by Derek Baker, Masood Azeem,
Stuart Mounter and Yue Zhang
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AgriFutures®
Chicken Meat

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Foreword

The digital transformation of agriculture and food offers significant benefits to Australia's agribusiness economy, consumers, interest groups and communities. Uptake of digital technologies has been the subject of much recent research, and the focus is now shifting to factors enabling and invigorating both uptake and the more far-reaching process of digital transformation by firms and industries. The report *Co-designed scoping study to unlock the power of digital* presents results from research conducted jointly by the University of New England and the Food Agility CRC that targets these processes in the Australian chicken meat industry. This research was commissioned as part of Agrifutures Australia's Chicken Meat Program. Its scoping study nature assembles and synthesises information from a variety of sources, to deliver a strategy and roadmap for change.

The industry has sustained growth and productivity gains over the past several decades, against the backdrop of falling prices and rising demand, unprecendented consolidation at all industrial stages, the challenges of regulation, and a demanding social license. Across these fronts, digital transformation offers some answers, and poses some questions. Its form has varied across many industries and its progress has been difficult to measure and explain. Projections for the chicken meat industry (i.e. the 'power' of digital) have concentrated on technologies' technical impacts rather than their influence on business models and associated digital transformation ('unlocking' the power). This research reports on developments on both fronts. The work has been conducted in partnership with chicken meat processing firms, including consultations and an industry workshop, and mapping of industry aspirations to technologies, their implementation, and organisational change for their most effective use.

A major conclusion drawn is that stakeholders in the chicken meat industry are well aware of potential gains from digital transformation; indeed many processing firms and producers are actively pursuing such change. They are doing this for a variety of reasons and from a variety of starting points. Another is that institutional and competitive conditions in the Australian chicken meat industry do not lend themselves to sharing of data; data governance's legal basis is one problem but trust along the supply chain is also a significant barrier to change. The report identifies a number of possible delivery mechanisms for digital services, and such barriers in a number of ways also constrain these developments. Producers and processing firms acknowedge the lack of decision support tools suited to analysis of investment and organisational change to achieve digital transformation. Processing firms' skillsets are a source of pride, but firms acknowledge that digital-related skills do constrain progress. Improved skills are not, however, a solution in themselves, as they require accompanying management change, particularly around decision making and automation. Regarding the development of a digital service industry for chicken meat, contact points are lacking among business analytics, data and communications provision, and technical chicken meat production and delivery.

The report's recommendations provide a road map for change and an associated set of proposed strategic steps toward achieving the outcomes identified by industry. The strategies allocate proposed action among producers, processors and various levels of government. They also identify actions for the industry as a whole, and funding mechanisms. Many of these steps use existing initiatives and resources, and all recognise firms' unique starting points and aspirations.

This report for the Chicken Meat Program is an addition to AgriFutures Australia's diverse range of research publications. Most of AgriFutures Australia's publications are available for viewing, free download or purchase online at www.agrifutures.com.au.

John Smith
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Executive summary

The ‘power’ of digital innovation within the Australian chicken meat sector is projected by many analyses to lie in digitally enabled advances surrounding traditional strengths of productive efficiency, consumer acceptance, and relatively low retail prices. The power also lies in variations to conventional models so as to innovate into value-added products, particularly those bearing information-related attributes such as traceability. This report characterises the nature of benefits available and the prerequisites and mechanisms for capturing them. However, there is considerable variation among stakeholders in the industry and each is motivated by contextually specific potential gains and unique capabilities in securing them.

This scoping study collects, evaluates and presents available information so as to map relevant literature, experience and knowledge to the field of digital transformation in the Australian chicken meat industry.

The method applied was:

- Consultation with chicken meat industry operators;
- A design workshop for chicken meat industry operators to establish key data, aspirations for digital transformation and a vision for the future;
- Desk research into industry-level impacts of potential changes due to adoption of digital technologies;
- A literature review to identify the scope of research activity in digital applications to chicken meat production and processing, focused on the key data identified by industry;
- Selection of key technologies;
- Synthesis of findings to establish strategic actions;
- A strategic roadmap linking actions to investments, and identifying investors and sources of funding and funds flows; and
- Design of decision support tools for digital transformation and technology evaluation and to contribute to strategy.

The industrial organisation of the chicken meat supply chain provides both accelerants and brakes on information flow between producers and processors; trust and other issues surrounding data governance need addressing. Management domains offering benefits from digital transformation have been identified by several researchers, and the generation of trust shows considerable return to all in the industry. This project’s strategic proposals for data governance recognise ongoing development of elements of data rules for Australian agriculture (Wiseman and Sanderson, 2019), which highlight the development of trust as a goal.

The lack of tools for objective analysis of investment in digital technology and related change at the firm and supply chain level has also been repeatedly highlighted. This project generated a prototype tool to contribute to facilitate these developments.

Firms in the industry recognise that digital transformation is a means to an end, rather than an end in itself. Clear goals for the industry were established at a design workshop, and aspirations about the role to be played by advanced uses of data were expressed. These statements provided the building blocks for the scoping study and its extension into strategy. Firms also identified conceptual gaps between their aspirations and current reality, and identified the consequences of these barriers to change. This project developed a survey questionnaire for future use in characterising these gaps and their influences on innovation at the firm and supply chain level.

A multi-stage equilibrium displacement model was used to project the distributional aspects of investment and return as they confront industry stakeholders. This highlighted farm productivity and consumer demand as targets for high-return applications of digital transformation, which also benefited producers relatively better than some alternatives such as automation-related farm labour cost reductions. This model is available for further calibration and use.

At the heart of digital transformation is data and the uses to which it is put. Industry defined a list of data referred to in this report as a ‘data wish list’. A systematic literature review was conducted to identify technologies and their state of development relevant to the delivery of elements of the wish list. A total of 91 published research papers were used. They reveal a concentration on optical and mechanical means of automated measurement of bird weight, optical means of recording animal health conditions (many related to animal welfare), and on sensors generating ever more inference from shed environmental conditions. Almost all these advances are addressed towards automation of systems and decisions by way of algorithms and machine learning. Identification of these key relevant technologies was an intermediate output of the project. This was formalised by development and use of a tool employing 19 criteria and a scoring procedure. This tool is available for further use and expanded development.

The scoping study’s parts are assembled to provide support for a number of strategic actions. Variation in industry stakeholders’ capacity to benefit from any one action and investment means that a number of options (for example the delivery mode for digital services) are left open to informed choice. One source of such variation is the maturity of digital transformation processes in chicken meat farms and processing firms. A tool for establishing and examining the nature of that variation is available, and is recommended for use.

The study’s roadmap presents strategic actions, investments and milestones that progress towards industry-defined goals. Investors, funding and payment mechanisms, and sources of funds are also proposed. The final output of the project is this strategy and roadmap.

1. Introduction

1.1. Background

The Australian chicken meat sector has embraced technology, genetics, marketing and industrial organisation so as to rival chicken industries in most advanced economies. It faces challenges from increasing costs of feed, energy and labour, static product prices, expanding compliance requirements, and retail market power. Maintaining chicken's place as the most affordable and popular meat in the domestic market will require leveraging existing strengths and capitalising on its untapped opportunities. Data, new ways of collecting and using it, and organisational change to mobilise its benefits along the supply chain provide a basis for innovation targeting these ends.

1.2. Objectives

This project entails a scoping study to explore the potential for digital innovation within the Australian chicken meat sector. The study identifies the challenges and opportunities for data collection, analysis and use. The project comprises two phases: consultation and workshops, followed by the scoping study itself and an extension into proposals for industry strategy. Its outputs include the workshop findings, reviews of existing barriers and opportunities for digital innovation, synthesised findings from research, and a contribution to chicken meat industry strategy.

1.3. Methodology

A scoping study collects, evaluates and presents available information so as to map relevant literature and information in a field of interest (Arksey and O'Malley, 2005). This review is concerned with the Australian chicken meat industry and its potential for adopting and benefiting from digital technologies. The tools employed are:

- Consultation with chicken meat industry operators;
- A design workshop for chicken meat industry operators to establish key data, aspirations for digital transformation and a vision for the future;
- Desk research into industry-level impacts of potential changes due to adoption of digital technologies;
- A literature review to identify the scope of research activity in digital applications to chicken meat production and processing, focused on the key data identified by industry;
- Listing, rating and ranking selected representative technologies;
- Synthesis of findings to establish strategic themes and actions, and support for strategy; and
- Design of decision support tools for digital transformation and technology evaluation and to contribute to strategy.

1.4. Outline of report

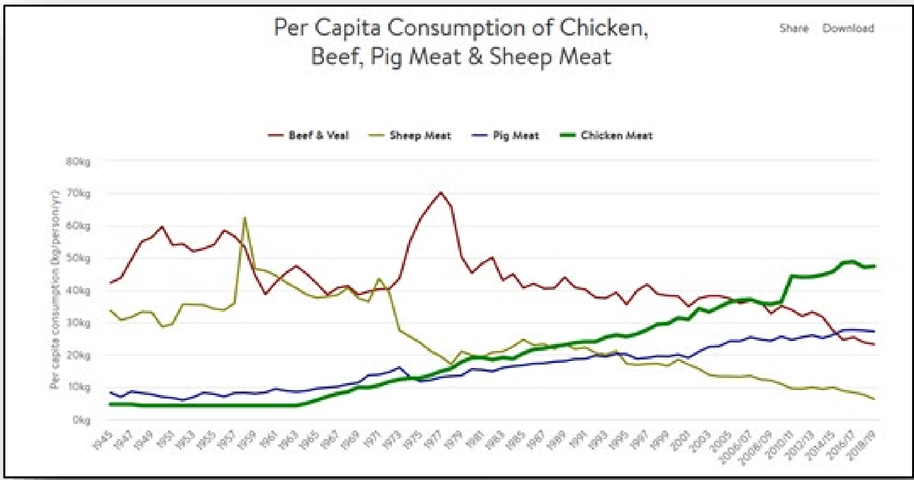
This report provides a brief summary of features of the Australian chicken meat industry and supply chains relevant to this scoping study (section 2), followed by a discussion of digital transformation and aspects of its initiation and progress (section 3). Section 3 scopes the concept of 'the power of digital' by steadily narrowing a conceptual discussion toward topics relevant to decisions in the Australian chicken meat sector, with some focus on barriers identified, relevant experience, and issues of implementation.

Section 4 reports analysis using an equilibrium displacement model to provide estimates of economic benefit to the industry of selected changes associated with digital transformation. Its contribution is that unlike previously used sector-wide models, the shares of projected benefit accruing to each stage of the supply chain – including retailers and consumers – are estimated. Section 5 presents the preamble to, and main results from, industry consultation and a design workshop held in November 2019 in Sydney; this identified key data and scoped industry aspirations for digital transformation as a contributor to overall chicken meat industry development. Section 6 presents issues associated with data exchange, principally the associated issues of ownership and trust, and a discussion of available organisational models. Section 7 is a narrow literature review that identifies research advances associated with the key data and management changes discussed in the industry workshop. Section 8 concludes the scoping study aspect of the work by rating technologies according to criteria developed from sections 2-6. The tool used for this process is attached to this report. Section 9 provides prototype decision support tools and discusses their development for future use. Section 10 refers to industry targets stated at the industry workshop, and proposes actions and strategy. Section 11 states conclusions and limitations of the work, and proposes next steps.

2. Aspects of Australia’s chicken meat industry

2.1. Pre-eminence of chicken meat

Chicken is Australia’s most consumed meat and is the only Australian meat from which real prices have consistently fallen in recent times, by an average of 2% over the 10 years to 2017-2018 (ABARES, 2020). Further, Australian consumer demand is expected to grow at 1.2% in the medium term, primarily due to its price relative to those of other meats (ABARES, 2020). Notwithstanding small declines in aggregate production due to recent drought, ABARES (2020) expects medium-term growth in chicken meat production of about 2% per annum.



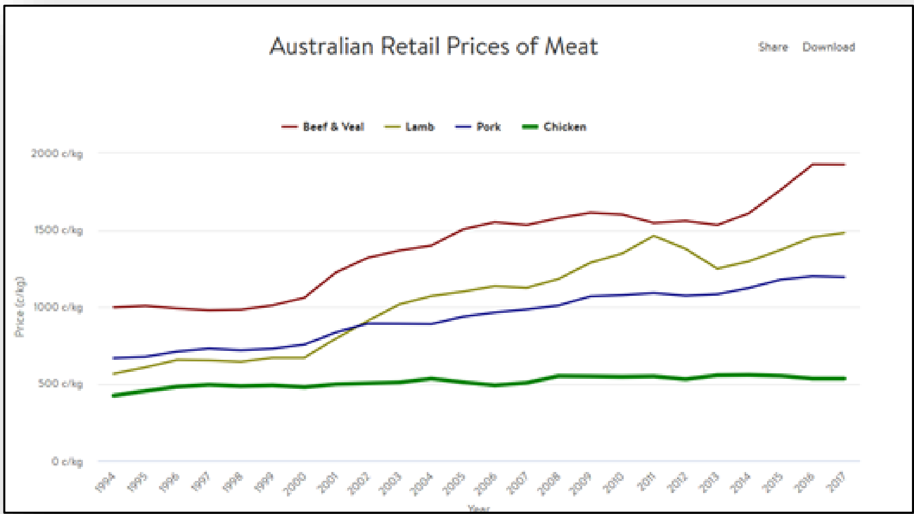


Figure 2-1. Chicken meat consumption and prices, relative to other Australian meats

Source: Australian Chicken Meat Federation (2020)[1]

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[1] https://www.chicken.org.au/facts-and-figures/

2.2. Markets and product status

In Australia, as in a number of other developed economies, sustained performance and expansion in the context of constantly declining real prices has required continuous improvement in efficiency throughout the supply chain. This has enabled by highly standardised production and processing systems, and strongly vertically co-ordinated supply chains (Wiedemann et al., 2017). Australia probably has the world's most concentrated retail food market (Bariacto and deNunzio, 2014), which exerts pressure on chicken meat processors, and in turn producers, to minimise costs. These forces have prompted strategic cost reduction actions, including processing plant location, and the adoption of large and highly mechanised production and processing operations geared to retailer needs (Yakovleva and Flynn, 2004).

Lindgreen et al. (2008) catalogued the Australian chicken meat industry's progression toward "commoditisation" in former years, and a more recent shift towards a more value-added offer. These authors outlined supply chain developments wherein tasks are allocated throughout the chain in increasingly more sophisticated contracted arrangements, and diversification into products such as free range. They also reported that product innovation is constrained by retailer practice. Although supermarkets represent the largest outlet for chicken meat in Australia, food service and other markets are also significant (Figure 2-2). With wholesalers' onwards sales likely divided between food service and other markets, this aggregate data suggests ongoing value addition beyond a commoditised product.

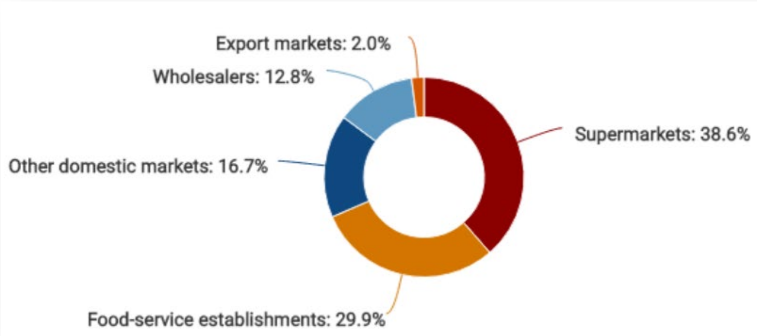

Figure 2-2 Product markets for chicken meat

Source: IBISWorld (2020)

2.3. Industry structure and performance

Chicken meat processing is dominated by two large firms, 5-6 moderately sized firms, and a competitive fringe of numerous small local firms.[2] In general, processing companies contract broiler farms and provide day-old-chicks, feed and support services (Henderson and Morison, 2016; Hopkinson, 2013), although a variety of supply arrangements exist, with several processing firms owning much of their production base.

Overall, the number of processing firms stayed steady in the period 2011-2019, and the number of farming enterprises fell by about 8% (Figure 2-3), although individual farms have become larger. Average processing revenues per enterprise have risen about 35% in that period, and for production about 8%. At the production level, revenues per employee have stayed steady over this period, and for processors these have risen by about 11%. Chicken meat processing value added per employee has risen 12% over this period and has fallen 14% for production (Figure 2-4).

[2] For details of the industrial organisation of the chicken meat industry see Australian Chicken Meat Federation's Facts and Figures page https://www.chicken.org.au/structure-of-the-industry/

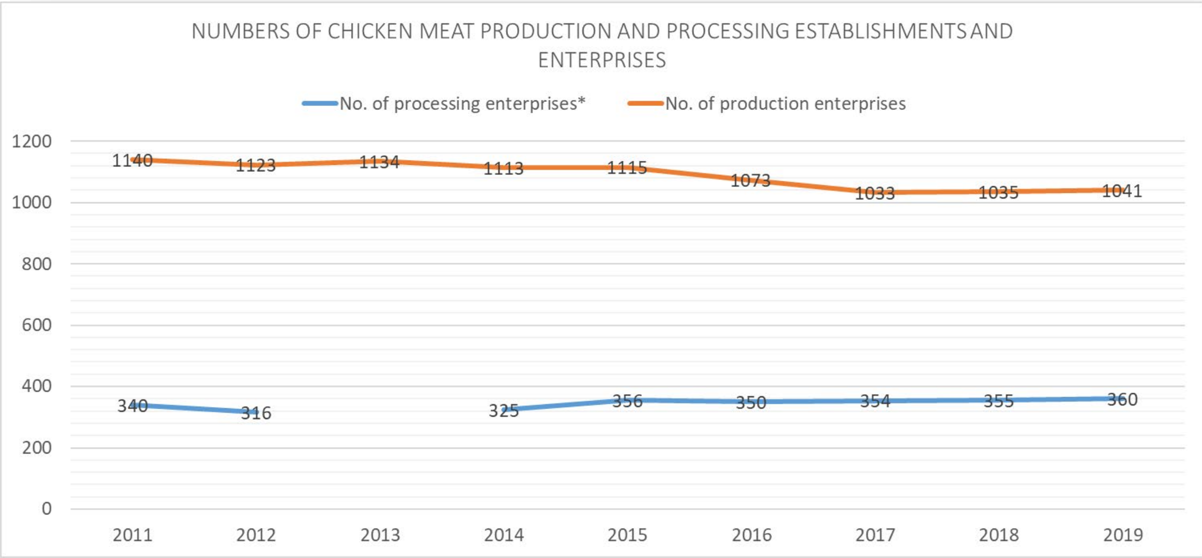

Figure 2-3 Numbers of enterprises in chicken meat production and processing

* Data missing for 2014

Source IBISWorld (2020)

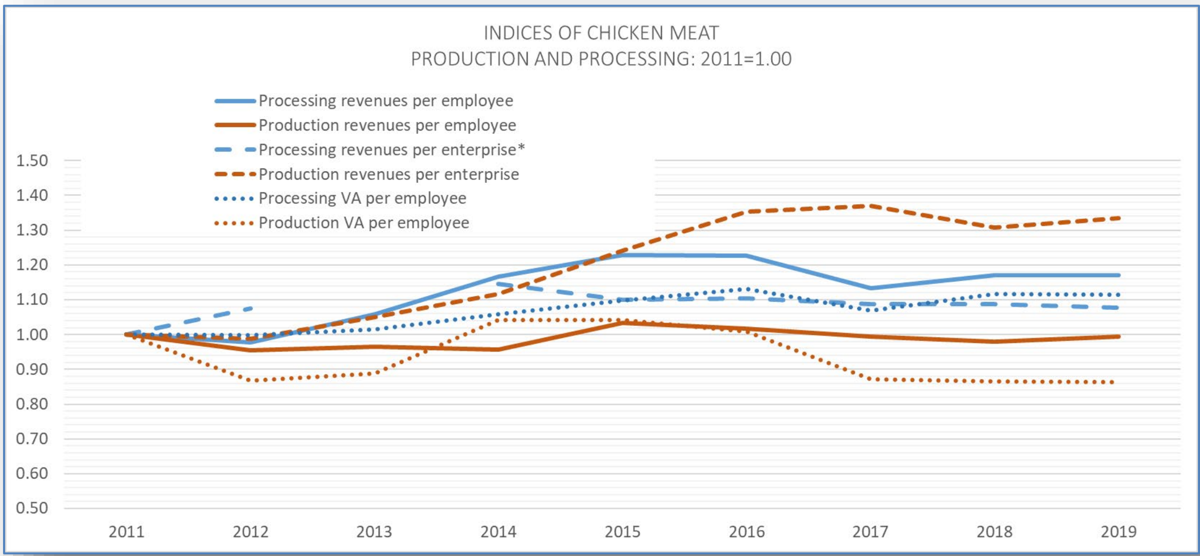

Figure 2-4 Revenue indices for numbers of establishments and enterprises

* Data missing for 2013

Source IBISWorld (2020)

2.4. Cost and revenue structures

Few reliable recent empirical estimates of firms' profitability are available.[3] IBISWorld (2020) provides estimates of 5% and 6% margins at production and processing stages of the poultry meat industry respectively (Figure 2-5). These numbers are indicative (due to aggregation) and reflect costs of processes at stages of the supply chain, rather than costs accruing to enterprises; this is because they include cost items at the production level (such as feed and the costs of day-old chicks), which under most contracts are provided by the processor.

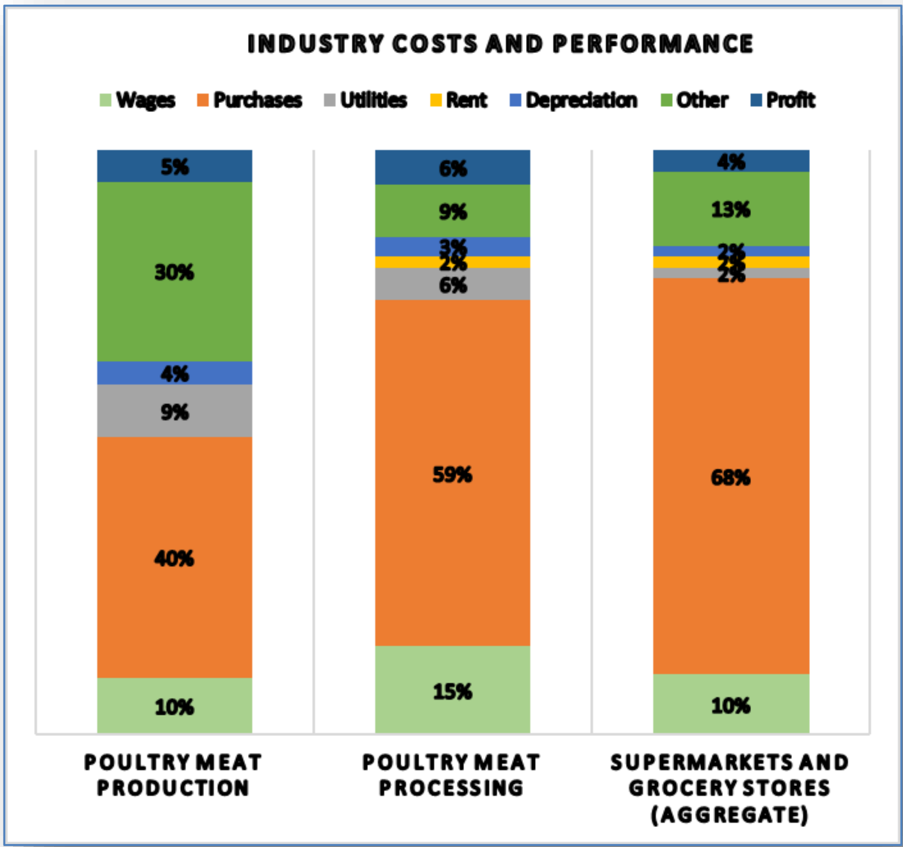

Figure 2-5. Financial performance in the chicken meat sector

Source: IBISWorld (2020)

2.5. Physical plant

No consistent data is available on the distribution of ages of chicken meat production sheds, nor on the technologies applied. Industry commentary is that a variety of ages of shed are in operation (Pitkin, 2017), and that shed age affects chicken meat productivity and profitability (Gillespie et al., 2017).

[3] Work such as Buloke Shires Council's Investment Guide, https://www.buloke.vic.gov.au/intensive-industry-investment-guides, provides useful material although it is not integrated along the supply chain stages.

2.6. Human resources

Employee numbers at both the production and processing stages of the industry are steady over recent years at about 2000 and around 18,000, respectively (IBISWorld, 2020). Drawing on 2016 data, one-third of these are aged under 35 years, and about one-third are women (ABARES, 2018).

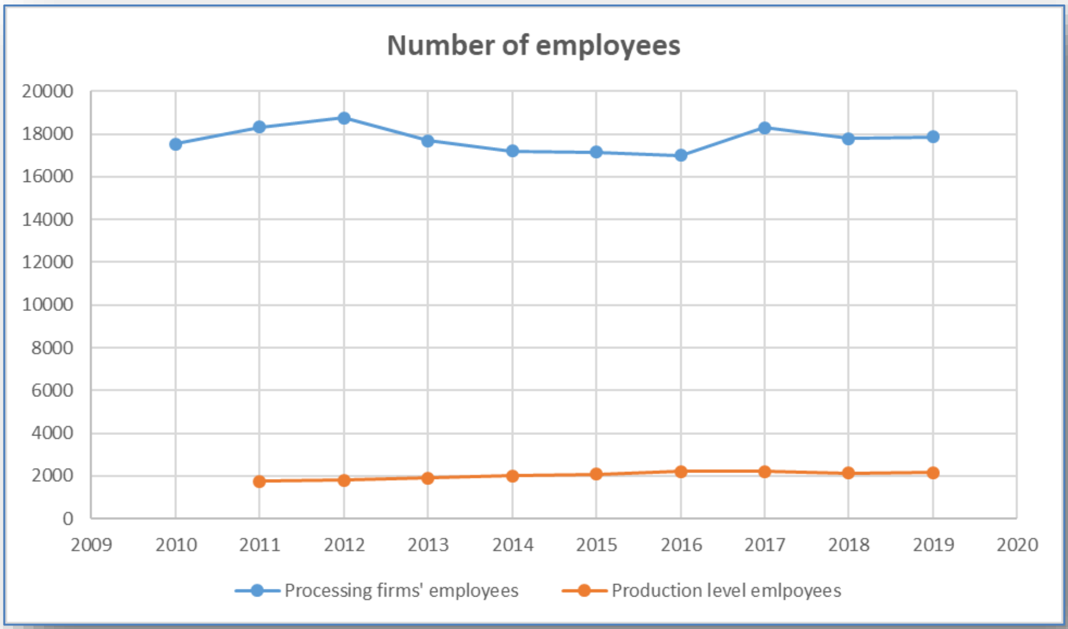

Figure 2-6. Number of employees in the chicken meat sector

Source: IBISWorld (2020)

2.7. Regulation, compliance and policy

The Australian chicken meat industry is regulated across the usual spectrum of policy areas, and specifically in food safety, the environment and animal welfare. It subscribes to codes of practice on issues such as animal welfare associated with transport. Regulation applies both to operations and to aspects of expansion investment. Local issues such as odour from operations, and building code compliance during expansion or renewal, impact the sector.[4]

The chicken meat industry at both production and processing levels is subject to audit and compliance requirements both from commercial partners (buyers, primarily focused on quality and food safety) and non-commercial groups with specific concerns such as animal welfare. Australian supermarkets require RSPCA compliance in terms of animal welfare, and this occasions an audit process at the farm level. Many related and third-party audit procedures are used on a voluntary basis, and animal health and welfare actions and outcomes are communicated by the industry.[5]

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[4] A listing of regulatory and compliance issues is beyond the scope of this study. The interested reader is referred to the industry-level submission to the Federal Ministry of Agriculture's Submission to the Agricultural Competitiveness Taskforce White Paper process, https://agwhitepaper.agriculture.gov.au/sites/default/files/SiteCollectionDocuments/IP500%20Australian%20Chicken%20Meat%20Federation%20Inc.pdf, and a concerted analysis of the whole spectrum of policy, and associated strategic proposals, prepared by the Victorian Chicken Meat Council, https://vcmc.org.au/wp-content/uploads/2014/12/VCMC-2025-StrategyDocument-Ver1.0.pdf

[5] The interested reader is directed to the Australian Chicken Meat Council's website, which details current industry status and spheres of action on animal health and welfare, https://www.chicken.org.au/chicken-health-welfare/

3. The power of digital in agriculture

3.1. Economy-wide and society-wide benefits from adoption of digital technologies

Benefits of adoption of digital technology and associated changes by Australian industry has been variously projected, for example at $315 billion over a decade (Alphabeta, 2018) and $140-250 billion by 2025 (McKinsey, 2017). The mechanisms for anticipated benefit generation generally focus on adoption of both new and existing technology by industry, and the development of new industrial subsectors to provide digital products and support services. Other projected benefits include inclusion of socially neglected groups and regions, and the productivity of government in its engagement with citizens and business, and in data sharing (McKinsey, 2017; Australian Government Digital Transformation Agency, 2018). Many similar projections have been made abroad, for example about the UK by Made Smarter (2017), which reported on consultation with a large number of industry leaders about future benefits to Britain, estimated at $894 billion over 10 years. That review particularly targets the generation of value by way of such changes as strengthened supply chains and improved export competitiveness, and creation of highly paid jobs, particularly in neglected regions and among disadvantaged groups.

3.2. Aspects of digital transformation

Digital transformation is a process that incorporates uptake of digital technologies, but extends to reorganisation of firms and their business models. This particularly refers to:

- Full exploitation of information technology and information-related developments in supply chain partnerships (Bowersox et al., 2005);
- Full engagement of the internet (PwC, 2013);
- Information-based networking among firms for decision making, and with broader society (Boueé and Schaible, 2015).

The 'transformation' is usually associated with a progression of steps taken by firms to change business models along these lines for value delivery, and to change the nature of relationships along the supply chain. The end point of such transformation, or measures of its maturity in firms and industries, is less understood, particularly for individual industries. Zhang et al. (2019, in review[6]) presents 13 examples of varying degrees of focus and analytic complexity, and featuring various themes or criteria, and indicators of action being taken. The criteria for assessing maturity generally span companies' culture and strategy, use of technology, data uses, human capabilities, and data governance.

Berghaus and Back (2016) offer a further empirical example of maturity measurement, which focuses on the existence of processes and decision pathways within firms. These authors also remark on the lack of demonstrated linkages between firms' maturity of digital transformation and their business performance and competitiveness. A 2017 report by MIT examines organisational aspects of digital transformation, and finds that firms more advanced in implementing these changes share a number of features: they innovate more, they enable staff freedom to innovate, they engage with customers and suppliers, and they work in cross-disciplinary teams. Such firms also require greater governance, specifically in implementing strategies.

Schallmo (2016) presented digital transformation as a cycle rather than an end point. The cycle progresses from current status through to implementation, which entails continuous re-alignment around needs, opportunities and capacities (Figure 3-1). Westermann et al. (2011) concluded from an international study of digitally transforming firms that the process is driven from the top of organisations,

[6] This work is further used later in this report.

and Loonam et al. (2018) concluded from case studies that engagement of customers as “active participants” in the process is required. Westermann et al. (2014) posed a key question of required focus: which areas of the business are to be digitally transformed? Those authors then sequentially examined the customer experience, operational processes and the business model itself.

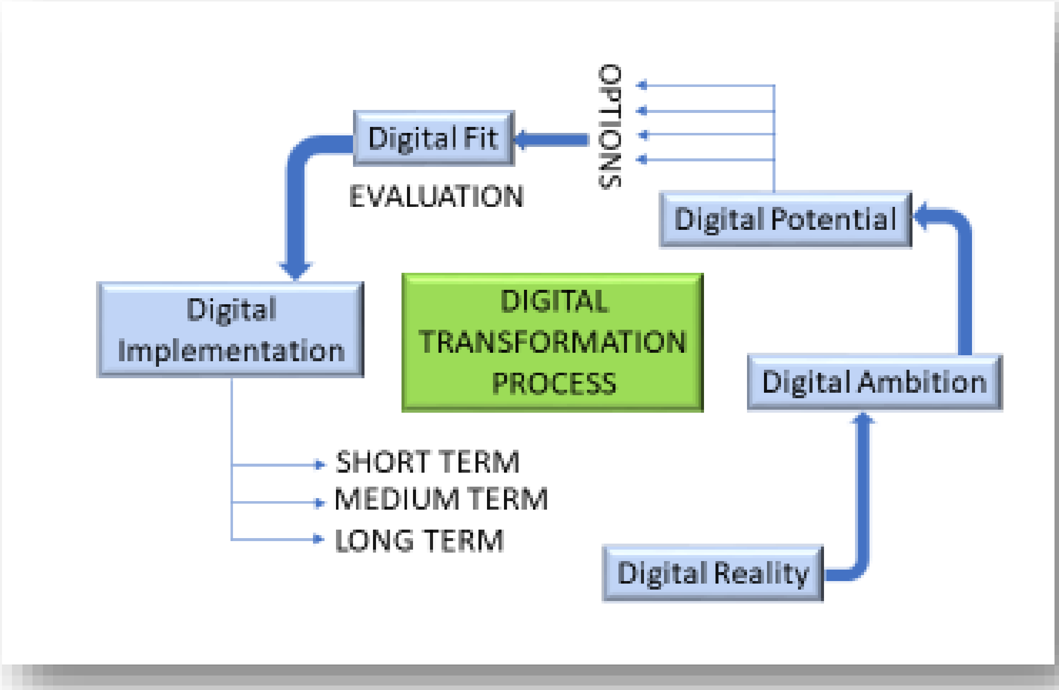

Figure 3-1 A representation of the digital transformation process in firms

Source: Schallmo (2016)

A growing management literature addresses a world “awash with data” (Kenney and Zysman, 2016; Short and Todd, 2017), amid developments in markets for data and data-related services that enable their operation. This provides some basis for firms’ and industries’ tasks in identifying the benefits and costs of change, in decision making. The decisions are substantial, given high-profile calls for embrace of new technologies for handling data, such as from PwC (2017) in identifying “the essential eight” technology “building blocks” for firms: artificial intelligence, augmented reality; blockchain; drones; Internet of Things; virtual reality; and 3D printing. The implied scale of the advocated action raises concerns over the capacity of all, or indeed any, individual firms to get on board digital transformation.

Barriers to firms’ digital transformation are common targets for popular press commentary, featuring “Top 6”,[7] “Top 5”[8] and “Top 3”[9] lists. These lists universally include fear of the unknown, resistance to change and lack of skills. An inability to collaborate externally is also commonly listed, supporting Berghaus and Back’s (2016) findings mentioned above.

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[7] e.g. https://www.ideas4allinnovation.com/innovators/gartner-barriers-digital-transformation/
[8] e.g. https://inthechat.com/wp-content/uploads/2018/10/Top-5-Barriers-to-Digital-Transformation.pdf
[9] e.g. https://www.softwareone.com/en/blog/all-articles/2017/12/08/key-barriers-to-digital-transformation

3.3. Agriculture and food in the digital revolution

Agriculture's participation in such a transformation, and generation of benefits from the resulting networks and ecosystems, has been viewed variously from being somewhat minor to a leading role. This interpretation may be based on assessments of agriculture's initial level of digital adoption, of aspects of adoption and access to commercial benefits, and issues surrounding the overall maturity of digital agriculture (Leonard et al., 2017). Measures of digital maturity have been developed for Australian agribusiness by Zhang et al. (2019), with metrics assigned across the spectrum of 'Emerging', 'Transitional', 'Competitive', and 'Transformative'. These metrics are applied to aspects ("pillars") of agribusiness enterprises, with an effort made to include as many diverse, but comparable, enterprises as possible.

Available studies of digital transformation's benefits to agriculture employ a range of perspectives. These include projections of gains to commercial firms from use of new technologies, or adoption of existing technologies; the inclusion in decision making of the data or knowledge generated by new technologies; the gains to consumers from greater choice and improved quality in products; and the value to society from reduced waste and GHG emissions.

Benefits from uptake of precision agriculture technologies in intensive livestock production were discussed by Banhazi et al. (2011), in terms of a likely slow rate of adoption but concerted use of particular measurement methods. By facilitating objective measurement, these target farm performance measures such as animal welfare, environmental performance, and product segmentation and traceability in the food supply chain. Lammers et al. (2018, in review) identified drivers of digital transformation in Australian agriculture as (the inter-related) environmental sustainability, productivity increase, and decision-making support. Australian Farm Institute (2016) and Griffith et al. (2013) summarised limited studies of on-farm benefits in Australia and elsewhere, associated with increased productivity from enhanced management information on soil fertility; improved inputs' use and plant and animal health monitoring; and gains from integration of data systems with the food supply chain in pursuit of price premia. Griffith et al. (2013) also projected benefits to the Australian agribusiness service sector by way of new marketing services and innovative co-ordination between the food industry and resource management. These authors also projected environmental benefits from reduced input use, and an improved quality of rural life due to the availability of digital communications and services.

A survey by CSB (2020) identified two high-level motivations for digital transformation in agriculture: solving problems inherent in feeding a growing population in the presence of challenges; and addressing new opportunities associated with food and agriculture's increasing complexity, regulation, competition, and uncertainty. CSB's survey results identified three "strategic models" for delivery of benefits from digital transformation: the internally and single-firm-oriented "process engineer"; and two forms of external relationship builder, one based on good transaction relationships and one "ecosystem builder" that facilitates and uses collaborative networks. These themes are also highlighted by DeMartini et al. (2018), whose case study work identified a set of internal and external drivers for capture of benefits of digital transformation: their results are substantially similar to those of Lux Research (2019) in identifying six core outcomes from digital transformation in the food industry. These are:

- Uncovering currently invisible insights;
- Predicting the future;
- Optimisation;
- Upskilling humans;
- Making information accessible;
- Automation.

These statements reinforce the view of Westermann et al that different areas of the business can provide opportunities for transformation. SMART (2019)[10] characterised developments at three levels of the European agrifood industry (see Text box 1), targeting three themes of problem resolution, a variety of technologies brought bear, and support for CSB's strategic subdivision between engineering, networking and customer relations.

[10] SMART is the 'Centre for Sustainable Manufacturing and Recycling Technologies (SMART) and the Internet of Food Things (IoFT) Network Plus'

Klerkx et al. (2019, in review), Australian Farm Institute (2016), Banhazi et al. (2011) and Perrett et al. (2017) identified a shortage of empirical analysis of the financial benefits of digitally enabled agriculture at the enterprise level, and also a shortage of available and widely applicable methods. Indeed, Rojo-Gimeno et al. (2019) referred to the relationship between the adoption of digital technology and value creation (presumably via the new business models referred to by Schallmo (2016)) as a "black box". These comments reflect a lack of suitable farm-level or firm-level data and analytic methods, and a corresponding lack of a robust counter-factual for analysis. Lack of a "value proposition for change" (Leonard et al., 2017) and the absence of "detail of the costs and benefits" (Griffith et al., 2013) are seen as barriers to the uptake of digital technologies at the farm level in Australia. Inability to conceptualise the post-transformation business model for the purposes of investment analysis is clearly a part of this problem. Griffith et al. (2013) pointed to lack of maturity of software and services in agricultural uses, and those authors' industry consultation identified localised absence of maintenance and spare parts, and of specialist advice, as a barrier to investment. Some software and applications for agriculture require substantial data over significant time periods to generate predictive results (Sykuta, 2016), which introduces delays between cost and return, and limits sustained interest.

Perrett et al. (2017) estimated the size of benefits available from use of digital technologies in decision making in Australian agriculture (including forestry and fisheries) at $20 billion, with spill-over impacts in the broader economy projected to generate an additional $5 billion.[11] Major components include automation and labour savings, genetic gains due to objective measurement, tailoring of inputs to need, and market access and biosecurity. These authors project significant changes occurring beyond farming and into Australia's food supply chain, generating further benefits.

3.4. Benefits available to the chicken meat sector from adoption of digital technologies

For the Australian chicken meat sector, Perrett et al. (2017)[12] projected impacts of digital technologies and associated enhanced decision making in five "practice" areas (animal health monitoring, nutrition management, shed monitoring, labour and product marketing). At the farm level, these impacts of precision agriculture are generally in line with those identified by Hartung et al. (2017) for EU broiler producers. Perrett et al. also discussed gains from improvements in traceability and biosecurity, although the benefits are not estimated.

Table 3-1. Projected benefits available to chicken meat production from adoption of digitally related decision processes

Practice	Amount ($m)		Actions	Mechanism
	Production stage	Processing stage		
Animal health monitoring	9.2	97.6	Remote sensing + decision support tools	Improved productivity
Nutrition management	9.7	81.3	Nutrition targeting, less wastage	Reduced feed costs
Shed monitoring	4.9	53.1	Automation of shed monitoring	Reduced labour costs
Labour	5.8	63.7	Automation, robotics, inline record keeping	Reduced labour costs
Product marketing	15.4	162.6	Enhanced information flow to consumers	Improved productivity
Traceability food safety	Not modelled		Digital traceability and provenance systems	
Biosecurity monitoring	Not modelled		Industry-wide digital monitoring platforms	

Source: Perrett et al. (2017)

[11] Results from CIE's computable general equilibrium model (see Perrett et al., 2017: appendix 1 and 2)
[12] See also Heath (2018)

These estimates are in part informed by the potential gains available from the alleviation of existing constraints on productivity. These were estimated in four categories: data, analytics, connectivity and trust. Seventeen commodity sectors were scored for their capacity to benefit in each category. Aside from forest products, chicken meat scored the lowest in potential gains from data, meaning that data availability is seen as a minor constraint and so a minor determinant of gains from digitally related transformation. Analytics, however, were viewed as a significant constraint (8th of 17). Connectivity was not viewed as a major constraint, notwithstanding indications of significant problems at a regional level (Hewson, 2017). For trust, although chicken meat showed among the lowest potential for gain, the analysis still estimated that 67% of productivity gains in the sector would be affected by trust issues.

A crucial aspect of data-driven change is the attachment of value to data, and the accumulation of value as data is enriched by analysis and availability. Wiseman and Sanderson (2019) call data “an asset which must be managed like any other”. Its value may well be recognised but not realised. One abiding indicator of value is the extent to which a farmer is rewarded for provision of data. Direct observations on this process are rare: HIMARKIT Ceas (2017) reported that in a number of European countries, chicken producers are paid a price premium for provision of (positive) objective animal welfare information (foodpad scores), and Denmark’s Danpo rewards producers for provision of flock performance data. Although traceability-related information provision is widespread in agriculture and food, this occasions market access/exclusion conditions rather than price premia for data provision per se.

Text box 1. UK study on mechanisms for delivery of digital benefits to the food industry

UK work by the Centre for Sustainable Manufacturing and Recycling Technologies (SMART) and the Internet of Food Things (IoFT) Network Plus (2019) focuses on three mechanisms for delivery of the benefits of digital transformation in the food industry. Their approach entails three mechanisms for delivery of additional value ("lenses") through which additional value is delivered, with examples and anticipated barriers to adoption.

Lens	Rationale and technological base	Example provided	Barriers to adoption
Real time resource-efficient production	Sensors, image recognition, connectivity via IoT Using all these to enable automation	Advanced automated meat processing system 	Lack of skills Cost and complexity of integrating tools with existing systems The need to digitise data Inappropriate decision models on adoption
A resilient and productive food supply chain	Data is accessed, processed and used more quickly Data is shared more efficiently	Satellite tracking of asparagus crop performance, product transport and product condition during shipping by sensors, RFID and satellite communication 	Data security Robustness of agreements on data sharing Data standards and governance
Digital technologies to engage the consumer	Mobile app Waste reduction Supply chain co-ordination Machine learning, advanced analytics	GOUSTO App for customised online grocery orders, delivered in boxes 	Fear of non-compliance with food safety regulation (firms and consumers)

Source: Centre for Sustainable Manufacturing and Recycling Technologies (SMART) and the Internet of Food Things (IoFT) Network Plus (2019)

Leonard et al. (2017) is cited above as calling for objective analysis of the value proposition, effectively the analysis of return on investment in firm-specific aspects of digital transformation in Australian agriculture, including provision of data. Pitkin (2017) reflected that in the chicken meat sector, there is substantial variation among farms and farmers, the forms of contract signed, and the levels of awareness of off-farm developments related to innovations such as digital transformation. There is also diversity along the supply chain, and between firms and farms at the same stage of the supply chain. These differences include, but are not limited to, variables such as the age of productive assets; the willingness of managers to change; skill types and levels; the starting point for, past history of, and maturity with digital adoption and/or transformation; and the size of the enterprise and its ownership structure. Beyond the firm, there is substantial diversity in the markets served, the kinds of collaboration in place, and the rewards for innovation. Pooling of prices is given as one example, and Pitkin calls for reward structures rather than blends of rewards and penalties, so as to foster innovation rather than defensive behaviour. External influences such as real estate values are another example, where land prices influence investment levels on chicken meat farms.

Notwithstanding earlier comments about labour productivity and the potential labour cost saving offered by digital transformation, skills as a barrier to digital transformation (CSB, 2020; Darnell et al., 2018; Perrett et al., 2017) is substantially understood in the chicken meat industry. Chicken meat industry commentary is that Certificate III and Certificate IV poultry work qualifications reveal no competency requirement with digital tools, nor in data collection to any specified standard. An inventory of VET agriculture-related training by KPMG and Skills Impact (2019) acknowledged that the strongly contextual nature of training design makes digitally relevant content difficult to identify, but these are rarely present, especially at Certificate III level. That study identified four primary industry sectors[13] for which VET courses emphasising digital skills are offered. It also reported low completion rates and some lack of persistence in the industry by students, which reduces firms' and industries' incentive to invest in training.

In posing questions about change and strategy for change, the central question most frequently encountered is "which change will make the firm or farm the most money?" Hence, analysis to identify such instruments of change as "key data" and "key technologies" is of limited use without the contextual elements of farms and firms' diverse capacities to both benefit from and pay for digital transformation. Such capacities are also affected by the transaction arrangements between stages of the supply chain, by likely flows of information among business at all levels, and by the potential for misuse of information by forces beyond the chicken meat supply chain.

[13] Agricultural and horticultural conservation and land management; seafood industry; meat processing; forest and wood products.

4. Projections of industry-level benefits of uptake of digital technologies along the Australian chicken meat supply chain

4.1. EDM purpose and method

We employ an equilibrium displacement model (EDM, Piggott, 1992) to project the benefits of selected changes in the chicken meat supply chain, as received by producers, processors, retailers and consumers. We specify aspects of digital transformation in terms of their effects on supply and demand, and compare projections of their impacts on the different stages of the supply chain.

An EDM is a 'structural' economic model that identifies price and quantity differences that occur due to disturbances or developments in supply and/or demand conditions. Industries are represented by a system of demand and supply relationships moderated by price response elasticities,[14] price transmission relationships and market clearing conditions, and they are calibrated with historical data on prices and quantities. Benefits are measured as changes 'producer surplus' and 'consumer surplus', which are analogous to the net benefit or cost to the industry from the change. An EDM is partial equilibrium in nature, which means that it does not capture changes throughout the economy as is the case for computable general equilibrium models as used in the Perrett et al. (2017) study. However, EDMs offer the advantage of providing results that are disaggregated along the product supply chain (including benefits generated for consumers through price and quantity adjustments), and are simpler and less demanding of input data than other models.[15]

The baseline for the EDM's application in chicken meat (Table 4-1) was assembled from aggregate data on farm-level production and retail consumption of chicken. Free range and other non-conventional production and consumption was subtracted from the aggregate numbers. The anatomy of costs and prices at each stage of the supply chain was established from IBISWorld (2020) cost estimations and consultation with industry specialists. An issue requiring special treatment in the model specification is producer cost, some large proportion of which is effectively paid by processors, including feed, day-old chicks and certain services. This specification required adjustments to both producer price and cost in the baseline. The critical modelling task is to ensure consistent treatment of the variables during model runs, rather than to have precisely accurate numbers for baseline data. This is to say that the change in values and the distribution of benefits among industry sectors are the key model outputs.

[14] See Annex 3 for a list of statistically generated candidate elasticity values.
[15] EDMs have been developed in relation to a number of Australian agricultural sectors, including cattle and beef (Zhao et al. 2001a, 2001b, 2003), sheep and wool (Mounter et al. 2008a, 2008b, 2009), pigs (Mounter et al. 2005a, 2005b) and dairy (Hill et al. 2001).

4.2. EDM data and specification

Table 4-1. EDM base equilibrium prices, quantities and revenue, and cost shares for chicken meat

Supply chain stage	Quantity and price (carcase weight equivalent tonnes; $/kg), total Value of sales ($m)	Cost shares
Final chicken meat products	X_5 = 847.39 kt P_5 = $6.02 TV_5 = 5,101.29	Chicken meat cost share = 0.59 Other processing inputs cost share = 0.41
Processing chicken meat	X_5 = 847.39 kt P_5 = $3.58 TV_5 = $3,033.66	Chicken meat cost share = 0.59 Other processing inputs cost share = 0.41
Farm production chicken meat	X_3 = 847.39kt P_3 = $2.119 TV_3 = $1,795.62	Producer cost share = 0.26 Processor cost share = 0.74
Producer inputs chicken meat production	X_1 = 847.39kt P_1 = $0.549 TV_3 = $465.22	
Processor inputs chicken meat production	X_2 = 847.39kt P_2 = $1.570 TV_3 = $1330.40	

Table 4-2. Elasticity values used in EDM

Elasticity	Notation	Value	Explanation
Own price elasticity of supply of producer inputs to chicken meat production	ipx1	2.0	Producer response to price changes (a 2% increase in inputs (such as labour) supplied in response to a 1% increase in price)
Own price elasticity of supply of processor inputs to chicken meat production	ipx2	1.0	Processor response to changes in prices paid by retailers, in terms of production inputs supplied (feed and day-old chicks)
Own price elasticity of demand for chicken meat	itx7	-0.5	Consumer Purchasing response to changes in the retail price
Other input supply elasticities		2.0	Input Supplier response to changes in prices paid by producers
Input substitution elasticities		0.1	Extent to which inputs (for example chicken for other protein at retail level; feed and labour at production level) can be substituted in response to price changes

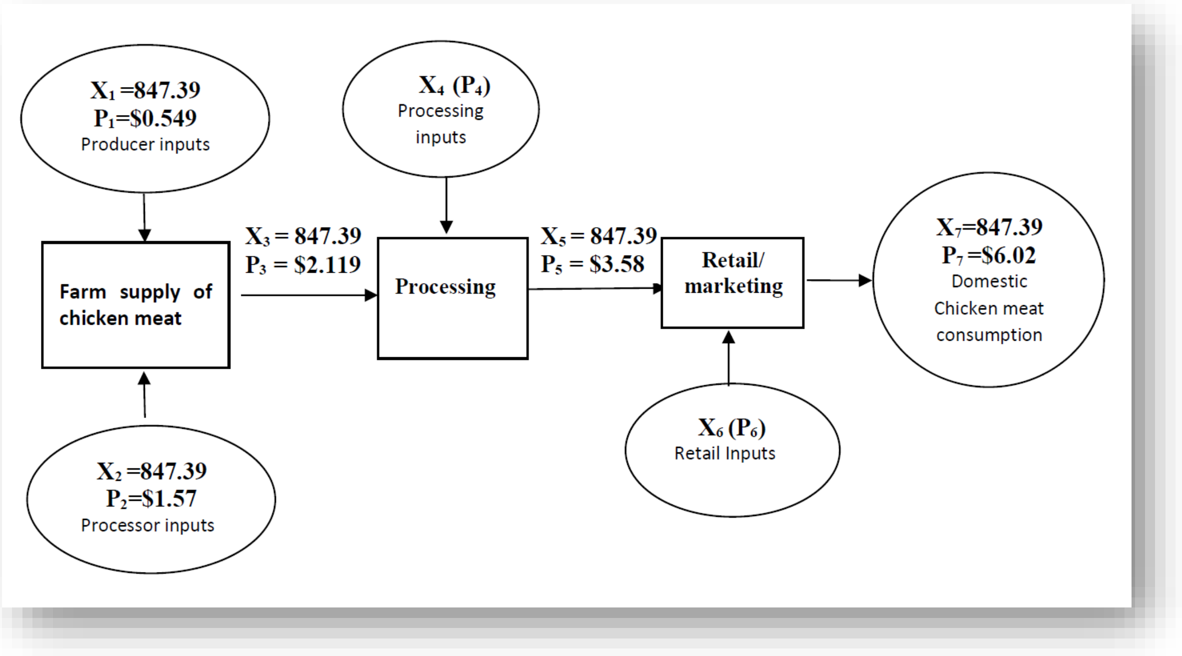


Figure 4-1. Schematic of EDM applied to Australian conventional chicken meat supply chain

4.3. EDM scenarios

Scenarios examined with the EDM (Table 4-3) target elements of management practice as addressed by Perret et al. (2017) to include reduced labour costs (at each of farm and processing level), feed cost reduction, increases in productivity (at each of farm and processing level), and successful promotion to consumers which alters demand behaviour.

Table 4-3. EDM scenario specifications

	Scenario	Rationale	Details of scenario specification
1	10% reduction in labour cost at farm level	Associated with automation, or reorganisation to reduce labour input to certain time-consuming tasks.	Total conventional production costs = \$2.119/kg. Wages = 10% = \$0.21/kg 10% reduction in labour cost = \$0.021/kg Producer cost = \$0.549/kg (0.021/0.549) * 100 = 3.8% vertical supply curve shift = 0.038
2	10% reduction in labour cost at processing level	This might be associated with automation, or reorganisation to reduce labour input to certain time-consuming tasks.	Total processing costs = \$3.58 Wages = 15% = \$0.537/kg 10% reduction in labour cost = \$0.0537/kg Other inputs cost = \$3.58 – \$2.119 = \$1.461/kg (0.0537/1.461) * 100 = 3.68% vertical supply curve shift = 0.0368
3	5% reduction in feed costs	Better targeted nutrition and less wastage of feed. Feed costs account for around 60% of total costs.	Total conventional production costs = \$2.119/kg. Feed = 60% = \$1.27/kg 5% reduction if feed costs = \$0.0636/kg Processor production cost = \$1.57 (0.0636/1.57) * 100 = 4.05% vertical supply curve shift = 0.0405
4	5% increase in productivity at production level	5% increase in farm productivity A 5% shift in Q-intercept of Farm Supply curve.	K = the vertical supply shift J = the horizontal supply shift ε = the elasticity of supply With ε = 1, K = J
5	5% increase in productivity at processing level	5% increase in processing productivity. A 5% shift in Q-intercept of Processing Supply curve.	K = the vertical supply shift J = the horizontal supply shift ε = the elasticity of supply With ε = 1, K = J
6	Better communication of product quality/new products to the consumer	A 1% increase in consumer demand, implemented as a 1% rightward shift in the Consumer Demand curve.	

4.4. Discussion of EDM results

Figure 4-2 presents results from the scenarios. A number of elements of the results agree with the general equilibrium analysis presented in Perrett et al. (2017): the size of benefits generated by equivalent-sized changes in productivity; and the relatively small proportion of benefits accruing to producers. A general comment on the EDM results is that the overwhelming share of benefits accrue to consumers; this reinforces earlier comments on the industry's sustained success in delivering consumer value in the context of constantly declining costs. It is also notable that projected benefits from reductions in farm-level labour costs are somewhat localised to producers, with lower overall benefits throughout the chicken meat supply chain than appears for other scenarios.

A 5% change in farm productivity (scenario 4) generates the largest overall benefit of the scenarios examined, and also the greatest benefit to each of producers and processors. Comparison of scenarios should proceed with caution as the sizes and practical details of the scenarios are quite different, but scenarios 3, 4 and 5 all entail productivity change. Interpretation of this result features the likely cost and difficulty associated with achieving such change, and this also relates to the potential and cost associated with individual farms and contracts. The industry has been successful in achieving sustained increases in farm productivity, and a notable result is that this continues to be a high-return activity, with projected benefits higher than, for example, improving processing productivity.

Notwithstanding data presented in section 1 of this report depicting a decline in value added per labour unit in chicken production, the benefits to the whole industry available from purely defined reductions in farm labour costs (scenario 1) are relatively low. However, the benefit generated to producers is higher than most of the other scenarios, second only to the closely related improvement in overall farm productivity (scenario 4). This result provides evidence of supply 'chain failure' (Mounter et al., 2016) in incentives for change in the industry, in that benefits accruing to one actor in the supply chain may follow different patterns to the benefits to the industry as a whole. More specifically, saving on labour cost at the farm level by way of automation will need to demonstrate other benefits (such as generation of data to the supply chain) to justify investment from beyond the production stage.

Processing automation to reduce labour costs (scenario 2) generates somewhat low relative returns to processors, due to the somewhat low share of costs that labour occupies relative to bird hatching, feed and other costs such as compliance. It is notable that labour cost savings at the processing level also generate benefits to producers and retailers, ostensibly at no cost to them. This provides some degree of incentive compatibility in design of change which establishes production and delivery procedures to facilitate automation in processing. It is notable that changes in chicken processing productivity (scenario 5) generate less benefit to producers and processors than do smaller % changes in farm productivity (scenarios 3 and 4). However, consumers consistently receive a significant share of benefits generated.

Scenario 6 portrays a small shift in consumer demand. This is ostensibly generated by supply of product information (telling a story, in terms of credence attributes) in the form of enhanced traceability or information about quality. It generates larger benefits to producers and processors than do the relatively large and difficult-to-achieve changes in labour costs at processing (scenario 2) and production (scenario 3) stages. Given that consumer demand for chicken meat is forecast to increase by some 2% per year for the foreseeable future, the capture of an increased share, of that increase, is a reasonable goal for individual processing firms.

These results are presented in a one-at-a-time context, which abstracts from the reality that all the scenarios' changes could be implemented together. The industries' multiple initiatives in improvement no doubt do this, and variation among farms, contracts, markets and individual years' challenges do require this. However, different returns are seen to be available on average, and when interpreted in terms of digital transformation these provide useful input to strategy.

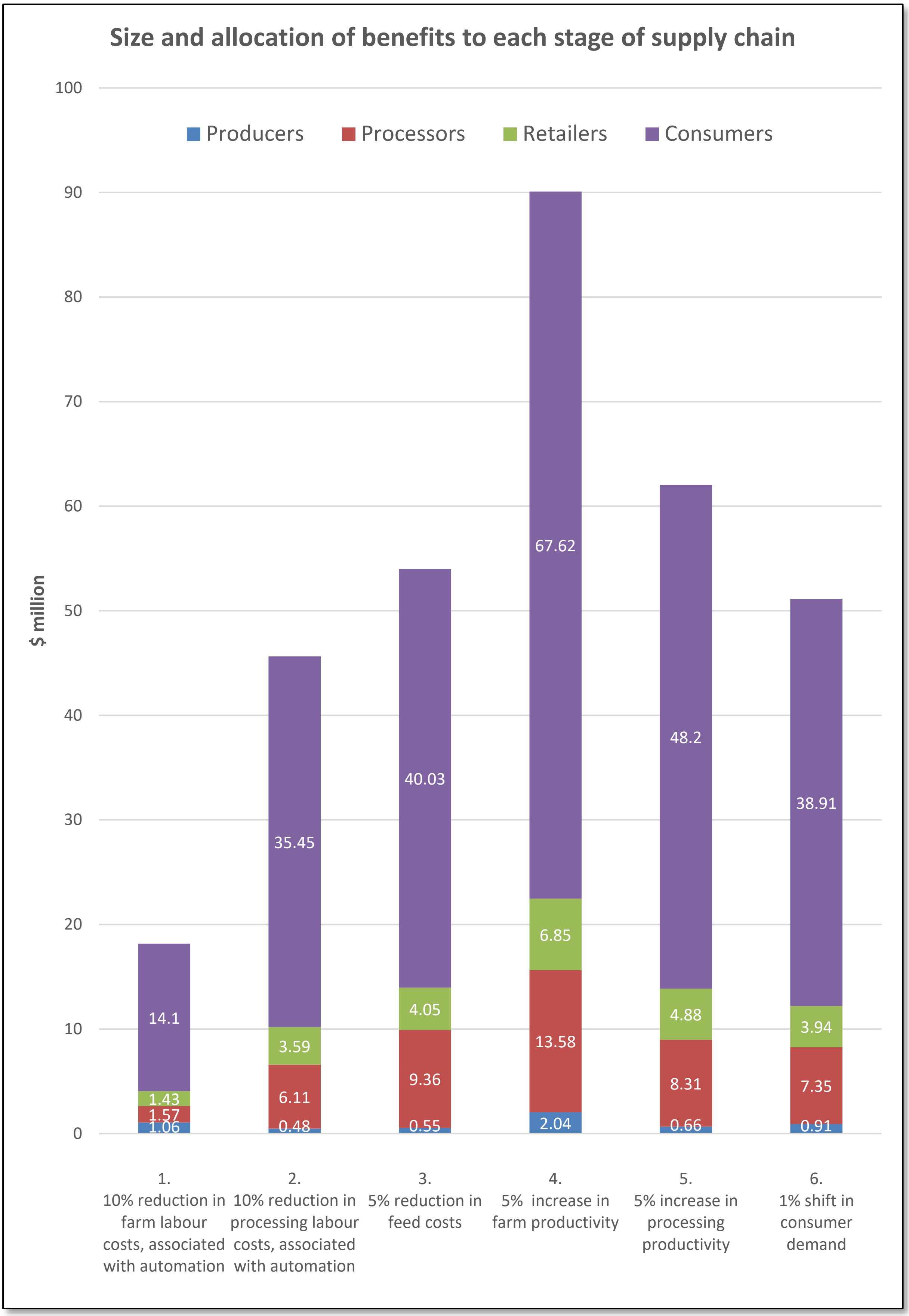


Figure 4-2. EDM results

5. Data exchange in advancing digital transformation

5.1. A supply chain for agricultural data

Leonard et al. (2014), Australian Farm Institute (2016) and Wolfert et al. (2017) identified "data supply chain" structures, and associated business models, as moderators of the progress and impact of digital transformation in agriculture. In discussing Big Data, various authors discuss developments where value is added to data in terms of management information. A "stakeholder landscape" (Wolfert et al., 2017) or "farm data ecosystem" (Australian Farm Institute, 2016) connects data collection at the farm level with use by other supply chain actors. Wolfert et al. suggested that the componentry of this data supply chain will dictate which business model will prevail in the use of data; its two extremes being "closed proprietary systems" and "open collaborative systems", with a number of intermediary outcomes associated with different networking options and the market conditions prevailing for the data itself and associated services. Associated with this data supply chain, Banhazi et al. (2011) advocate the development of services as a means of commercialisation of precision agriculture technologies. These authors see this as the basis for a "new service industry" which would develop new products on an organised and "professionally managed" basis. Envisaged support to this development includes whole-of-industry, government, or research organisations' participation in co-ordination.

5.2. Platforms as a delivery mechanism for digital transformation

Australian Farm Institute (2016) described an ongoing transition in US crop-based agriculture away from proprietary and in-house systems (centred on brands of machinery and their data collection systems) towards open data protocols that allow data aggregation and the development of a market for data and associated services that use inter-operability of data by way of platforms. The data supply chain elements of which are collection (at farm), collation and curation, processing for management use, and mobilisation of specialised management software. Darnell et al. (2018) identified four types of platforms, and described their levels of complexity and functionality. In the first ("aggregated views of information"), data visualisation is provided, but not interpretation. In the second ("mobile apps"), multiple sources of data are accessed, and analysis and synthesis targets specified problems and uses. The third ("federated analysis platforms") uses multiple data sources, including the Internet of Things and other real-time updated sources. Sophisticated analysis is made available, and data flows and uses lend themselves to machine learning. The fourth is a "pure platform", which serves a diverse community of users essentially by providing "software infrastructure". Users of the platform operate a "two-sided market" within which service sellers seek service buyers, and the platform's data is an asset that is used to provide the service. Services might extend to dedicated analysis and business advice on a consultancy basis, or development of apps that continuously draw on data and provide saleable services to whomever pays for the app.

Darnell et al. (2018) addressed the obvious gap between platform-oriented development and the current reality in Australian agriculture. Key tasks are defined as the management of cross-sectoral data assets, the mobilisation of analysis-ready data for predictive analysis, and the development of platform mechanisms for data delivery. Although simpler, and wholly within-firm, versions of platforms may be funded as finite projects, the development of pure platforms is seen to be time-consuming and expensive. It also lacks the elusive proven business model referred to widely above. Darnell et al. identified an "industry good", in the nature of data-based service provision by industry-owned Meat Standards Australia (Fleming et al., 2015), requiring a policy intervention, and unanimous and comprehensive industry commitment, to initiate.

Digital transformation in poultry faces alternative routes and strategies akin to those outlined above in that models for data sharing and collaborative digital development are likely to fall into three categories. Single-firm models, which to some extent retreat from data sharing, may appeal to some. Whole-of-chain models, which operate proprietary systems based on existing supply chain integration, as predicted by Leonard et al. (2017), may appeal to others (see Textbox 2 for a Danish example). Embrace of a broader market-based multiple stakeholder model in the form of "platforms" represents a third choice.

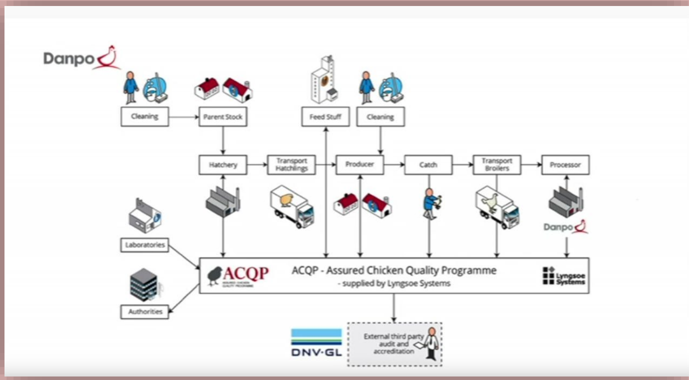
Within firms in Australia's chicken meat industry we find few individuals or groups akin to those portrayed in the MIT survey above, being skilled and motivated toward digital technology uptake and development. Conversely, few IT and technology specialists display a knowledge of the chicken meat production systems, supply chains and consumer markets. Meanwhile a small number of foreign-based specialised food industry technology providers offer a product and service range, which has to date been adopted by rather few firms around the world as an end-to-end system. A logical conclusion is that responsibility for production, input supply, processing, marketing and distribution will not necessarily change hands or become subservient to a central provider of technology, but rather will persist in being a chain of partners with appropriate and different skills.[16] This piecemeal approach, in some way united and directed by the power of digital, lends itself to platform development and data exchange.

[16] Thanks are due to Kristof Mehrtens of Porphyrio and David Speller of Optifarm UK for this insight.

Text box 2. Assured Chicken Quality Programme (ACQP) used by Danish chicken meat company Danpo, implemented by Lyngsoe Systems, Denmark.

ACQS is a comprehensive end-to-end data platform first developed in the early 2000s.

Its goal was to provide “the world’s best-documented chicken” and started out as a whole-of-industry collaborative program but is now an individual program for processor Danpo.

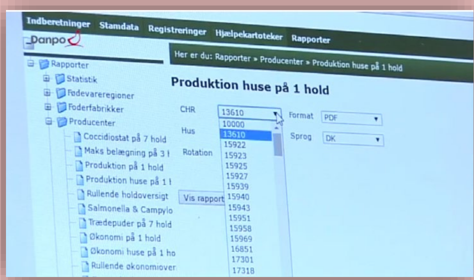


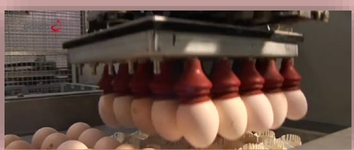
Client entering data into the systems include:

- 125 producers supplying one processing plant
- 20 feedmills
- One hatchery
- Test labs for *Salmonella* and *Campylobacter*

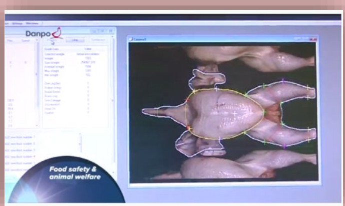
In addition, other users extract data from the system:

- Veterinarians
- Service companies
- Auditors
- Government food authorities
- Third-party consultants





Hatchery information accompanies chickens into production, and shed systems record and enter shed data (environment, weights, feed and water use) and slaughter information (weights, footpad scores). Full traceability is maintained through processing and delivery. Data ownership is held by the party entering the data, and producers may choose to restrict access to financial information.



The system provides a variety of producer reports and is also available for third-party consultants to extract and analyse clients’ data on a service basis.

Other developments include banks’ use of ACQP reports for due diligence on lending, tracing of potential genetic problems throughout the national flock, replacement of farm visits by retailer and animal health and welfare audit personnel.

5.3. Data ownership, access and trust

Dyer (2016) reported that farmers exhibit a range of degrees of concern about the use of their data: from indifference, to avarice, concerning anyone else benefiting from it. These attitudes span a range of actual and potential data users (Antle et al., 2015). The family farm-related perceptions of farming blur distinctions between private household information and the commercial records of businesses or technical information associated with industrial process (Sykuta, 2016). Wiseman and Sanderson (2018) cited a European Union approach that delineates "farm data" from "farmer data".

Digital transformation's emphasis on availability and useability of data within the supply chain raises concerns over underlying assumptions about the frameworks within which data is collected, made available and used in agriculture. Li and Ngugen (2017) summarised the incentives and requirements for data sharing within transaction environments, which implicate aspects of the product market, of the interests of all sharing parties, intellectual property rights, and a host of elements of overall supply chain collaboration strategy. Australian Farm Institute (2016) presented principles followed in several countries with advanced agricultural economies, particularly noting that data belongs to "the owner of the land or livestock" on which it is collected; and further identified a need for policy assistance in definition of data ownership in share farming or contracted farming.

The value of farm data is assumed, but seemingly not measured. Australian Farm Institute (2016) identified few cases where farmers are paid for data provision, and suggested that market developments towards standardisation and aggregation of data select against this. They cited examples of Australian producers' sharing of data with supply chain actors and service providers for some mutual benefit. In one, data on management of horticultural crops is supplied to buyers and used to quantify risks and aspects of insurance coverage (Hortus, 2016). Best farm-level practice in a more general sense is also cited for supermarkets providing suppliers' production information (Sedex, 2015; see Text box 3). Although the impact to a user of agricultural data of acquiring one additional farmer's data may be small, Sykuta (2016) pointed out that the proportional increase in is rather larger than that of a single additional customer for the massive operators such as Google or Facebook. Shared farmers' ownership of data, on a co-operative ownership basis, has also been attempted (Berti and Mulligan, 2016; Levand Stephenson, 2011) and shown some benefits in generating economies of scale and countervailing market power for input sourcing and supply chain management.

As a nominal reward, Pierce et al. (2019) advocated crediting of data providers, which in a research context entails citations and referencing, but falls short in terms of commercial incentives for data sharing. Wolfert et al. (2017) pointed out that farmers benefit in many ways from data sharing and by using technologies empowered by data, but Wiseman et al. (2019) found that Australian farmers have "mixed feelings" about it, particularly where agreements and licencing arrangements involve complex property rights issues and undertakings. They examined farmers' data-sharing preferences associated with precision agriculture and digital technologies, and reported on a survey of 1000 farmers across 17 commodity groups, in this regard. The survey addressed several aspects of data sharing, and asked firms to rate their level of comfort for each:

- Knowledge of the terms and conditions of data sharing: poultry farmers (eggs and meat) ranked among the highest in this regard but still scored 2.1 out of a possible 5.0 for "level of comfort".
- Service or technology providers having access to data: poultry farmers had the lowest comfort level, scoring 2.2/5.0
- Service or technology providers using client data to make a profit: poultry farmers had the lowest level of comfort, scoring 1.7/5.0
- Comfort around maintaining privacy: poultry farmers had the lowest level of comfort, scoring 1.7/5.0
- Trust in service providers not sharing data: poultry farmers had the lowest level of comfort, scoring 1.8/5.0

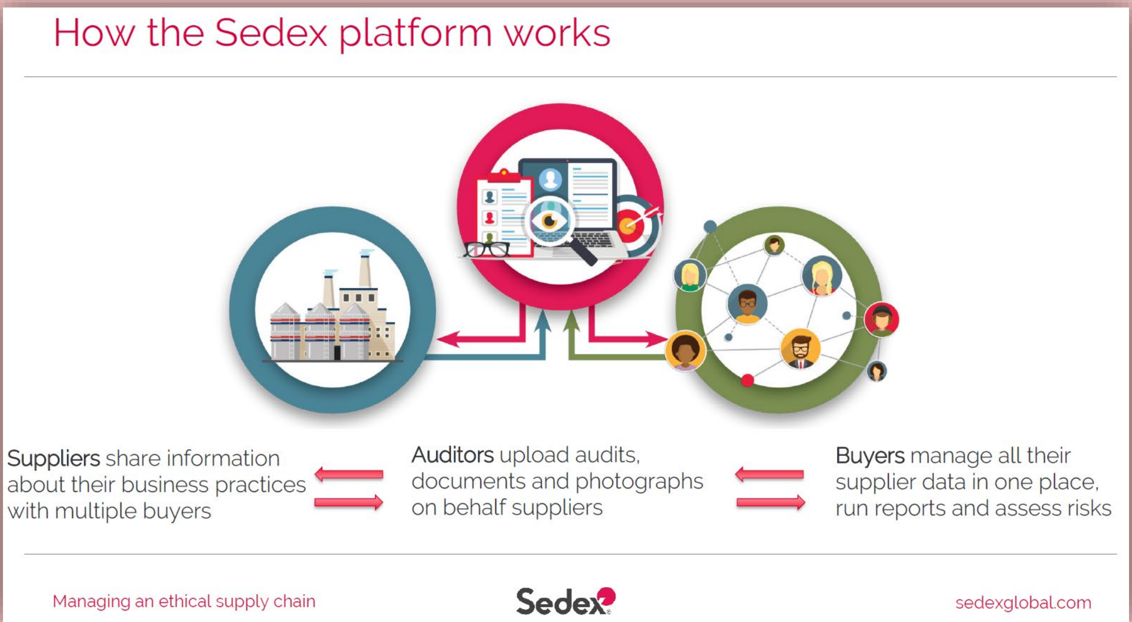
Identified legal aspects of agricultural data ownership in Australia centre on privacy and confidentiality (Cho, 2018), and from a commercial point of view, “trade secrets” (Australian Farm Institute, 2016). Trade secrets ostensibly refer to intellectual property that generates competitive advantage, which in farming systems are difficult to protect. Some of these concerns are addressed in the National Farmers’ Federation (2020) Farm Data Code. Sanderson et al. (2018) compared more advanced scenarios for data governance, in comparing national-level Codes of Practice for agricultural data in New Zealand and the US. These both focus on “consent, disclosure, transparency and, ultimately, the building of trust” (p. 1). In both cases, upward communication to higher-level policy was emphasised by linkages to laws on business operation and privacy, while downward linkages enabled the use of a trademark by commercial firms certified according to the Code of Practice.

Such Codes of Practice have been advocated for Australia by Zhang et al. (2017). Recent work by Wiseman and Sanderson (2019) identified best practice in terms of a three-part Australian framework that seeks to foster trust: “Policies and procedures”, which addresses privacy and transparency; “Capacity and capability”, which centres on who owns and/or controls data and what should be with it; and “Risk, regulation and compliance”, which addresses laws on privacy and confidentiality, and their best application.

As part of CSIRO’s Data61 project, and dealing with a public sector data platform, Box et al. (2015) proposed a “data framework” based on an ISO standard. This specifies that data entering and being stored and used in a collaborative system be subject to standards of quality, interoperability among collaborators, harmonisation regarding formats and content, and efficiency in satisfying the needs of data users.

Text box 3. The Sedex platform

Sedex operates a platform and set of related services to enable transmission of information in the supply chain. Initially addressing ethics, sustainability and responsible sourcing, Sedex enables transmission of information about production methods and other credence attributes to assist in buyers' risk management.



Based in the UK, Sedex has been operating for 15 years and has 55,000 members operating as buyers and sellers along the supply chain. Members maintain a compliance checklist with Sedex, and these checklists are audited and provided to buyers.

In Austalia, Sedex operates across a range of industries. In the food industry, all the main supermarket chains are served, and supplier members are drawn from across the agricultural commodity spectrum. A suite of services are offered, from capacity building and technical elements of supply chain transparency and buyer engagement, through to data analytics.

6. Digital transformation in the Australian chicken meat industry: a report on industry consultations and a design workshop

6.1. Industry consultations

Messages emerging from early meetings with industry in August-December 2019 featured substantial enthusiasm for digital transformation. All firms agreed that there is a "power of digital", but firms differed in their self-assessment of the extent to which they were benefiting from it. Some expressed aspirations that were basic: a move away from paper-based data recording. Others were substantial: the sharing of all production data with producers. Most aspirations were focused on solving particular problems, such as eliminating particular delays or better meeting quality criteria.

Several processors expressed the view that a great deal of data was being collected, and the immediate opportunity was to use it better. In some cases this required conversion – essentially a step in digital transformation – from paper-based to digital data recording, or from facsimile or e-mail transmission of data to digital transfer mechanisms. Automation in collection was discussed in this regard, favouring objectivity and consistency of data and so greater scope for its use.

Firms stated varying levels of knowledge about available technologies, and expressed the wish to know more about such technologies. They also expressed concerns about implementation mechanisms for digital transformation involving the whole chicken meat supply chain. In particular, the extent to which processors can impose technology uptake and use on contracted producers. This refers both to a generalised requirement such as type of equipment, and more specifically to equipment brands and protocols. A related concern is the availability and quality of support to producers in maintaining equipment that may be a first or one-off installation for equipment suppliers.

Producers and processors recognise, and seek to preserve and enhance, the highly regarded husbandry skills among their staff, neither substituting them for some form of automated stockmanship nor retraining such staff as computer programmers. Rather, synergy among automation and human labour is anticipated as each specialises in its most effective and expensive-to-replace tasks, while the necessity of bringing digital skills into firms is recognised. Full time electronics and data management is not envisaged, but rather familiarity with data information systems: data collection (organisational, statistical, technical and electronic aspects); understanding of analytic tasks; and interpretation.

There is substantial uncertainty about the returns available to producers on investments and recurrent costs associated with technology purchase and use. In this connection, it is desirable that payback periods at the production level be synchronised with, or at least appropriate to, the length of production contracts (typically five years). The allocation of benefits of digital transformation along the supply chain was also discussed.

6.2. Design workshop

The project held a design workshop in November 2019 with the objective of answering a number of questions about digital transformation:

1. What does success look like in digital transformation of the chicken meat industry?
2. What is the key data in the supply chain and production system?
3. What are the key transformations needed to unleash the power of digital

4. What are the benefits and cost of change?
5. What are the next steps?

6.3. Measures of success

A 2030 date was proposed to industry representatives for the development of a vision for using digital in the industry. Desired functionalities included a platform-based interactions, real-time handling of data, and automated decisions. The desired impacts of success would ideally build on traditional industry strengths of cost and productivity, but would also include product price increases. Prediction and analytics, alongside the anticipated automation, would be strengthened by platform-related interactive decision making. In addition to conventional desires for financial sustainability, digital transformation is seen as a means of achieving and sustaining and achieving other performance measures such as social objectives and social licence.

Within firms, a dynamic environment is aspired to where internal structures and leadership develop to enable innovation. Efficiency of data processes is referred to in the desire that only that only the data that is to be used, will be collected.

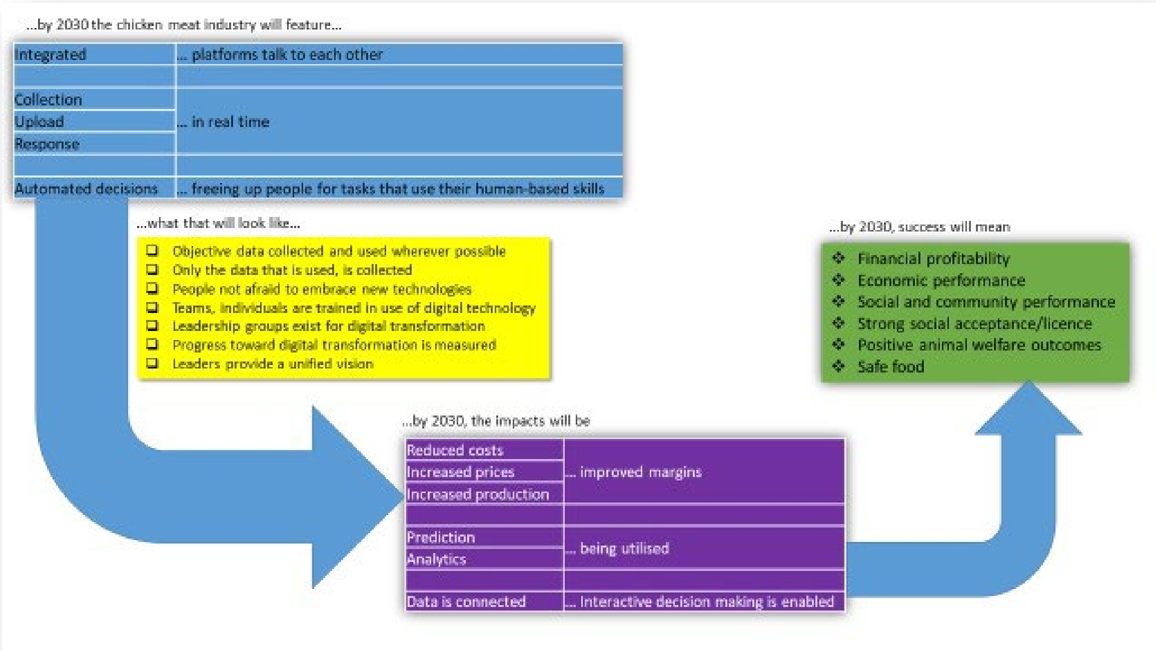


Figure 6-1. Workshop output: measures of success of digital transformation in the Australian chicken meat industry

6.4. Desired data

To operationalise the data functionality, and desired efficiency of use, the workshop generated a ‘digital twin’ documentation of key data, identified along the chicken meat supply chain. This exercise provided a data “wish list” (Figure 6-3), which maps key data to activities beyond the commercial supply chain.

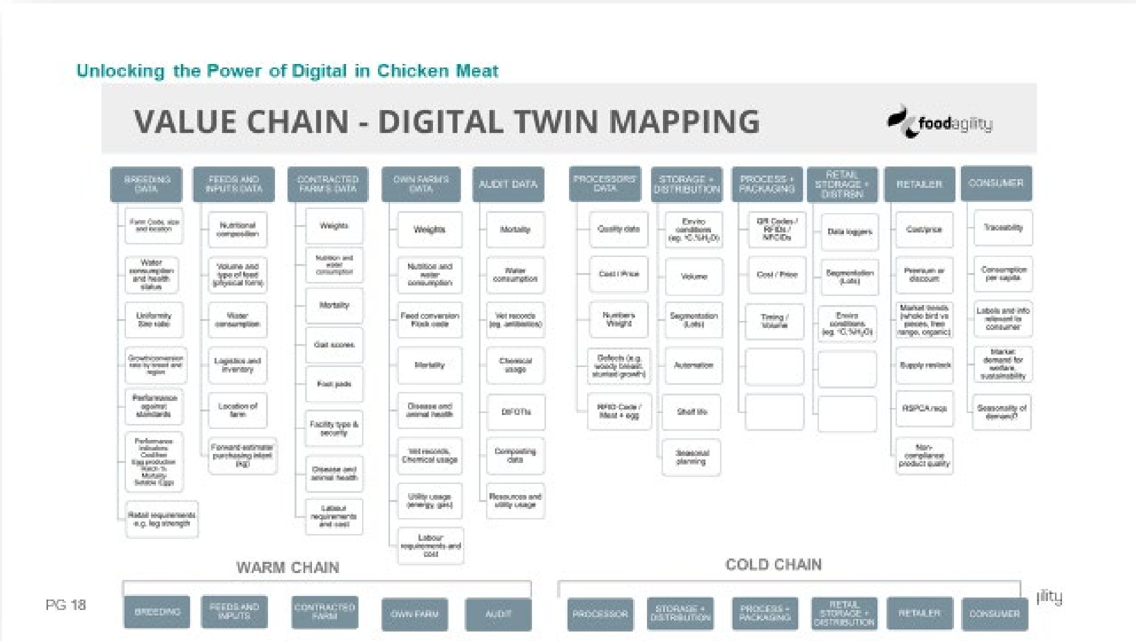


Figure 6-2. Workshop output: key data in relation to supply chain activities

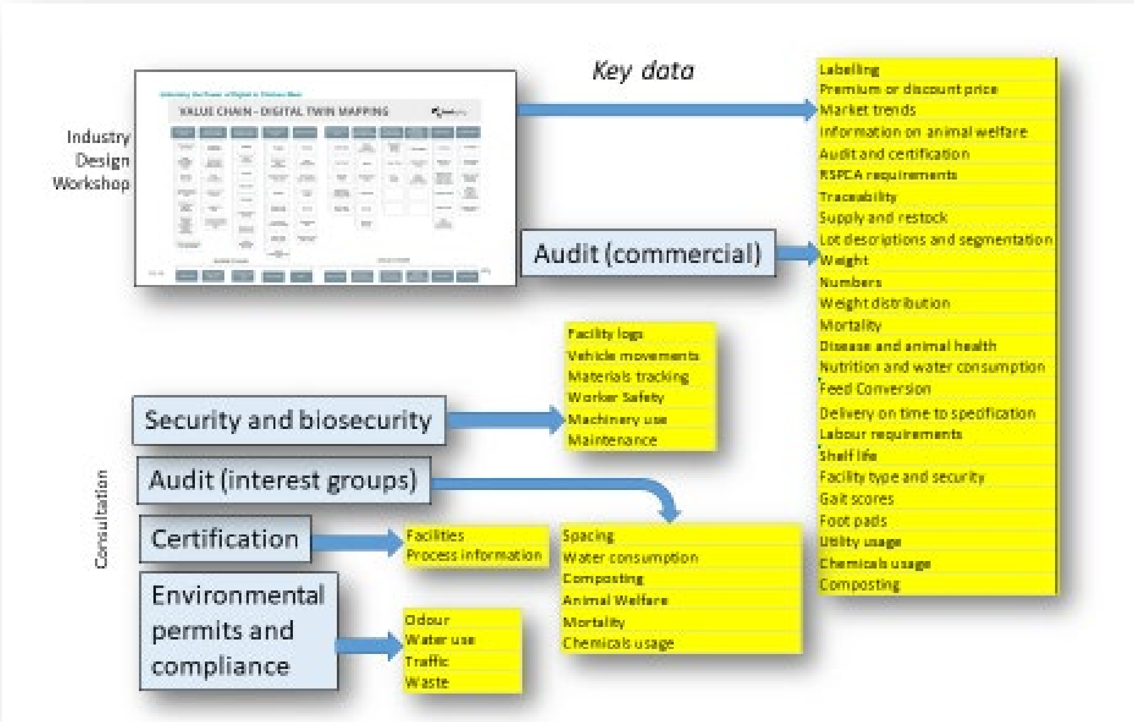


Figure 6-3. An industry data wish list

6.5. Developmental steps identified

The workshop identified steps to contribute to digital progress, including better use of existing technologies, deployment of new technologies, capacity building for staff and/or hiring of new staff, and the provision of rewards and incentives for employees to take risk to experiment and innovate. The link between innovation and digital transformation, particularly the enabling power of data and decision-ready analysis, had strong momentum coming out of the workshop.

The workshop advocated a gap analysis within firms, to identify which data is being collected manually, as opposed to digitally. This principle would also apply to desired data that is not currently being collected. Within each frm, this would contribute to the establishment of a central database, which would eliminate double-handling of data and provide a trusted and shared resource for analysis and decision making. On a similar theme as gap analysis, there was enthuasiam from the workshop about development of milestones for firms' managers' use in making progress on digital transformation.

Workshop participants were keen to implement simple pilots. This extends to plans for deployment of a simple and cheap sensor with which to monitor a small number of basic variables (temperature, humidity, certain gases), and which sends data wirelessly to a central database. Further ideas extended this database to the development of a data platform within each firm.

7. Contributions from the research literature about technologies associated with define key data

7.1. Literature search goal and method

A literature review was employed to capture as much information as possible about emerging technologies and their applications in chicken meat production.[17] A number of research databases were used (Table 7-2). Search criteria included English language, peer-reviewed, empirical studies published in the period 2005-2019. Exclusion criteria included review papers and literature reviews. Search strings used included structured lists of terms as shown in Table 7-1. These search strings reflect reading on likely terms differentiating digital transformation issues from scientific research on poultry science and management.

Table 7-1. Search terms used in the literature review

Search terms OR	Search terms AND
"Digital transformation"	AND
OR "industry 4.0"	(Poultry
OR "internet of things"	OR Broiler
OR technolog*	OR Chick*
OR digital*	OR Hatchery
OR "blockchain"	OR Hen)
OR "big data"	
OR "artificial intelligence"	
OR automat*	
OR robotic*	
OR "3D printing"	
OR "machine learning"	
OR "machine vision"	
OR "sensors"	
OR "augmented reality"	
OR "virtual reality"	
OR intelligen* OR "decision support"	
OR camera*	
OR "automated monitoring"	
OR "automated welfare"	
OR "biosensor"	
OR "image analysis"	
OR infrared thermal imag*	
OR "integrated management system"	
OR "intelligent farming"	
OR "noise analysis"	
OR "radio frequency identification"	
OR "sound analysis"	
OR "wireless"	

[17] Further information about the literature review methodology is available upon request.

Table 7-2. Research literature databases searched

Database	Date searched	References retrieved
ProQuest Business	13 November 2019	527
EBSCOHOST	14 November 2019	491
Scopus	14 November 2019	449
Web of science	14 November 2019	326
	Total	1793
	after removing duplicates	1687

This search process was supplemented by pursuit of a small number of references appearing in the ones retrieved. Inspection of papers proceeded by viewing of titles, abstracts and, in many cases, the entire publication to arrive at a total of 91 papers to be included in the review. A small number of studies featuring laying hens and turkeys were retained where technologies and management issues matched the search criteria and appeared applicable.

The resulting set of papers (see Annex 1) were examined using a questionnaire-type form recording in general categories the production or management topics addressed, the forms of technology being tested or employed, and the analytical advances relevant to digital transformation. Other data included the country where the research work took place and whether the research work took place in a commercial environment.

7.2. Literature search results

The literature reviewed came from 91 journal articles in 45 publications (see Table 7-3; and a listing of publications in Annex 1). Although a large number of publications yielded just one article, just a handful of publications (*Computers in Agriculture*, 33 articles; *Poultry Science*, 10; and a few others) produced almost half the material reviewed. These journals are leaders in the related fields of precision agriculture, data processing in agriculture, and poultry science. The literature is sourced from a large number of countries, with dominance from Belgium, the UK, the USA and China. Just one Australian study was yielded (Figure 7-2). Something of a peak in publication numbers is observed in 2013 and again in 2017 (Figure 7-1). Just 15 of the 91 studies were conducted under commercial chicken meat production conditions, with most of the remainder using laboratory or demonstration conditions; in a few cases, studies dealt with conceptual and analytical procedures.

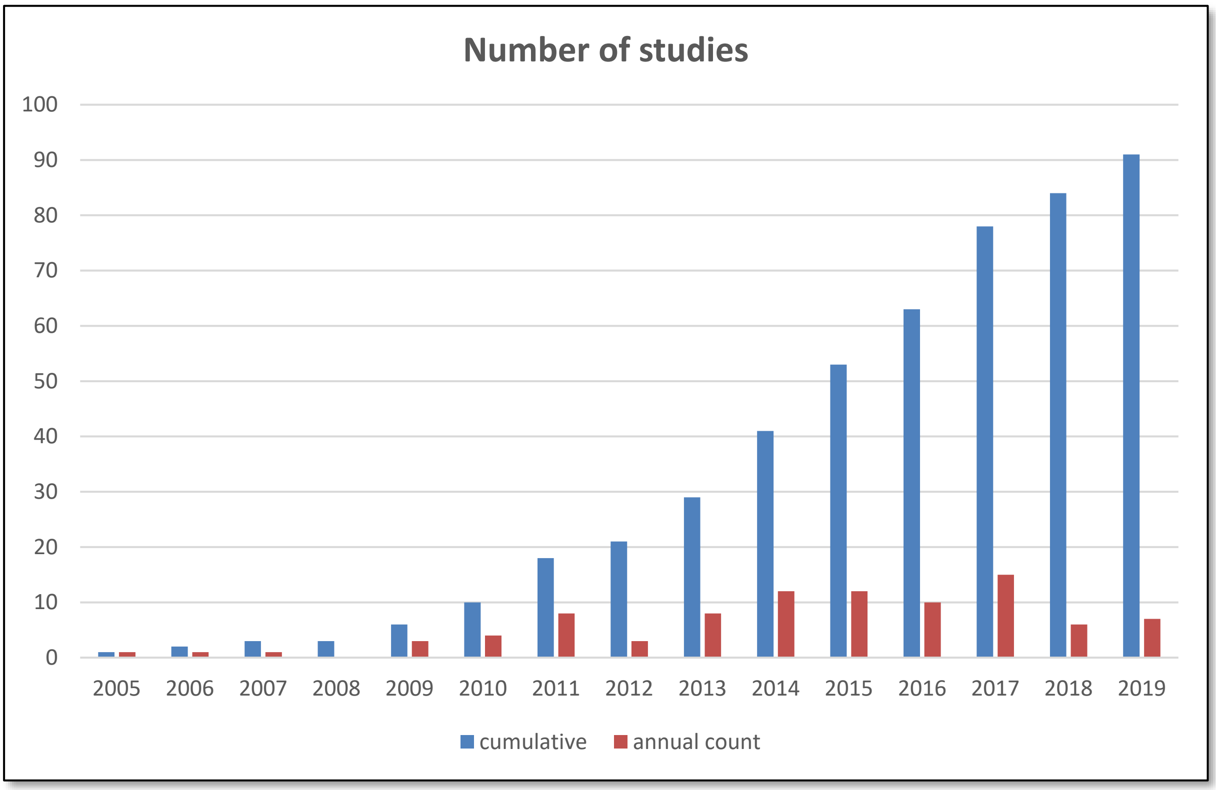


Figure 7-1. Pattern of published dates for reviewed material

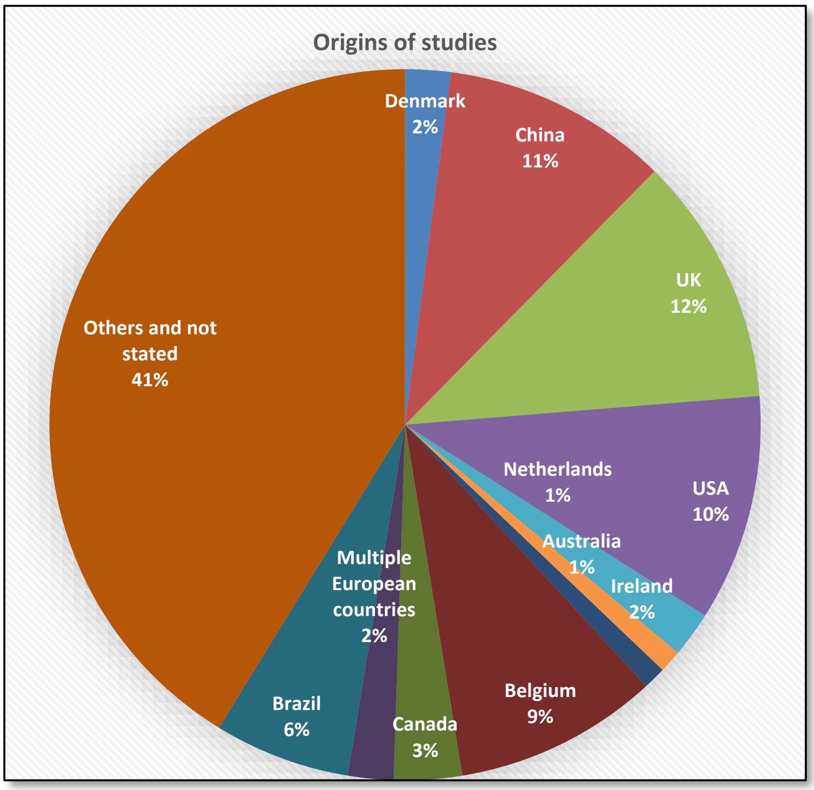


Figure 7-2. Countries of origin of reviewed literature

Table 7-3. Journals yielding material for the literature review

Publication	Frequency
Computers and Electronics in Agriculture	33
International Journal of Online Engineering	1
International Journal of Advanced Research in Computer Science	1
Wireless Personal Communications	1
Solar Energy	1
Journal of Agricultural & Environmental Ethics	1
IEEE Transactions on Biomedical Engineering	1
Neural Computing & Applications	1
Computer Standards & Interfaces	1
International Journal of Pattern Recognition & Artificial Intelligence	1
IEEE Control Systems	1
Journal of Animal Science	1
Journal of the Science of Food and Agriculture	1
Environmental Monitoring and Assessment	2
International Journal of Education and Management Engineering	1
Future Internet	1
Animal Behaviour	2
Poultry Science	10
Expert Systems with Applications	1
Packaging Technology and Science	1
Sensors	1
Infrared Physics & Technology	1
Food Chemistry	1
Precision Livestock Farming	1
Animal	1
Journal of Applied Poultry Research	1
Nongye Gongcheng Xuebao/Transactions of the Chinese Society of Agricultural Engineering	1
American Society of Agricultural and Biological Engineers Annual International Meeting	1
International Journal of Control and Automation	1
Proceedings IEE Industrial Electronics Society	2
Biosystems Engineering	1
Food Science and Technology	1
Hyperspectral Imaging and Practical Applications	1
Emerging Technologies in Meat Processing: Production, Processing and Technology	1
International Journal of Scientific Research	1
Control Theory and Informatics	1
International Conference on Enterprise Information Systems	1
Monatshefte fur Chemie	1
International Journal of Simulation: Systems, Science & Technology	2
International Conferences on IT, Information Systems and Electrical Engineering, ICITISEE	1
Journal of the Royal Society Interface	2
Applied Animal Behaviour Science	2
The Veterinary Record	1
Information Processing in Agriculture	1
Total	91

7.3. Overview of literature review content

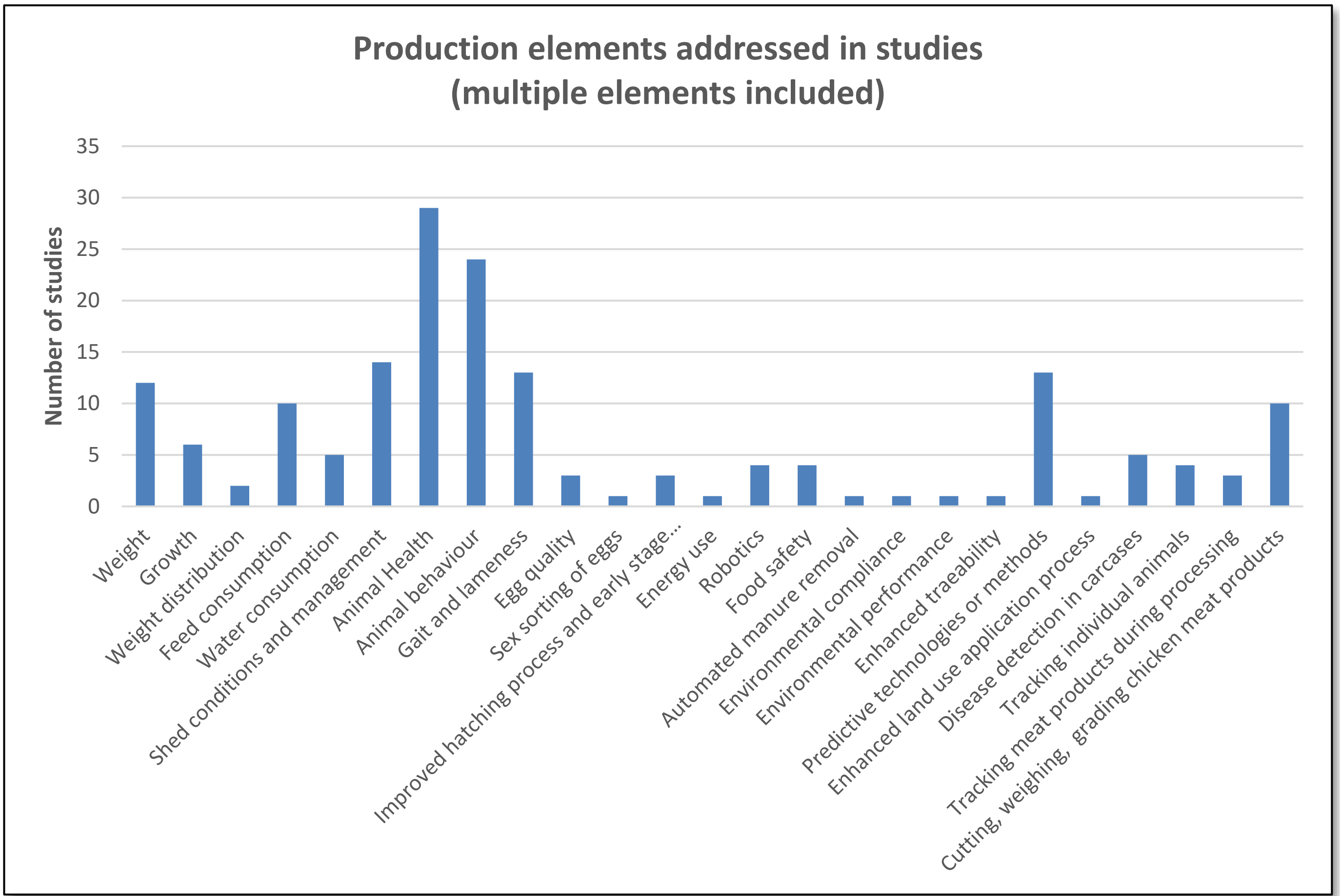


Figure 7-3. Production elements and issues addressed in literature reviewed

The production elements addressed in the reviewed articles largely mirrored those viewed as:

- Key issues as defined at the chicken meat industry workshop (see above)
- The main avenues for delivery of the benefits of digital transformation to the chicken meat industry as outlined by Perrett et al. (2017).

25-30% of the studies were concerned with digitally oriented methods of detection and recording of animal health variables, and these tended to be associated with key indicators of animal welfare, as well as productivity. Digitally based methods for measurement of weight, and water and feed consumption also featured strongly. Alongside measurement, decision tools such as predictive methods and enhanced traceability also featured. Digital tools in meat processing, cutting, quality and food safety also appeared.

A variety of digitally based methods of weight estimation were covered. Within-flock distribution of weight and size was addressed only in terms of egg management, which in all but one case referred to breeding of layers. Measurement and feed consumption was mostly related to development of real-time efficiency measures.

Most studies reviewed pursued automation, primarily for acceleration of data analysis and use, rather than for addressing labour costs. Studies concerned with shed conditions primarily focused on environmental monitoring such as for humidity, temperature and aerosols.

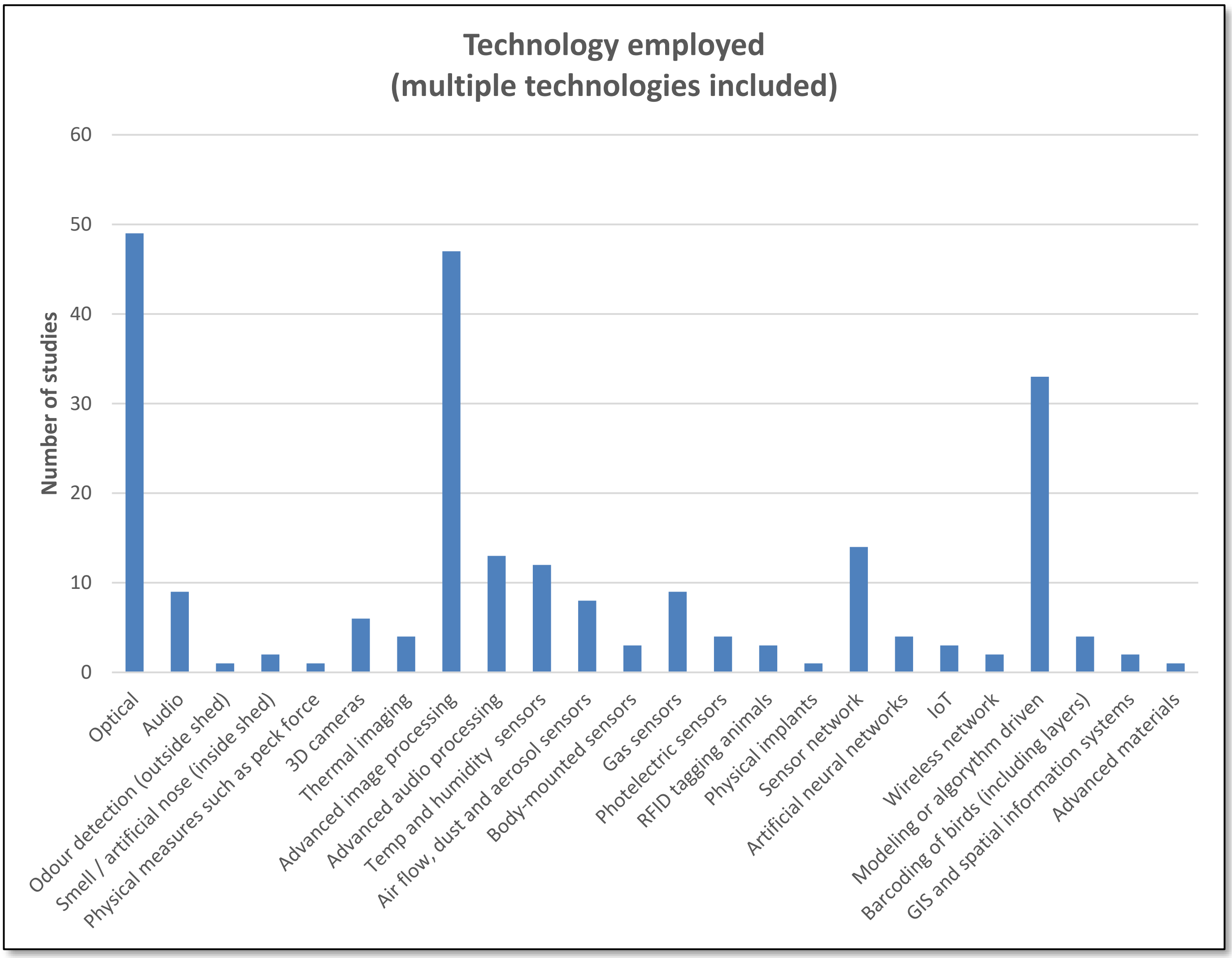


Figure 7-4. Technologies employed/featured in literature reviewed

A large number of the studies featured optical devices (cameras of various forms), and the use of image processing. This covered most aspects of management, from weight estimation and many health and welfare-related variables to dust and aerosol measurement. Sound measurement, and associated interpretation, were also widely observed in association with algorithms for weight estimation, aspects of animal health, and feed intake measurement.

Sensors appeared widely in the reviewed studies, although just a few studies evaluated or tested them. Tagging animals, and mounting or inserting sensors, were a feature of several proposed technological advances in experimental or surveillance methods rather than commercial practices.

7.4. Mapping management issues to literature review material

Table 7-4 presents the technologies accessed in the literature (Figure 7-3, columns), mapped to the management domains associated with key data (Figure 7-4, rows).

Table 7-4. Mapping of management issues to technologies as seen in the literature review

	Technologies employed																Integration					Misc. tech		
Management element	Optical	Audio	Odour detection (outside shed)	Smell / artificial nose (inside shed)	Physical measures such as peck force	3D cameras	Thermal imaging	Advanced image processing	Advanced audio processing	Temp and humidity sensors	Air flow, dust and aerosol sensors	Body-mounted sensors	Gas sensors	Photoelectric sensors	RFID tagging animals	Physical implants	Sensor network	Artificial neural networks	IoT	Wireless network	Modelling or algorithm driven	Barcoding of birds (including layers)	GIS and spatial information systems	Advanced materials
Weight	5	3				2		5	3	3	2		1	1	1		4	2			6			
Growth		1			1				1	1	1		1		1	1	2	2			4			
Weight distribution		1							1		1										1			
Feed consumption	4	3			1			4	3	3	2		2		1	1	4	1			7			
Water consumption	1									3	3		2				3	1			5			
Shed conditions and management	4	1						3	1	6	3		4				5	1	2	1	5			1
Animal Health	18	2				2	2	17	2	4	5	1	2	1			4	2	1	1	15	1		
Animal behaviour	20	1				2		20	2	2	1	2	1		1		4	1			15			
Gait and lameness	12						1	12				1					1				8			
Egg quality	3						1	3		1														
Sex sorting of eggs													1											
Improved hatching process and early-stage growth	2							2			1	1												
Energy use																					1			
Robotics	3					2		2	1															
Food safety	3							3										1			1			
Automated manure removal																					1			
Environmental compliance			1	1						1			1				1				1			
Environmental performance																					1			
Enhanced traceability																							1	
Predictive technologies or methods	6							6		2	3		2				2	2			10			
Enhanced land use application process																								
Disease detection in carcases	5						1	5																
Tracking individual animals	1							1							1							2		
Tracking meat products during processing	2							2													1	1		
Cutting, weighing, grading chicken meat products	8			1		2		7	3					1							1			

The largest concentration of research papers accessed occur around animal health and behaviour, and associated data points such as gait score. Most reviewed publications stopped short of direct inference from these variables to animal welfare, an issue addressed in some separate literature survey work (see Text box 4). Meat processing topics and predictive technologies (as management subjects) are second in abundance and bird weight, feeding and productivity form a third cluster.

Optical technologies, and associated image processing, form the largest number of digital technologies accessed in the literature review. Collection of audio data, and associated sound processing, forms a second group, often addressing the same variables, particularly aspects of bird behaviour. A full spectrum of sensing technologies is seen.

Modelling and analytic approaches, particularly the development of predictive methods via algorithms and machine learning, are seemingly applied to almost all data streams and in association with most management elements. A variety of analytic approaches (e.g. neural networks) are observed. Certain descriptive terms used in the classification may not have been fully expressed in the publications' content, and so Table 7-4 may under-represent their occurrence; examples include Internet of Things and use of a sensor network. Predictive technologies appear in a large number of the reviewed studies, often associated with optical methods of data collection, but also across the range of types of sensors.

7.5. Mapping of detail of the technologies to key data

Table 7-5 lists technological developments addressed in the literature and maps them to data needs associated with production and efficiency, and cites the articles addressed in the review (see Annex 1). Table 7-5 suggests that a very broad range of technologies are used to address production and efficiency data. Integration of these sources with data, listed as "developments", suggests significant efforts to develop predictive management methods, and to automate systems. Constraints identified are in two general categories: practical issues of installing and maintaining sensors and other recording devices and ensuring their transmission;[18] and management needs associated with decision scale, specifically whether data on flocks, individual animals or some section of a shed provides a suitable basis for data being collected.

A variety of technological approaches to measurement of the production data are apparent. Not only do optical, audio, tactile and olfactory and gas span the sensory range, but approaches to feed measurement, for example, includes numerous ways of measuring animal intake or equipment output. Analytic approaches include a variety of ways of integrating such data, particularly for predictive purposes. Technologies from piggery management are mentioned, as cases where there is a track record of sensors differentiating between (the larger) animals and attribution of performance to the (smaller numbers of) individual animals.

Technologies for overcoming identified problems, such as sex and size bias in birds' weights, are little addressed. The more general subject of uniformity of birds (and products) is addressed by management of eggs, hatchery arrangements and early growth stages. The literature review does not investigate systematic change such as demonstrated in the Netherlands' Hatchability initiative, where control of source eggs and egg handling targets uniform lines of broilers.[19]

[18] Thanks are due to Dr Thomas Banhazi of the University of Queensland (currently at the University of Seville, Spain) for this insight.
[19] https://hatchability.com/ (with thanks to Hatchability's Dr Sander Laurens, pers comm).

Table 7-5. Mapping of literature review to key data: weight, feed consumption and efficiency

	Technologies						
Key data	**Automated equipment**	**Automated autonomous equipment**	**Optical devices**	**Sound sensors**	**Physical force sensors**	**Solid flow measures**	**Gas sensors**
Weight	Automatic weighing	Cameras and sensors also mounted in robots	Cameras (Mollah et al., 2010) 3D cameras (Mortensen et al., 2016)	Sound frequency linked to weight (Aydin et al., 2015)			Linkage between NH_3 and weight (Lin et al., 2013)
Weight distribution	Hatch time monitoring (Romanini et al., 2013)		Egg condition measurement by thermal imaging (Lin et al., 2014); other imaging (Yu et al., 2013; Sungur and Özkan, 2015) Early-stage growth measurement Growth monitoring (Fontana et al., 2015; Yan et al., 2019)	Embryo sounds to measure stage of egg development (Exadaktylos et al., 2017)			Sex sorting of eggs (Tran et al., 2010) Air flow moderation during transport (Pardo et al., 2017) Cloud-based egg monitoring system (Malah and Jaynathi, 2017)
Feed and water consumption	Attached measuring devices at feeder, drinker level (Olaniyi et al., 2014)	Co-ordinated feeding systems within a larger organisation (Reboiro-Jato et al., 2011)	Beak and head motion (Abdanan et al., 2014)		Peck force measures (Tu et al., 2011)	Sensors on pipes, feeders, drinkers (Banhazi et al. 2011, Silva et al., 2007 in piggery systems)	
Feed conversion	Effectiveness of feeder devices (Neves et al., 2015)			Repeated observations on feeding sounds linked to weight (Aydin et al., 2014; 2016)			
Constraints	Integration of individual and whole flock data. Sex, weight bias		Cost, calibration, within (metal) shed transmission. Processing required to differentiate individual birds. Predictive models less accurate on large birds (Mortensen et al., 2016)	Scaling to individual animals		Scaling to individual animals	Maintenance of sensors with reactive gases
Concept	Hop on/hop off		Machine vision (3D camera based) (McCarthy and Billingsley, 2009 and ongoing AgriFutures research)				
Developments	Integration with cameras and sensors. Sensor networks (Ghazal et all., 2018)	Integration with cameras/optical. Multiple tasks for robots (Vroegindeweij et al., 2016).	Convenient mounting of 3D cameras (low level, on autonomous devices) Use of cell phones as cheap cameras with on-board processing power (Dawkins et al., 2017)		Solid flow measurement (Banhazi et al., 2011 in piggery systems) Integration with cameras	Integration with cameras	
Predictive analysis	Integration of different data; different information sources: Automated systems (Olanyi et al., 2014; Muttha et al., 2014); Neural networks (Tu et al., 2011; Johansen et al., 2019) Data visualisation to facilitate uptake of integrated systems (Van Hertem et al., 2017) Machine learning requires on-farm calibration (Fontana et al., 2015; Ribeiro et al., 2015)						

Table 7-6. Mapping of literature review to key data: animal welfare, health and behaviour, food safety in processing

Key data	Technologies				
	Optical devices	Sound sensors	Sensors	Implants	Control systems
Disease and animal health	Monitoring using various spectra and thermal imaging (Zhuang et al., 2018)	Monitoring birds' sneezes (Carpentier 2019) Use of sound in disease diagnosis (Banakar et al., 2018)	Wireless sensors on birds and health/welfare observations (Nishihara et al, 2013; Daigle, 2014).	Sensors implanted in birds for healthy monitoring (Iyasere et al., 2017)	Shed lighting and stress levels (Rogers et al., 2015) Air quality and detection of coccidiosis (Grilli et al., 2018)
Behaviour	Binocular cameras and image reconstruction (Xiao et al., 2019 for caged birds) Identifying environmental preferences in birds (Pereira et al., 2013; Kashiha et al., 2014 in laying hens) (Zaninelli, 2018 in laying hens)		RFID labelling of birds for density studies (Campbell et al., 2017 in free range systems). RFID labelling to track flocking behaviour (Sales et al., 2015)		
Gait scores	Measuring lameness and inactivity (Ayden et al., 2017; 2010) Automated monitoring of foot health in commercial trials (Silvera et al., 2017)				
Foot pad health (live)	Thermal imaging for specific foot diseases (Wilcox et al., 2009) Video and imaging of bird and flock movement to quantify foot health (Dawkins et al., 2017, 2012, 2013, 2009)		Sensors and monitoring jumping behaviour in laying hens (Banerjee, 2014)		
Foot pad health (processing)	Optical detection of footpad disease at processing (Vanderhasselt et al., 2013)				
Food safety and disease detection in processing	Optical detection of disease in chicken carcases (Yang et al., 2005). Hyperspectral imaging of carcases to detect faecal matter (Yoon et al., 2011)				
Constraints	Predictive power limited to observed data (e.g. not mortality (Dawkins et al., 2014))	Flock averages Equipment not well suited to rigours of poultry sheds (Sassi et al.,2016)	For research purposes		
Concepts	"Optical flow" employing video analysis of moving birds to record, analyse and predict bird health and other variables				
Developments	Multispectral imaging for disease detection in meat processing (Yang et al., 2017)	Rapid response and predictive applications due to integration of sensors' output (Sassi et al., 2016)		Raised quality of life for birds (Rowe et al., 2019)	
Predictive analysis	Data integration and neural networks to predict intestinal microflora (Hemati et al., 2013) Prediction of feather-pecking in laying hens (Lee et al., 2011); Prediction of broiler welfare outcomes (Roberts et al., 2012) Neural network for prediction of flocking behaviour (Pu et al., 2018) Image processing for real time flocking behaviour monitoring (González et al., 2017) Early warning systems to predict disease in broilers (Zhuang et al., 2018)				

Text box 4. Reviews of animal welfare and its connection to precision agriculture

Two recent reviews of the use of technology in animal welfare assessment focus on the uses of precision agriculture methods in non-intrusive measurement of animal welfare. Rowe et al. (2019) addressed the purposes to which precision agriculture is put in poultry (eggs and meat across all poultry species); whether animal welfare is effectively traded off against productivity as a management goal. In the context of accelerating intensification in many livestock industries, precision agriculture can of course achieve both ends.

Sassi et al. (2016) focused on reporting the available technologies enabling a move from resource- and protocol-based assessment of welfare to more objective measures in poultry (eggs and meat), the processing of information into rapid response or predictive methods, and communication via mobile apps. Rowe et al. advocated the use of new technologies to improve bird welfare and quality of life, as well as in measuring and monitoring welfare. Both studies emphasised the generally limited uptake of precision agriculture in poultry, and called for accelerated commercialisation of available technologies; this particularly applies to demonstration of technologies in commercial settings and evaluation of financial returns to producers.

Turning to animal health and related issues such as farm-based aspects of food safety, Table 7-6 maps the technologies emerging from the literature to the key data and management tasks. A number of technologies appear (e.g. implanted sensors) that are research-oriented rather than commercial, and these have been retained because they demonstrate certain challenges to newer technologies, such as how to handle data from individual birds.

As for production-related data, optical technologies for data collection are seen to dominate, many directed at consistent and automated real-time quantification of data such as gait score and footpad health, which have day-to-day relevance for productivity, profitability and animal welfare. A strong conceptual element of the technologies and associated data collection is the linkage between measurable aspects of bird behaviour, and health and productivity. An encouraging aspect of the gait score and footpad health predictive work is that it has been carried out in commercial conditions with somewhat cheap hardware (video cameras and mobile telephones in 'optical flow').

Across the spectrum of management issues for animal disease, the literature review identified audio technologies to detect disease symptoms (sneezing), video and sensors to monitor flocking behaviour, and shed air quality for detection of specific pathogens. Included in Table 7-6 are technologies for shed-related threats to food safety, and indicators of animal health, which are detected by various means on carcases during processing.

The animal health (and to some extent welfare) field of research generated the largest numbers of examples of advances in predictive modelling. Much of this effort trials integration of data from several sources, and employs machine learning via neural networks. This lends itself to data generated in this category of research, which is a blend of flock, shed and individual animal observations, and comes in a variety of forms.

Table 7-7 maps shed data and management issues to digitally oriented research. Research focuses remarkably little on automation, and sensor-based research is concerned with gas, air quality, smell and radiation rather than optics. As seen earlier, progressive research is using cheap hardware, and research is focusing on integration of the disparate data sources. Terms such as 'SMART SHED' appear as part of the development of predictive analysis.

Notably, no studies were identified on shed management elements of robots. In one of the few published analyses of robots' use in poultry sheds (primarily for layers), Timmerman et al. (2017) profiled the hypothetical installation and use of a multi-level automated system focused on animal welfare monitoring. Its appeal to producers was assessed in a survey, which showed enthusiasm both for the anticipated labour cost savings and the sharing of data along the supply chain.

Table 7-8 presents mapping of meat processing data to digitally related research. Emerging themes centre on robotics for cutting and grading of chicken meat based on optical sensor guidance, meat quality and safety assessment by machine, and efforts in traceability using shared databases along the supply chain.

Table 7-7. Mapping of literature review to key data: shed management

	Technologies					
Key data	**Automated equipment**	**Automated autonomous equipment**	**Sensor networks and IoT**	**Electronic nose**	**Radiation sensors**	**Gas sensors**
Shed conditions	Use of fixed, mobile devices and cloud storage for monitoring shed conditions (So-In et al., 2014)		Remote sensing of shed environment (Li et al., 2015)		Radiation sensors and advanced materials (Cordeau and Barrington, 2011) Automated temperature controls (Wicaksono et al, 2018)	Particulate matter and aerosols (Roheela et al., 2019)
Litter/composting	Automated manure removal (Lijia et al., 2014 in small-scale systems)			Internal shed smell as guide to litter (Pan and Yang, 2007)		
Labour requirements						
Constraints			Lack of connectivity to internet. Lack of connectivity among components within shed.			Maintenance of sensors with reactive gases
Concept		Substitution of labour for automation in litter treatment	Online/offline to counter lack of web connectivity			GHG emissions measurement (Bartzanas et al., 2015)
Developments	Use of mobile phones as data collection and processing devices	Sensors and cameras mounted on robots	Reductions in costs of sensors (Griffith et al., 2013) Data processing for integration of shed environment data (Duan et al., 2018)			Integration of multiple sensors with IoT for automated shed management (Zhang et al., 2016)
Predictive analysis	Linking dust and aerosol concentrations to broiler activity levels (Fernández et al., 2017) SMART-SHED development (Mahale and Sonavane, 2016)					

Table 7-8. Mapping of literature review to key data: meat processing

	Technologies			
Key data	**Sensors**	**Advanced optics + real-time use**	**Machine learning**	**Supply chain software + real-time use**
In-line cutting and product decisions		Photo-electric sensor for cutting, grading chicken wings (Zhao et al., 2018) Carcase contour tracking for automated processing (Chen Wang 2018)	Automated poultry cutting (Heck, 2009) Automated poultry de-boning (Hu, 2013)	
Labelling				
Traceability	Passport systems for internationally traded animals, and feed-animal product traceability (Banhazi et al., 2011, in review)			e-tracking of laying hens (McInerney et al., 2011) e-tracking of barcoded product through processing (Fröschle et al., 2009)
Lot descriptions and segmentation	Infrared sensing of chicken quality attributes (Barbin et al., 2015; Koutchma et al., 2016)	3D vision system for automated breast fillet extraction (Misimi et al., 2016)		
Delivery on time to specification		Hyper-spectral imaging for quality measurement and control in chicken meat (Kamruzamman et al., 2014)		
Shelf life	Methyl Red sensing and classification of chicken meat freshness (Kuswandi et al., 2014) Electronic nose and ultra-fast gas chromatography to determine shelf life (Wojnowski et al., 2018)			
POS data				
Constraints				
Concept			Non-carcase portion retail orders	
Developments	Automated poultry meat inspection (Chao et al., 2014) Automated chicken traceability recording system (Sallabi et al., 2011)			
Predictive analysis	Use of infrared scanning for woody breast detection (Geronimo et al., 2019)			

7.6. Gaps left by the literature review

The search strings used deliberately targeted digital technologies and digital transformation, and so was an inter-disciplinary (falling between or among disciplines) effort. This has several consequences for literature review as a knowledge-boosting exercise: first, that few journals have specialised in this subject; and second, that appropriate search vocabularies are not standardised so that appropriate literature becomes difficult to find. Several review papers on related subjects were examined for correspondence. Where the interdisciplinary theme was maintained, as in Sassi et al.'s (2016) review of the use of sensors in animal welfare assessment, crossover was strong and largely the same set of publications appeared. Where the emphasis was on farming themes rather than digital transformation (e.g. Rowe et al. (2019) on precision farming and its consequences for animal welfare), the correspondence was less good, but the same technologies appeared. Where reviews dealt with emerging scientific techniques not linked to new digital technology (e.g. Park et al. (2014) on *Salmonella* detection in poultry meat), little crossover was found.

A gap in the literature reviewed concerns practical application. A disappointing number of the published studies presented trials in conditions of commercial chicken meat production or processing. Moreover, and typically for scientific research, none of the studies addressed the importance of quantification itself on business management decisions. Contributions in feed use measurement, animal health and shed conditions, for example, are not applied to day-to-day Australian issues. Use of objective data on litter condition, for example, would be a useful advance in RSPCA compliance monitoring. To echo earlier statements by commentators on agriculture's uptake and use of digital technologies, no single study offered analysis of a technological option as an investment decision.

Environmental concerns received little coverage in the research reviewed, and this particularly applied to local regulation and compliance for odour and building requirements. Remote monitoring of a number of similar variables (e.g. air circulation in road tunnels) is monitored by environmental agencies and opportunities exist for this approach to compliance for chicken sheds.[20]

Just a few of the reviewed studies featured data sharing (primarily for traceability), and these did not discuss implementation issues such as technology, data ownership, privacy and trust. Surprisingly, little of the reviewed literature addressed automation, and in the Australian context this leaves unsatisfied the need for management options on labour use and skills.

[20] Thanks are due to staff of the NSW Environmental Protection Authority for discussion of this issue.

8. Results: Identification of key technologies in the Australian chicken meat industry

8.1. Criteria and rating procedure

In this section, criteria developed throughout the scoping study work (see Table 8-2) are employed to rate the categories of technology identified in the literature and elsewhere (see Table 8-3 with explanations). Rating is carried out using a six-point scale, one level of which is a blank where criteria are non-applicable (Table 8-1). Ratings represent correspondence to 19 criteria as specified in Table 8-2.

Table 8-1. Scale for ratings of technology

Rating	Score
High correspondence	4
Moderate correspondence	3
Some correspondence	2
No correspondence	1
Unsuitable	0
Not applicable	

Table 8-2. Criteria for ratings of technology

Criteria
Fit with Perrett et al. (2017) priorities at production level
Addressing significant cost items
Addressing productivity
Addressing health and animal welfare communication
Addressing food safety
Suitable to be applied widely across all sheds
Fit with digital transformation process
Fit with EDM analysis
Fit with elements of the data wish list
Accessible by simple and available technologies, off the shelf
Compatible with existing practice and technologies/equipment
Incentive compatible with sharing of data
Likely financial benefits
Likely low financial costs
Financial benefits likely to be generated within one production contract (five years)
Availability of service and spares
Not requiring of industry organisation or large-scale commercial data development
Conducive to industry organisational change in the longer term
Associated with improved supply chain performance

8.2. Description of technologies

From the various technologies drawn from the literature review and other sources throughout this report, a shortened list is presented and explained in Table 8-3. This list is truncated from longer lists presented during the literature review and is somewhat generalised to combine aspects of data collection, processing and use in decisions.

Table 8-3. Listing and explanation of technology descriptors

Technology	Explanation
Optical	Use of cameras in sheds: observation on various behavioural variables. Extension to machine vision-type work with 3D or video
Audio	Use of sound sensing devices in sheds
Odour detection (outside shed)	Generation and transmission of data related to odour on site: fan use; internal temperature, others
Smell / artificial nose (inside shed)	Use of odour sensing devices in sheds
Physical measures such as peck force	Use of sensors which measure forces or distensions in pipes and equipment
Temperature and humidity sensors	Use of sensors that measure temperature and humidity
Air flow, dust and aerosol sensors	Use of sensors that measure air flow, dust and aerosols
Gas sensors	Use of sensors that measure concentration of selected gases
Sensor network	Wiring sensors into networks to enable collation of data
Wireless network	Use of a wireless networks to enable collation of data from sensors
IoT	Devices distributed in shed that access and deliver data streams in communication with the internet
Modelling or algorithm driven, using multiple data sources	Use of decision tools driven by data, generally to automate shed operations
Automated weighing	Use of automatic scales
Robotics in sheds	Use of shed robots
Meat processing robotics	Use of robots in aspects of meat processing
Advanced meat quality control	Use of data streams in meat quality control during processing
Advanced information processing for quality	Use of data streams to identify, sort and separate meat quality lines during processing
Advanced information processing for traceability	Use of data streams to identify and preserve product origin or other traceability information

8.3. Rankings achieved

Ratings on Table 8-1's scale are subjectively applied to generate Table 8-4. Averages of ratings are taken (this includes zero values but avoids blanks) and rankings are then applied to the ratings both separately across production and processing, and jointly for both supply chain stages. The ranking tool used to generate these results is attached to this report.

Table 8-4. Ratings and rankings of technology

	Sensors								Networks		IoT	SMART SHEDS	Automation		Processing automation		Information processing for meat industry	
Criteria	Optical	Audio	Odour detection (outside shed)	Smell / artificial nose (inside shed)	Physical measures such as peck force	Temp and humidity sensors	Air flow, dust and aerosol sensors	Gas sensors	Sensor network	Wireless network	Internet of Things	Modelling or algorithm driven, using multiple data sources	Automated weighing	Robotics in sheds	Meat processing robotics	Advanced meat quality control	Advanced information processing for quality	Advanced information processing for traceability
Fit with Perrett et al. (2017) priorities at production level	3	3	2	2	2	4	4	4	3	3	3	4	4	4	3	4	4	4
Addressing significant cost items	3	4	4	3	4	4	3	2	2	2	4	4	1	4	4	2	4	3
Addressing productivity	3	4	1	2	4	4	4	4	3	3	4	4	4	3	3	2	2	2
Addressing health and animal welfare communication	4	3	0	2	1	4	2	2	3	3	3	4	2	2		4	2	3
Addressing food safety															3	4	4	4
Suitable to be applied widely across all sheds	3	2	3	0	1	4	2	2	1	0	1	0	3	1				
Fit with digital transformation process	4	3	3	2	2	3	3	3	4	4	3	3	4	2	3	4	4	4
Fit with EDM analysis	3	1	1	2	2	3	3	3	3	3	2	3	4	2	2	4	4	4
Fit with elements of the data wish list	4	0	1	1	1	4	3	3	3	3	3	4	4	3	2	2	2	2
Accessible by simple and available technologies, off the shelf	4	0	1	1	0	4	3	2	1	2	1	1	3	1	2	2	2	2
Compatible with existing practice and technologies/equipment	4	1	3	1	0	4	3	2	2	1	2	1	4	2	1	1	3	3
Incentive compatible with sharing of data	4	3	4	2	2	4	4	4	2	2	0	2	2	2	3	3	4	4
Likely financial benefits	3	2	1	1	1	3	3	3	3	3	3	3	3	3	3	4	3	3
Likely low financial costs	3	1	1	1	1	4	3	2	1	1	1	1	2	1	1	2	1	1
Financial benefits likely to be generated within one production contract (five years)	3	1	1	1	1	3	3	2	2	2	0	1	2	1				
Availability of service and spares	3	0	1	0	1	3	2	2	1	1	1	2	1	1	1	2	3	3
Not requiring of industry organisation or large-scale commercial data development	4	4	2	1	2	3	3	3	2	2	2	2	4	2	1	3	3	3
Conducive to industry organisational change in the longer term	3	3	1	1	2	3	3	2	2	2	2	3	4	3	3	3	4	4
Associated with improved supply chain performance	4	2	1	1	2	2	2	2	3	3	3	4	4	2	3	4	3	4
Averages	3.44	2.06	1.72	1.33	1.61	3.50	2.94	2.61	2.28	2.22	2.11	2.56	3.06	2.17	2.38	2.94	3.06	3.12
Rank: processing and production separate	**2**	11	12	14	13	**1**	**4**	**5**	7	8	10	6	**3**	9	4	3	2	1
Rank: processing and production together	**2**	15	16	18	17	**1**	6	8	11	12	14	9	**5**	13	10	7	**4**	**3**

The top three ranked technologies are environmental (temperature and humidity) sensors, cameras (broadly defined) and automatic weighing. Figure 8-1 is a star chart comparing the three technologies across the 19 criteria, and near-complete coverage of the criteria by the top three technologies is worth noting. Likely benefits to the investor in technology and associated changes, and the short timeframe in which these are available, are criteria not well addressed by these top choices, despite reasonable coverage elsewhere. Alongside these concerns, which are specific to the production stage of the supply chain, the whole-of-chain issue of food safety – and more generally the delivery of consumer information – is not well addressed by these technologies.

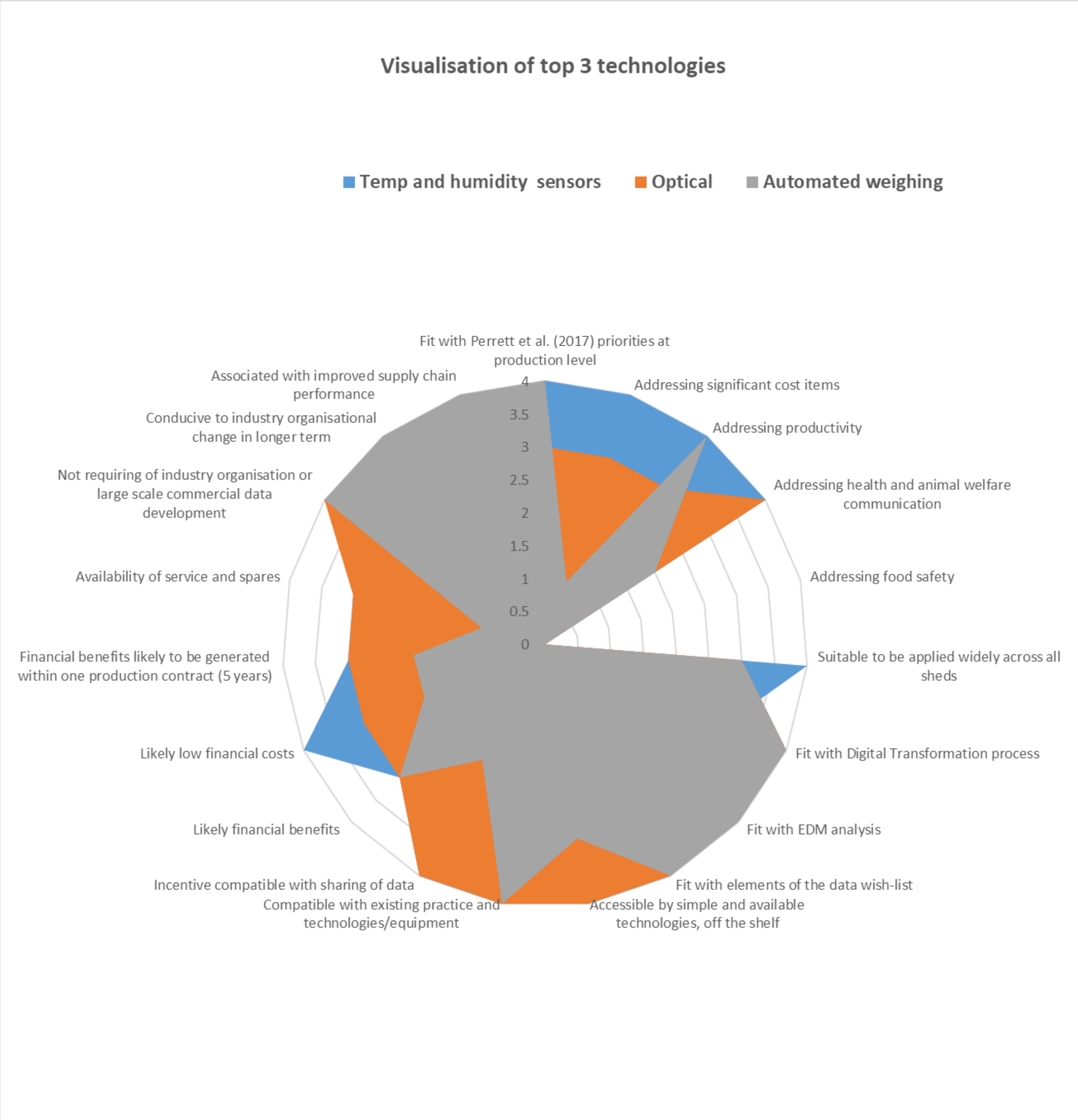


Figure 8-1 Visualisation of top three ranked technologies

9. Implications: Actions to unleash the power of digital in the Australian chicken meat industry

9.1. Goals, actions, and incentives

The goals of the chicken meat industry taken forward here are as expressed in the industry workshop:

- Financial profitability
- Economic performance
- Social and community performance
- Positive animal welfare outcomes
- Safe food.

Uptake of digital technologies, and broader digital transformation, are not goals in themselves but are means of achieving the goals listed above. Actions to achieve these goals centre on data: mechanisms of collection; use in analysis to support decision making; and mechanisms for sharing. These actions are enabled by the adoption of digital technologies, digital transformation of firms and farms, and innovation toward the development of new business models.

Industry goals are targeted in a competitive market environment, with substantial variation among stakeholders at production and processing stages of the supply chain. The highly integrated nature of the chicken meat supply chain means that benefits of investment are passed along the chain from the point of investment as seen in section 4. This generates both short-term (within a production cycle) and medium-term considerations of the incentives for such investment: in the short term, who is best positioned to benefit from investment by a supply chain partner? In the medium term, can competitive advantages be eroded?

9.2. Data collection

Advances in data collection fall into four categories:

- Improved collection of variables on which data is already collected
- Conversion of existing subjective measures to objective ones
- Abandonment of paper in collection and communications in favour of digital records, collection devices and transmission modes
- Collection of data on new variables

Improved collection is associated with better quality of data, lower cost of collection, and improved coordination with management and decision-making activities. Better-quality data is associated with consistency, accuracy, timeliness and usefulness in a variety of uses. Lower cost is associated with organisational changes to reduce duplication or reduce time and effort, to combine activities, and changed data collection methods. Improved co-ordination with decision making focuses on the format of the data and its suitability for transmission (including automatic transmission), and use in analysis to support decision making. The decision making may also be an automated process.

The shift from subjectively to objectively measured data offers precision and other elements of transparency. It also lends itself to quantitative analysis and alignment to key performance measures at the firm, farm and supply chain levels. Moving from paper recording and paper-based transmission to digital methods removes costs of data entry and provides for low-cost and rapid (possibly real-time) transmission. Given suitable quality and format conditions, this allows alignment with other data for advance or automated processing.

A potentially infinite number of new variables are available to be measured. Industry concerns over excessive data collection (and its associated costs) and more general concerns over businesses being swamped in large volumes of unused data, call for discipline in identifying new variables to measure and embarking on the associated data collection. On the other hand, development of sophisticated analysis and particularly machine learning require large volumes of data on a large number of variables.

High priority technologies for enhanced data collection have been identified in section 8:

- Environmental (temperature and humidity) sensors;
- Cameras (broadly defined); and
- Automatic weighing.

9.3. Advances in data handling and analysis

Opportunities for advances in data use have been established in section 7, in line with industry's expressed interest in:

- Predictive technologies;
- Networked systems which integrate data; and
- Algorithm-driven analytics that provide advanced decision support or automate selected decisions.

9.4. Data sharing

Technical approaches to sharing data are discussed in sections 3 and 4:

- Within farms;
- Within firms;
- Within supply chains;
- Within the industry; and
- Beyond the industry to interest groups and government.

9.5. Delivery mechanisms

Several modes of delivery of digitally based advances are discussed in this study. Within firms, this is technology adoption and actual or potential uptake of additional elements that expand the benefits generated: moving from collecting data to digitising its collection, and onwards to processing the data in association with other data to provide decision support, and onwards to automation of decisions and interaction among pieces equipment. Such systems might conveniently be replicated across sheds, or between farms, and onwards within the supply chain, for example surveillance cameras transmitting vehicle movement records from multiple farms to one processor for biosecurity purposes.

Whole-of-chain modes entail combinations of data collection, analysis, sharing and use along the supply chain. Synergy among supply chain partners would be expected, for example data collection in multiple sheds, analysis by a processor and transmission of results to both producers and retailers.

Short- and long-term considerations apply, particularly where data sharing encounters risks (real and perceived). In the short term, information on feed intake and growth occasions analysis, which contributes to joint benefits for producers and processors. In the longer term, cost and productivity information may impact price negotiations between producers and processors, and between retailers and processors. Processors' sharing of product logistic data can assist retailers in inventory management; and in the long term, both processors and retailers will learn about aspects of the other's costs.

Third-party service modes of delivery, where data is analysed and advice provided to individual farms, represent single-firm investment decisions unless processing data is being employed in analyses, for example of weight distribution achieved at sale to retailers. Other interactions include benchmarking of performance across a third-party provider's client base. Sophistication of analysis and advice given is also related to volumes, varieties, and qualities of data, imposing costs on producers who may wish to limit data collection to some minimal number of variables and/or some minimal cost level.

Data submitted to platforms, where confidentiality can be assured, becomes a resource for platform activities. For general management information such as required by Sedex on an occasional basis (see Text box 3), this offers checklist-type compliance information at the firm or facility level. This might target special interests, such as those promoting animal welfare by way of compliance monitoring. For more granular data referring to flocks, platforms accumulate resources for use by third-party providers as above, and also to enable the operation of apps, benchmarking and other services. A full end-to-end service such as Sense-T (see Text box 5) uses active data feeds and analytics, involves all stages of the supply chain, and can also reach to consumers' feedback.

9.6. Partnerships and data ownership

Chicken meat industry stakeholders exist beyond production and processing. Buyers operate as auditors of compliance, consumers seek assurance on product attributes, insurers seek evidence of food safety and other risks, governments at various levels act as regulators, and special interest groups act as compliance auditors. Opportunities exist to extend digital transformation to these relationships in pursuit of reduced costs, enhanced effectiveness, and value added. Beyond the supply chain, interest groups and government agencies are the recipients of data from the chicken meat industry. As envisaged by CSB (2020), digital transformation offers a number of opportunities to redesign and improve those relationships, and to reduce the costs of compliance and audit activities.

Management techniques such as benchmarking are reliant on data sharing. Advanced analysis and predictive methods, and organisational changes such as platform development, all require large volumes of data over lengthy periods, disaggregated by farm and flock. The volume of information potentially available to be compiled on a single flock of chickens offers substantial opportunities to align with prices received along the supply chain and better identify product value. This promotes transparency in pricing so as to magnify incentives for change in production and processing. Decision support tools also enable scenario analysis for the examination of such changes from commercial and technical points of view, and reconciliation with management change.

Opportunities exist to provide high-quality information to commercial partners such as banks, insurers, veterinary laboratories, feed suppliers and product buyers. In these cases the transactions costs for farms and processing firms can be reduced by way of real-time provision of personalised, standardised and ready-analysed information, which would reduce the turnaround time and cost of, for example, applications for loans or insurance coverage.

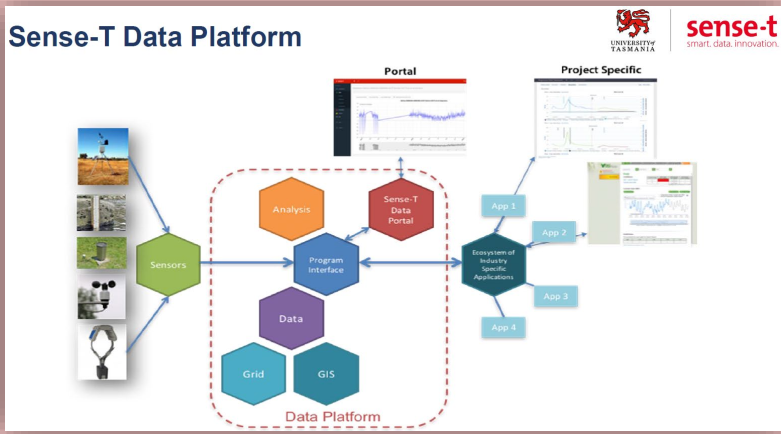
Transparency for buyers is enhanced by information transmitted along the supply chain, often involving information about the firm and its practices, rather than products. In some cases, these are requirements for market entry on a checklist basis, but in other cases can activate price premia. On this expanded view of the supply chain, providers and users of insurance and credit, and other services can use these checklists as assurance mechanisms and as indicators of desirability as repeat suppliers. Risks to privacy, confidentiality and 'trade secrets' are recognised and have both short and long-term effects. The risks of long-term dissipation of intellectual property affecting competitiveness, and revelation of cost levels and structures, refer directly to a loss of bargaining power within the supply chain.

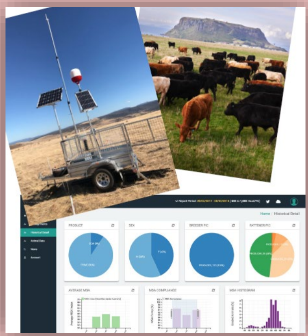
The chicken meat industry represents an anomaly within current developments in the ownership of agricultural data in that the owner of chickens is not the farmer. Key steps to be taken include the assignment of ownership of farm-level chicken meat data. This extends beyond ownership and onwards to control: the capacity to use and share data, as well as the right to retrieve analysis based on the data and control the uses to which the data is put, and the right to nominate individuals and companies who may use the data and analysis for any purpose. The sharing of data with others within and beyond the chicken meat supply chain offers benefits associated with enhanced decision making, alongside costs and risks of appropriation or misuse of the data by others. Chicken producers are unlikely to collect and share data if they do not participate in the benefits it generates. A recommendation from recent Australian work by Wiseman and Sanderson (2019) is the appointment by agribusinesses, but also by RDCs, of a “data steward” with responsibility for data management and also to establish and maintain currency with various compliance requirements.

Text box 5. Sense-T, the University of Tasmania's data platform serving primary industries

Sense-T was set up in 2012 as a project to harvest Tasmania's natural and agricultural environment's Big Data.

It is resident at the University of Tasmania, and clients frequently leverage their investment with research funds.

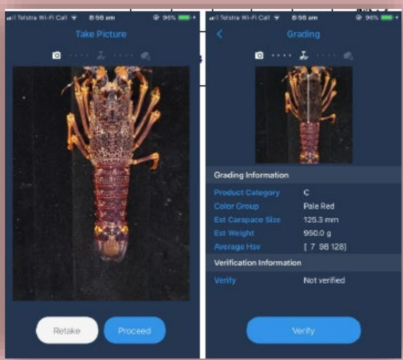




Sense-T now forms the basis for a number of end-to-end supply chain initiatives.

Sense-T has hosted and commercialised a number of data and analytics-based projects for food industry firms. Sense-T's platform enables food processors to reach in both directions in the supply chain to provide performance and decision-support analytics on distribution, retail, and consumers as well as suppliers.

Traceability and quality assurance functions are driven by user-specific blends of resource Big Data on environmental conditions, sensor-based tracking and logistics throughout the supply chain, and linkages to social media for consumer response.



The approach taken by Sense-T is forward-looking, addressing firms' problem-solving needs, and use of anticipation with machine learning and artificial intelligence. Examples include:

- Real-time visibility of export cold chains
- Waste due to product rejection
- Validation of premium products' differentiation
- Prediction of microclimatic or disease events

Returns on investment address both value addition and innovation for cost reduction.

9.7. Barriers to change

The industry's diversity of digital capacities and maturities, variation in sizes and market stances of farms and firms, equipment's age and investment history, and variation in the perceptions of perceived returns on investment all provide barriers to change with regard to digital transformation in the chicken meat industry.

Costs are recognised as a barrier to change. Technologies largely dictate not only the cost of data collection but the potential for synergies and economies of scale in data collection. The cost of installation and use of sensors, for example, is little affected by the number of variables being measured (temperature, humidity, non-reactive gases), and mounted hard-wired cameras can take a variety of different filter and lens configurations. The cost of a networked system within a shed is not greatly affected by the number of sensors included nor the time durations for data collection.

The much-cited fear of the unknown, associated with both known and unknown technologies, and uncertainty over the impact on cost and benefit streams, are interpreted from the elements of this scoping study as being associated with three issues:

- Firms are, to a varying extent, unaware of available technologies;
- Although the location, form, cost and allocation of an investment item may be well known, the form and allocation of benefits may not be, in short- and long-term conditions which differ; and
- Firms lack the methods, experience, practical knowhow and time to define and conduct financial analysis of scenarios for change.

Reluctance to collaborate, widely seen as a barrier to change, is found in this study to be primarily manifest as concerns over:

- Data ownership;
- Protection of intellectual property, particularly associated with preserving 'trade secrets' that enable competitiveness at a stage in the chicken supply chain or in relations between contracting partners;
- Data security, particularly with regards to potentially malicious or naïve use of sensitive information; and
- Data format and collection protocols generally affecting data quality.

Staff skills are widely cited as a barrier to digital transformation, primarily:

- Orientation toward quantitative tasks as it affects interest and willingness to commit to objective measurement of management variables;
- Computer familiarity as it affects willingness to use digital data entry and communications as the norm; and
- Computer literacy as it affects ease of learning new software and interpreting output.

There are also acknowledged reciprocal shortages in both chicken stockmen and stockwomen with data-related skills, and data and systems analysts with technical chicken management skills. This both limits chicken meat producers and processors' advance with digital transformation, and constrains the development of service industries surrounding the supply and use of digital technologies and specialist analytics.

10. Recommendations: A strategy and roadmap for digital transformation in the Australian chicken meat industry

10.1. A roadmap

Figure 10-1 presents a roadmap where all roads lead to the stated industry goals for 2030. Based on the scoping study and industry consultation, actions (yellow boxes) are proposed. Actions are seen as organisational and technical changes enabled by investments (hollow boxes), which progress through milestones derived from key target achievements identified at the industry workshop. The investments are linked to key technologies as identified in section 8 above, but extend onwards to the industry's enabling environment. A schematic key is in the bottom right-hand corner of Figure 10-1.

10.2. Strategic actions and enabling investments

The roadmap's actions and connections to investments and milestones, through to goals, are further presented in Tables 10-1(a) to 10-1(c). The tables subdivide actions into imperfectly distinct groups that emphasise change at different points in the supply chain. Table 10-1(a) deals primarily with shed management, which is expected to be a major contributor to benefits from digital transformation. Actions "digitalised manual collection of data" and "automation of data collection inside sheds" essentially provide improvements to existing systems for data collection and use. They generally address industry's expressed imperative to make better use of existing data, and use high-priority data and technologies as identified in this study's literature review. Hence, these are identified in Table 10-1(a) as high-priority investments. Industry goals targeted are primarily improved financial performance by way of improved production, reduced costs and improved animal welfare (also seen as a separate goal, but also contributing to profitability). Data on weights, particularly where automated, are presented as one of several mechanisms for improving sales procedures and narrowing weight distributions at sale. Shed environment data as delivered by sensors, and analysis from optical devices, are presented as means of providing a volume of objective animal welfare data, which both assists in marketing a credence product and saves on labour and compliance costs.

Table 10-1(a) proposed investors are identified as producers for on-farm investment and processors for data processing. Use of new objective data in improving animal welfare compliance is proposed, requiring investment in consultation to lead to new procedures. Covered more fully below, this investment would proceed at industry level, so costs are shared.

Table 10-1(b) addresses barriers to digital transformation associated with data ownership, use and sharing. As seen in the roadmap, this requires investment in legal and governance changes, immediately in clarifying chicken meat producers' data ownership status, given that almost uniquely in Australia, they do not own the livestock on their farms. Sequentially following the establishment of enabling data, governance actions on data sharing are presented in two contexts: within the supply chain (producers, processors and retailers); and beyond the supply chain to regulatory bodies, special interest groups, and regarding generalised compliance issues such as WHS and biosecurity. Priorities assigned for investment reflect diversity in firms' and farms existing data activities and status, the size of the benefits from change (e.g. WHS), and the effectiveness of incumbent systems (e.g. biosecurity). Table 10-1(b)'s preoccupation with data governance and legal issues means that investments are industry-wide and subject to significant stakeholder consultation. Certification for use of data Codes of Practice is also proposed.

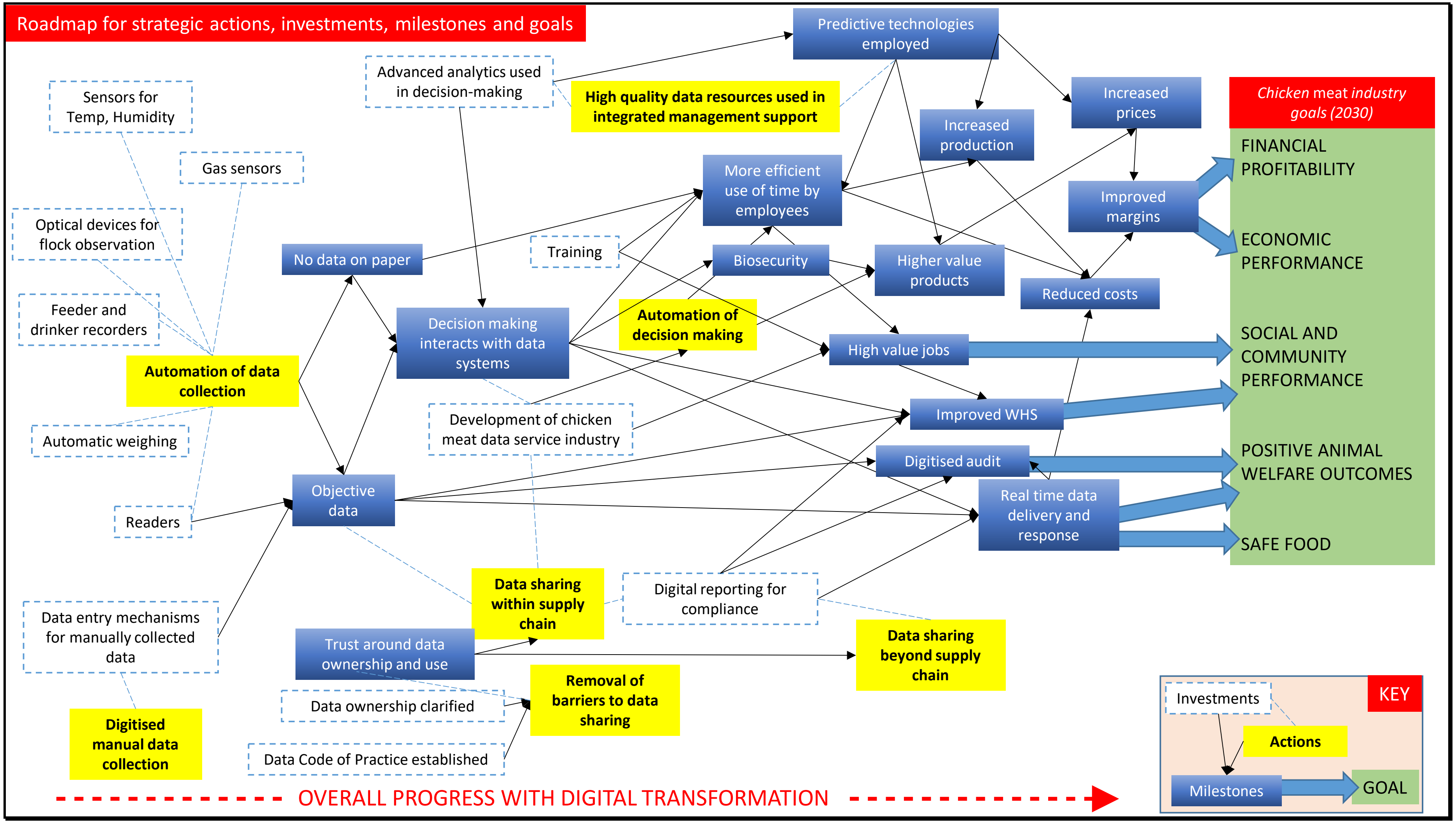


Figure 10-1. Strategic roadmap

Table 10-1(a). Summary of strategic actions and enabling investments: shed management

Action	Enabling investment options	Priorities and approach	Milestone to be achieved	Goals targeted and mechanism	Investor	Funding and payments options
Digitalised manual collection of data	• Hand-held devices • Bespoke shed management software • Wireless linkages to on-farm database	High priority, enabling data sharing	• Objective data • No data on paper	• Financial performance by way of reduced costs	Producer: devices and wireless communications within and between sheds	
Automation of data collection inside sheds	• Sensors for temperature and humidity • Automated weighing • Data ownership clarified	High priority, in modern sheds, enabling development of chicken meat data services industry	• Predictive technologies • Increased production • Higher prices • More efficient use of staff time	• Financial and economic performance, by way of higher value products • Social and economic performance by way of high value jobs	Producer: sensors, automatic weighing platforms Processor: data processing, algorithms and performance standards	Bonus payment to producers demonstrating objective measures of superior shed environment or weight distribution.
	• Optical devices for flock observation • Data ownership clarified	High priority, in modern sheds	• Objective data (bird lameness, footpad health, movement)	• Positive animal welfare outcomes • Increased prices and margins, by way of higher-value products	Producer: optical devices Processor: algorithms and performance standards	Bonus payment to producers demonstrating objective measures of superior animal welfare.
	• Sensors for litter condition • Data Code of Practice established	Moderate priority, in modern sheds	• Objective data (for RSPCA compliance: *see below*)	• Positive animal welfare outcomes • Financial performance by way of lowered audit costs	Producer: sensors Industry level engagement with policy makers and special interest groups	
	• Gas sensors • Feeder and drinker recorders	Low priority	• Increased production • Decision making interacts with data systems	• Financial performance by way increased production, reduced costs		

Table 10-1(b). Summary of strategic actions and enabling investments: data sharing, trust and governance of data systems

Action	Enabling investment options	Priorities and approach	Milestone to be achieved	Goals targeted and mechanism	Investor	Funding and payments options
Removal of barriers to data sharing	• Data ownership clarified	High priority, for sheds with high-quality data available	• Trust around data ownership and use	• Decision making interacts with data systems • Real time data delivery and response	Industry level engagement with policy makers A “data steward” role Industry level generation of certification for data use according to a Code of Practice	Partnership with civic groups or farmers’ representative groups.
	• Code of Practice on data use	High priority, enabling development of chicken meat data services industry	• Trust around data ownership and use • Real-time data delivery and response	• Real time data delivery and response • Predictive technologies		Research partnerships targeting networked economic effects (e.g. ARC LIEF) Charges for certification
		High priority for retailer-processor interface on demand at point of sale	• Real-time data delivery and response • Predictive technologies employed	• Financial and economic performance by way of higher value products and reduced costs	Processor engagement with retailers	Join with on-going action by farmers’ representative groups and governments on data governance.
		High priority for retailer-processor quality and safety audits	• Real-time data delivery and response • Reduced costs			
Data sharing within the supply chain	• Data Code of Practice • Data ownership clarified • Automatic weighing	High priority for producers with persistent quality and consistency problems	• Trust around data ownership and use • Decision making interacts with data systems	• Financial performance by way of increased production, reduced rejections	Producer: equipment Industry level engagement with policy makers	Additional contract payments to producers for data provision
Data sharing beyond the supply chain	• Digital reporting for compliance	High priority where good relations with interest groups have been established	• Objective data • Digitalised audit • Reduced costs • Higher-value products	• Positive animal welfare outcomes • Financial performance	Industry consultation with special interest groups for monitoring animal welfare compliance	
		High priority in locations with land use pressures		• Social and community performance (environmental compliance)	Industry consultation with state and local government on mechanisms for monitoring environmental compliance, and use of data for planning applications.	Participation in state and federal projects accelerating digital transformation in government
	• Readers on vehicles, equipment, packages	High priority	• Improved WHS	• Social and community performance (WHS outcomes)	Consultation with staff representative bodies	
		Low priority	• Biosecurity	• Financial performance • Social and community performance		Partnership in Federal research grant programs on Biosecurity

Table 10-1(c). Summary of strategic actions and enabling investments: enabling advanced analytics

Action	Enabling investment options	Priorities and approach	Milestone to be achieved	Goals targeted and mechanism	Investor	Funding and payments options
High quality data resources used in integrated management support	• Development of chicken meat data service industry • Advanced analytics	Medium priority, requiring advances in data sharing	• Decision making interacts with data systems • Predictive technologies employed	• Financial performance	Options: • Whole of chain (one processor) • Whole of industry (multiple processors) • (Single) third-party provider	Flows of funds: • Pay per use • Pay for third-party services and apps • Levy on data supplied • Payment for apps' data access
	• Training in data collection and curation • Training in selected analysis tasks	Medium priority, requires development of business model	• High-value jobs	• Financial performance • Social performance by way of high-value jobs		• Participation in university training as part of research collaboration • State-level subsidies are available for VET training.
Automation of decision making	• Advanced analytics (within sheds)	High priority, where producers have data available	• Decision making interacts with data systems	• Financial performance • Positive animal welfare outcomes	Options: • Producer • Third-party consultant	
	• Advanced analytics (producers and processors)	High priority, where demonstration effect can be made	• Decision making interacts with data systems • Real-time data delivery and response • Reduced costs • Higher-value products	• Financial performance, by way of better sales decisions, fewer rejects	Options: • In-house development • Third-party consultancy	Payment for services Levy on data supplied
	• Training in acquisition and interpretation of analytic output	High priority, transformation is imminent or underway	• More efficient use of staff time	• Social and community performance by way of high value jobs and improved WHS		State-level subsidies are available for VET training

Table 10-1(c) addresses the use of data in advanced analysis, both the technical matters of how data is transmitted and handled for analysis, and the commercial organisational matter of who might provide services and under which business model. Benefits projected from these strategic address improved performance and profitability, as well as the enhanced capacity for using information in marketing: the development and delivery of a narrative around the product. Training, a subject encountered at many points in the scoping study, is presented here as an enabling factor for advanced analytics: learning how to use analytic results on one hand, and learning to manage automated decisions and related information flows on the other. Investments in training are assigned priorities associated with the extent to which firms and farms have established targets for, or elements of, their business models for the post-digital transformation environment.

10.3. Sources of funds

The final columns of Tables 10-1(a) to 10-1(c) identify investors and funding options. Financing is treated simplistically here to include flows of funds similarly as for investment sums. This is because the key task in such financing is to recognise and mobilise the value of data, which is represented by flows of funds that would ostensibly fund investments over time.

The principles followed in these nominations are essentially that the user pays, with opportunities recognised for shared cost burdens where whole supply chains are beneficiaries of change or where the entire industry can be considered a beneficiary. Opportunities appear where synergy with a partner's initiative occurs, such as participating in government's digital transformation plans at state or federal level by employing digital approaches to tasks such as compliance monitoring. Other opportunities are embodied in research projects, where investments by firms and farms can be leveraged with research grants. Notes are included about such potential sources of funding. Investments in governance, such as certification for use of data according to a Code of Practice, may generate user fees. The principle of user pays is extended in Tables 10-1(a) to 10-1(c) to the potential for producers to be paid for submission of some data, or to be paid bonuses over contracts for provision of objective proof of performance in dimensions such as animal welfare or narrowness of weight distribution.

10.4. Progress with digital transformation and tool development

A number of management tools have been proposed or implicated in this study:

- A measurement tool for digital maturity;
- At farm level, an assessment tool for digital technology uptake, barriers to uptake, data sharing behaviour, and the relationship between digital transformation and innovation, and a basis for gap analysis;
- A balanced scorecard for firms' progress on digital transformation; and
- A suitable, and widely applied and calibrated, analysis method for investment in digitally related assets and equipment, and in more general changes related to digital transformation.

A digital maturity measurement tool has been developed for agribusiness by Zhang et al. (2018) and is proposed here for use by poultry processors and producers (Figure 10-2). A farm-level survey on the above topics was prepared as part of this project (Figure 10-3). A balanced scorecard would provide a management tool based on these two instruments, developed in consultation with firms. The investment analysis tools would ideally be integrated into firms' bespoke decision support software, so the Microsoft Excel-based prototype presented here is intended to promote such development.

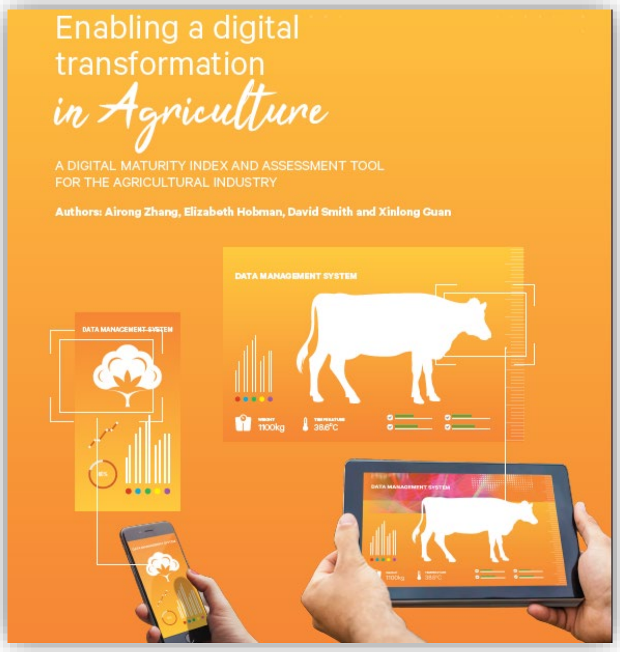


Figure 10-2. Digital maturity measurement tool

Source: Zhang et al. (2018)

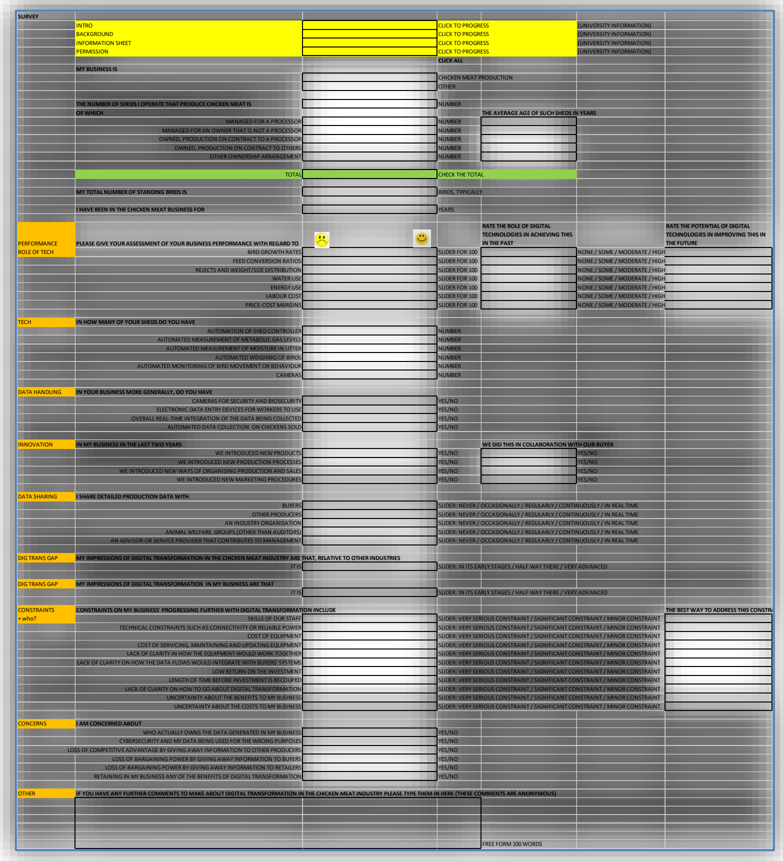


Figure 10-3. Farm-level survey instrument for digital uptake and innovation and gap analysis

Figure 10-4. Investment analysis tool

11. Conclusions and next steps

11.1. Overview of project

This scoping study explores the potential for, or 'power' of, digital innovation within the Australian chicken meat sector. It centres on the technical, organisational and institutional drivers of, and barriers to, exploitation of data so as to 'unlock' its power. The first stages of the project entailed compiling individual firms' views on what that power is, and how much of a gap existed between existing and desired exploitation of it, and establishing a collective vision of the industry's future and the steps necessary to harness digital transformation in achieving it.

The second stage of the project entailed a scoping study. This drew together relevant commentary and other information to inform decisions on digital transformation. Features of the Australian chicken meat industry and supply chain conditions are well documented, and these were briefly summarised to provide context to digital transformation. Substantial work has already been done on technology-related issues in Australian agriculture, and this work is reviewed where relevant to the chicken meat supply chain and industry as a whole. Research and commentary from Australia and abroad, and previous modelling work on the production sector, were reviewed to establish relevant features of the value proposition for digital transformation in Australian chicken meat. Barriers to change, and potential delivery models for change, were also included to inform later analysis. A multi-stage equilibrium displacement model was used to characterise the distributional aspects of investment and return as they confront industry stakeholders. A systematic literature review was conducted to identify relevant technologies, and their state of development, in delivery of the key data as defined by the project's industry partners.

An intermediate output of the project was the scoping study's identification of key technologies. Candidate technologies were identified from the literature review, which was then mapped according to its scope for delivery of the key data. A set of 19 criteria for selection of technologies was established from the elements of the scoping study, and a systematic assessment procedure was used to select three key technologies.

Based on the scoping study, a set of strategic actions was formulated and key considerations in their implementation were established. On this basis, a flow chart-style roadmap was prepared to bring the scoping study's results to bear on strategy: actions, investments, milestones and goals. Scoping study findings were also used to propose investors, funding and payment mechanisms, and sources of funds. The final output of the project is this strategy and roadmap.

11.2. Conclusions drawn

The project identifies a number of features of the Australian chicken meat industry that are indicative both of past success, and of the very significant contribution that digital transformation can make to future success. These include the product's market placement from a commodity towards credence-based value addition, the industry's heavy and informationally intensive regulatory and compliance environment, and the vertically co-ordinated nature of the supply chain with conflicting incentives for data generation and use on one hand, and data sharing on the other. Past research has identified deep producer dissatisfaction with existing data governance, to a greater degree in poultry than in any other Australian agricultural sector. Current development of elements of data rules for Australian agriculture is presented by Wiseman and Sanderson (2019), with development of trust highlighted as a goal.

The project was able to draw on a substantial body of Australian research and commentary on farm-level adoption, particularly in association with digital technologies. As for other sectors, preferences, fears, costs, skills and risks all were cited as barriers in chicken meat industry consultation, both at farm and processing level. The lack of suitable tools for analysis of the associated investments, and the (related) inability to envisage new business models that would exploit the digitally enabled business, were repeatedly cited. These barriers are unique neither to chicken meat nor to agriculture, but rather are widely acknowledged across the new but developing field of study concerned with digital transformation for business.

Another evolving field is that of mechanisms for delivery of data-energised management information for decision support. The current study identified a number of emerging models, particularly third-party services and data-sharing platforms, which provide vastly different business interfaces with data than a conventional purchase of software by a firm. Many hybrid models also exist, where platforms are implemented within a single supply chain.

Past modelling of the chicken meat industry's potential gains from uptake of technology (primarily associated with precision agriculture) had projected a modest gain to producers. Modelling conducted in the current study profiled more completely how benefits from a variety of digital transformation scenarios are distributed. The results confirmed that producers' gains are dwarfed by those accruing to processors, retailers and consumers. However, the extent to which this occurs depends on the type of digitally related benefit occurring. Notably, increases in farm productivity, and actions taken to increase consumer demand, both deliver benefits to producers and processors to an extent that other scenarios do not. This supports the results of previous modelling, which identified advances in shed management as having a high investment return, but contradicts it in terms of showing limited return, for example, to labour reductions. The model used is available for analysis of further scenarios.

The project's literature review yielded 91 peer-reviewed journal articles featuring the application of digital technologies to tasks associated with generation and use of key data as defined in the industry consultation and design workshop. The inter-disciplinary targeting of the review meant that the papers were overwhelmingly drawn from just a few high-quality journals. Mapping of the technologies encountered to the data required revealed substantial concentration of technology development. Optical devices (cameras of various kinds) are applied heavily in weight estimation, observations on flocking behaver, and identification of animal health and welfare problems. Environmental sensors are applied in relating shed conditions to many elements of bird productivity and growth, particularly when empowered by integrated and networked data systems with predictive algorithms and enhanced by machine learning. Gaps in the literature review included, predictably, an absence of investment analysis and little coverage of individual cost items, particularly labour.

The various elements of the scoping study provided the criteria for selection of key technologies. A ranking procedure delivered the result that the three most important technologies to Australian chicken meat are optical devices and atmospheric sensors, and technologies associated with weighing birds. Notably, these three technologies span almost all the criteria applied. The rating and ranking procedures used have been retained, and the tools used are available for re-use.

The industry does not view digital transformation, nor indeed technology, as an end in itself, but rather a means to an end. The narrow set of stated goals then lend themselves to construction of a roadmap and list of strategic actions. These feature, as expressed early in the project, making better use of existing data, and mobilising data sharing along the supply chain. Integration of various forms of data and use of advanced analysis are also to be pursued. Skill constraints are addressed by training. There is a need to substantially alter incentives and governance arrangements for data sharing along the supply chain. Few conclusions could be reached on choices between delivery modes, such as within-firm software purchase or whole-of-chain data-sharing platforms, so these choices are left open in the proposed strategy. Payment streams and investor stances are also proposed, along with potential sources of funding of development projects.

11.3. Limitations of the work

There were limited communications (telephone, video recordings) for project updates and ongoing consultation in early to mid-2020. The consequent desktop approach has promoted the researchers' view, and more particularly the scoping study-based synthesis of options and evidence through to conclusions. Industry reaction to the report, and possible refinement and redirection of it, is anticipated.

11.4. Next steps

Following this report's finalisation, its strategy and roadmap will be iterated with firms and with industry as a whole. A final set of strategic actions will emerge, and be much more precisely allocated among chicken meat industry stakeholders. This process requires significant communications and consideration at the farm level, along supply chains, between processing companies, and with external interest groups and regulators.

Final lists of strategic actions can then be designed for scale, reach and targeting, and costs can then be calculated. A set of decision-support tools have been produced as part of the project, and these can be further developed and applied to the planning tasks at hand. All elements of the scoping study are available for re-use and re-application, and so can accommodate shifts in decision criteria and strategic emphasis.

Appendices

Annex 1: Papers included in literature review

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Annex 2. List of people consulted

Name	Organisation
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Sander Lourens	Hatchability, Netherlands
Aiden Connelly	Cainthess, Ireland
Julie Moriarty	NSW Environmental Protection Authority
Kristof Mehrtens	Porphyrio, Netherlands
Helen Thompson	Federation University, CERDI
Dylan Bradley	HIMARKIT CEAS Consultants, UK
Pema Wangchuk	PIRSA
Alexander Walrut	Sedex Global, Australia
Henrik Bang Jensen	Danish Agriculture and Food Council
Laurie Bonney	University of Tasmania, Sense-T
Morten Jørgensen	Lyngsoe Systems, Denmark
Anders Langballe	Lyngsoe Systems, Denmark
Guy Hebblewhite	Chicken producer, Tamworth NSW
John Deste	MTECH Systems (Australia)
Graham Kirby	PROTEN
Ashley Etherington	Inghams
Peter O'Neill	Inghams
Adrian Wilson	Inghams
Tim Byrne	Inghams
Gerard Springer	Woodlands
David Greaves	Darwalla
Juan Corredor	Darwalla
Jonathan Millard	Darwalla
Mark Heintz	Hazeldenes
David Parrott	Cordina
Jorge Ruiz	Baiada

Annex 3 Elasticity values upon which EDM assumptions are based

Elasticity of supply of chicken meat		
Author	**Year**	**Estimate**
Bhati	1987	0.90 (medium run)

Elasticity of demand of chicken meat		
Author	**Year**	**Estimate**
Bhati	1987	-0.36 (medium run)
Mounter et al.	2012	-1.37 (AIDS)
		-0.30 (Rotterdam)
		-0.27 (LA/AIDS)
Tighe et. al	2019	-0.29

TABLE 4. RETAIL ELASTICITIES OF DEMAND FOR CHICKEN IN AUSTRALIA

Year of Publn.	Researcher	Market Level	Geog. Coverage	Change in CHICKEN consumption from a change in the price of				in	Data Period	Data Set	Method	Functional Form
				Chicken	Beef	Pork	Lamb	Income				
1970	Paton	Retail	Aust.	-1.31			0.42		A	1954 to 1969	OLS	Double log
1979	Fisher	Retail	Aust.	-0.23	0.28	-0.27	-0.25	0.20	Q	1962(1) to 1977(2)	FIML	Modified Translog
1979	Fisher	Retail	Aust.	-0.16				0.16	Q	1962(1) to 1977(2)	FIML	Double log
1984	Murray	Retail	Aust.	-1.14	-0.19	0.01	0.02	1.34	A	1949-50 to 1978-79	SUR	AIDS
1984	Murray	Retail	Aust.	-0.65	0.26	-0.06	0.08	0.57	A	1949-50 to 1978-79	SUR	Translog
1984	Murray	Retail	Aust.	-0.40	0.61	0.08	0.12	-0.49	A	1949-50 to 1978-79	OLS	Indirect Addilog
1985	Martin/Porter	Retail	Aust.	-0.31	0.18	-0.15	0.00	0.34	Q	1962(1) to 1983(1)	OLS	Log difference form
1985	Dewbre *et al*	Retail	Aust	-0.77	0.12	0.02	0.06	0.29	A	1964-65 to 1982-83	OLS	double log
1987	Alston/Chalfant	Retail	Aust.	-0.31	0.12	-0.01	0.08	-0.93	Q	1968(1) to 1983(1)	OLS	Double log
1987	Alston/Chalfant	Retail	Aust.	-0.37	0.21	-0.14	0.08	0.17	Q	1968(1) to 1983(1)	OLS	Double log
1991	Cashin (p)	Retail	Aust.	-0.47	0.03	0.26	0.12	0.06	Q	1967(1) to 1990(2)	SUR	LA-AIDS (a)
1991	Cashin (p)	Retail	Aust.	-0.23	1.07	-0.11	0.99	1.11	Q	1982(1) to 1990(2)	SUR	LA-AIDS (a)
1996	Piggott *et al.*	Retail	Aust.	-0.46	0.34	0.23	-0.10	0.18	Q	1978(3) to 1988(4)	OLS	Double log

OLS: Ordinary Least Squares, SUR: Seemingly Unrelated Regression, FIML: Full Information Maximum Likelihood Estimates
Q: Quarterly data, A: Annual data, AIDS: Almost Ideal Demand System
(p) Pigmeat and Pork estimate respectively

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