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Big Data, Trust and Collaboration

Exploring the socio-technical enabling conditions for big data in the grains industry

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Research Report

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1 Executive summary

1.1 About the research

'Digital agriculture' offers the potential to deliver a step change in productivity and/or profitability across the value chain. However, realising this potential benefit requires conducive social and institutional conditions. To increase understanding of these conditions, we conducted a study of grains industry stakeholders' perceptions of, and experiences with, digital technologies and big data in agriculture. The study explored how big data is understood by these stakeholders (in particular, its perceived benefits and risks) and whether it is seen to integrate with existing supply chains and relationships. Our study paid particular attention to how big data may affect relationships between members of the supply chain, and, the role that trust plays in mediating potential risks and benefits for, and between, different actors.

> "The term big data is typically used to refer to computerised analytical systems that interrogate extremely large databases of information in order to identify particular trends and correlations" (Keogh and Henry 2016: 4).

We interviewed twenty-six grains industry stakeholders to explore their perceptions of, and experiences with, digital technologies and big data in agriculture. The stakeholders that we interviewed included growers, input providers, grain handlers and providers of advisory services in the Wimmera-Mallee region of Victoria, as well as representatives of government, grain trading, research, development and extension (RD&E), agri-business, and industry representative and commodity associations.

1.2 What does big data mean to grains industry stakeholders?

When asked what 'big data' means, several interviewees described it as the 'next step on' from precision agriculture technologies. It was often described in terms of a potential or emerging ability to improve on-farm decision-making. It was expected to provide new insights or to identify and solve complex problems that were currently not 'visible' in the farming system or supply chain. These views were most commonly held by non-grower interviewees. However, many interviewees (often, but not always, growers) were uncertain about the likely benefits or otherwise of big data. They were unsure what 'big data' actually looked like in practice, or how it differed from precision agriculture or other digital technology applications in agriculture.

Overall there was considerable variation in the level of understanding or engagement in ideas about big data amongst the grain industry stakeholders that we consulted. Different stakeholders had different views as to whether big data applications should support or replace farmer decision-making. This suggests that proponents of big data need to better explain and demonstrate the practical implications of these technologies in a way that supports individuals and organisations to develop an informed view that fits within a variety of famer values, styles and motivations.

We also asked participants how they saw the application of big data merging with broader social and economic trends in the grains sector and farming more generally. Compared to other participants, representatives of industry and grower groups had the clearest views on this subject. They saw big data intersecting with:

- the shift towards precision and prescription farming;
- structural changes towards fewer, larger farming operations;
- the changing demography of farming communities;
- the application of digital services to support local and regional economic development;
- growing consumer and processor demand for improved traceability and segmentation in the grain market; and
- the emergence of new niche markets and marketing strategies.

In contrast, continued concerns about the limitations of digital infrastructure in rural and regional Australia was highlighted as a factor that could work against the uptake of big data applications.

1.3 What are the benefits of big data?

Benefits of big data to growers or the industry at large were largely spoken about in 'future' terms, with current benefits described as 'patchy'. Interviewees anticipated several benefits including:

- improvements to on-farm productivity and profitability through greater efficiencies in inputs;
- improved yield and market forecasting; and,
- improved capacity for real-time decision-making by growers.

Stakeholders engaged in logistics (storage, transport and shipping) emphasised that big data would support supply chain optimisation through more accurate predictions of yields over large areas and the tracking of grain volumes and flow rates. This would enable grain handlers to improve their planning and resource allocation. Marketers and traders saw benefits in improved estimates of export demand and market futures.

1.4 Which growers are likely to benefit?

According to our interviewees, the capacity of different grains supply chain actors to engage with or benefit from digital agriculture (including big data applications) is highly varied, especially amongst farm businesses. There were cases of growers who were investing heavily in digital technology, sensing, automation and other data intensive elements of their business in readiness for future big data applications. These growers reported that they were already realising significant benefit from that investment. However, our analysis suggests that farming enterprises may respond to digital disruption in varied ways due to the structure of their enterprise and existing information and advice networks. Those farming enterprises that have greater levels of value chain integration and higher quality information and advice networks may be more likely to benefit. Conversely, businesses with less dense advice networks that are less integrated into the value chain may be more exposed to risk.

1.5 What are the costs and risks?

Digital agriculture technologies and big data applications were also expected to bring costs or risks. These fell into three main categories: social and institutional, technical, and financial. By far the greatest concern related to the potential for third party (especially large corporation) use of, and benefit from, data generated in the course of farming operations. The language of data 'ownership' and 'security' was often used by growers and other participants, however the underlying concern here related to issues of *transparency*. There was a desire for clarity in terms of who would be using the data, for what purpose, what value this generated, and how benefits would be distributed.

Issues of *trust* appear to be central to these concerns about ownership and transparency, which are grounded in perceptions of an uneven distribution of benefits. There was a commonly held view that, under current settings and capacities, businesses upstream and downstream of the farm gate (i.e. input suppliers and manufacturers, traders and marketers) are positioned to derive greater, or perhaps more immediate, benefit from big data applications. This was seen as due to their capacities to gather, aggregate and apply large data sets within their existing business models.

1.6 Recommendations

Responding to the concerns and opportunities outlined above requires working both individually (with businesses and farming enterprises) and collectively (across the sector and value chain).

The primary recommendation from this study is the need to:

- Invest in building the capability of growers and farm businesses to be both informed data **consumers** as well as **co-creators** and **curators** of data, by involving growers and their trusted information and advisory networks in the cooperative development and trialling of these systems.

Given the variability in understanding of big data and its benefits, together with participants' concerns that large corporations are positioned to derive much of these benefits, more needs to be done to involve growers, their trusted information and advisory networks and their representative organisations in the cooperative development and trialling of digital agriculture technologies and big data applications. Currently, grower cooperatives and industry associations are active in developing new business models incorporating data-related services. However, these activities are largely occurring in the absence of agreed overarching governance arrangements. Nonetheless, these boundary organisations will be critical intermediaries in socialising, tailoring and embedding these technologies and services in local farming cultures and industry practice. For many growers, these organisations will be critical for buffering risk, navigating complexity and ensuring that the value of big data applications is captured at the farm enterprise level.

Identifying the underlying values and assumptions about the benefits and risks of these potentially transformative technologies is critical to developing acceptable governance responses. This includes dealing with concerns of transparency and trust and uneven benefit. Social researchers

can work in a participatory way with industry and RD&E stakeholders to help develop these responses.

Activities to help achieve these outcomes could include:

1. Conducting case studies showcasing experiences with big data applications across the supply chain. Ideally these would showcase “easy win” high impact data integration initiatives that would capitalize on existing but underutilized data sets and demonstrate the value of collaborating to join up data.
2. Providing plain English advice to farming businesses about the practical and legal issues surrounding data privacy, security and ownership.
3. Facilitating industry level dialogues via farmer groups, industry associations or cooperatives about best practice principles for data sharing, transparency and equity of outcomes derived from big data.
4. Evaluating the suite of emerging data service and governance models for data sharing, transparency and equity.
5. Identifying opportunities to establish new training or advisory services for digital agriculture.

2 Introduction and aims

This research supports efforts to derive greater value from digital agriculture through big data applications by providing insight into the social context for these initiatives. Specifically, we carried out interviews with representatives of stakeholder groups to explore:

- How stakeholders understand the concept of big data and its associated risks and benefits;
- How big data applications integrate (or do not integrate) with existing practices and emergent trends in the agricultural sector.

These questions were designed to provide early insight into the types of perceptions or actions needed to support the effective and acceptable use of big data initiatives in Australian agriculture. However, since the applications of big data are likely to vary across different agricultural sectors, we began our research by focusing on one of Australia's largest agricultural industries where digital agriculture applications are emerging, namely, the grains sector.

> "…there is a data revolution underway that constitutes a key moment in evolution and mutation of data assemblages. Due to the confluence of several emerging developments in computing, methodological techniques, and the political and economic realm, the volume, variety, velocity, resolution, and availability of data, and how data are being processed, analysed, stored, and employed to leverage insight and value, is being radically transformed." (Kitchin 2014: 26)

Along with cloud computing, social media, artificial intelligence, robotics and mobile applications, big data represents a form of digital technology with the potential to transform the way in which business is carried out in many different sectors. Big data refers to the capability to extract information and insights at a large scale where previously it was economically and technically not possible to do so (Sonka 2015), through the use of "computerised analytical systems that interrogate extremely large databases of information in order to identify particular trends and correlations" (Keogh and Henry 2016: 4). Kitchin (2014) provides a useful overview of the nature of and influences on big data, which we illustrate in Figure 1.

The exponential growth in the capacity and applications of digital technology is creating what many refer to as 'digital disruption'. Digital technology is changing not just how we do things but more fundamentally, the value proposition associated with goods and services. In the process, some (often new market entrants) are prospering and others are left behind. There is no formula for success in the digital economy but those industries and firms which are investing in technology are generally showing improved productivity over the long term (Brynjolfsson and Hitt 2003, Cardona, Kretschmer, and Strobel 2013, Stiroh 2002). Individually, Australians are enthusiastic adopters of digital technology but Australian businesses have been relatively slow to adopt digital technology (ABS 2013, Sensis 2013) and experts warn that Australia is at risk of falling behind in an increasingly global digital economy (Mason, O'Brien-McInally, and Dane 2014). The slow uptake of digital technology by Australian businesses can be attributed to many factors, including the high cost of access and uneven roll-out of high-speed broadband across the nation (ABS 2013). However, lack of confidence and understanding of the benefits associated with digital technology

has been found to be a key determinant of willingness to engage with digital technology (LonerganResearch 2013, Yamine et al. 2014). Deriving benefit from digital technology such as big data is not just a technical challenge, it also represents a social and institutional challenge. Once the technology is available, we need individual and collective capacity to be able to use it to its full potential.

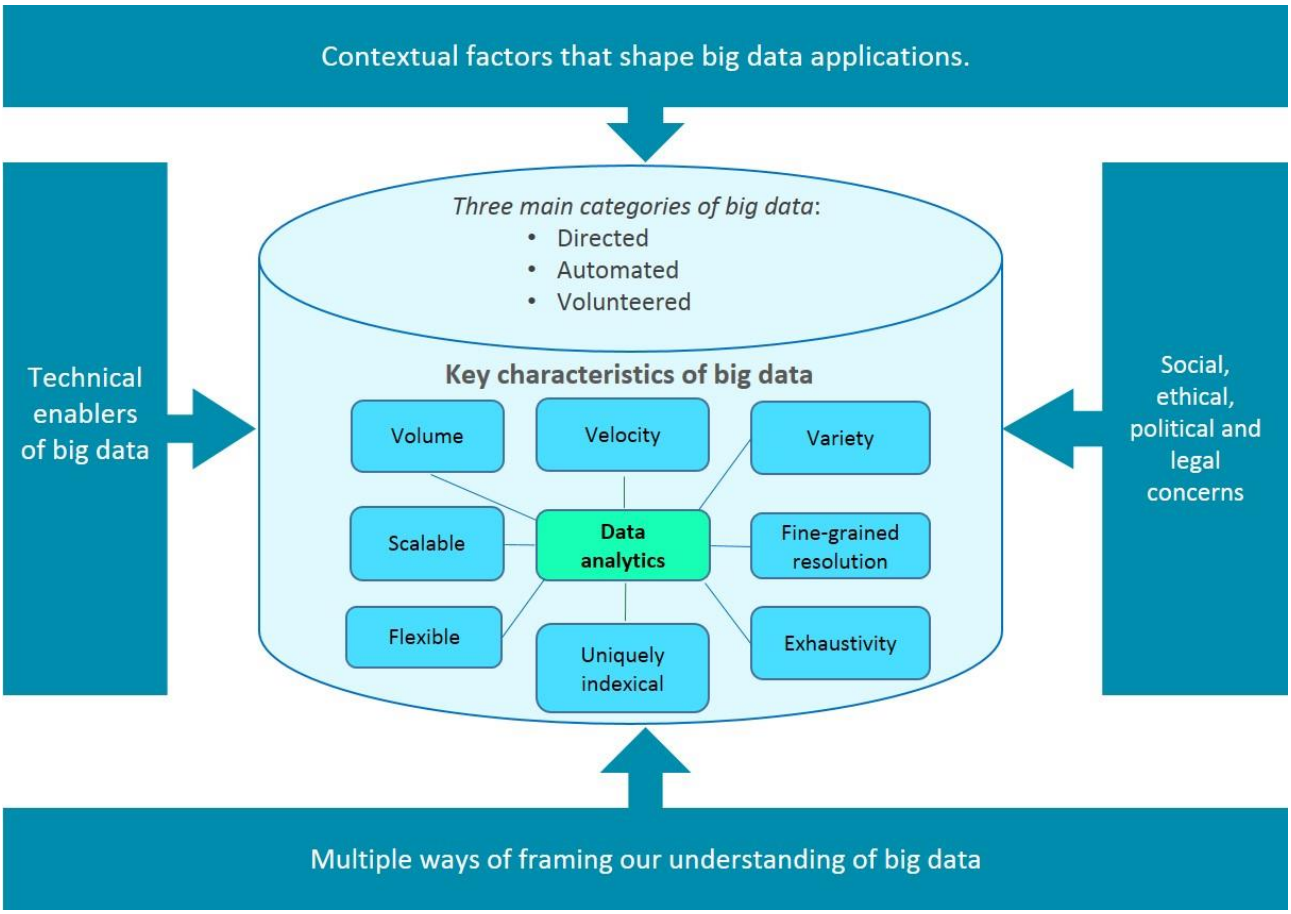

Figure 1 Conceptual framework for understanding big data, drawing on Kitchin (2014)

Big data applications (e.g. Kirby Smart Farm, Qld Digital Homestead, Sense-T) are already being deployed to improve productivity and profitability and minimise risks within agriculture. Analysis of these early experiences with big data reveals that their success hinges upon multiple factors. These include the willingness of stakeholders to share and integrate data, end-user acceptance of the technologies, and the existence of protocols for protecting farmers' rights to privacy and data ownership and control (Eastwood and Yule 2015, Griffith et al. 2013, Kaloxylos et al. 2014, Poppe et al. 2015, Sonka 2015). Consequently, big data applications are socio-technical in their nature, their development and deployment being a product of social interactions between people, institutional and regulatory settings, as well as the nature of the technology itself (Vines, Jones, and McCarthy 2013). In this respect, big data applications may be similar to other agri-environmental decision-support technologies that rely upon multi-stakeholder collaboration (Carberry et al. 2002, Jakku and Thorburn 2010) and trusted local networks and intermediaries that buffer farmers' perceived risks and enhance local benefits (Taylor and Van Grieken 2015).

This study sought to identify those social factors that could enable or constrain the development and adoption of big data applications in Australian agriculture. We focused on those social factors

that have been found to influence uptake and outcomes associated with technology more generally. These include stakeholders' perceptions of the risks and benefits of the technology and the extent to which the technology is seen to be compatible with existing practices and relationships (Rogers 1995). In doing so, our goal was to identify any practical policy and management actions that would facilitate the effective utilisation of big data applications in agriculture.

3 Methodological approach

Our research adopted a qualitative case study approach, which allowed us to empirically explore perceptions of the benefits and risks associated with digital agriculture and big data applications in the Australian grains industry. With the help of subject matter experts from within CSIRO Agriculture, we characterised and mapped the key supply chain actors in the grains industry and selected interviewees using a purposive sampling approach (Patton 1990), where we collaborated with key informants to identify and recruit participants from different sectors within the grains industry.

We conducted semi-structured interviews with 26 grains industry participants: 14 participants from the dryland broad acre and mixed farming systems regions of Wimmera and Mallee, Victoria to provide regional level grains sector insights; and 12 policy and institutional participants from the grains industry at the state and national level (see Table 1 for details).

Table 1 Interview participants by stakeholder category

STAKEHOLDER CATEGORY	NUMBER OF INTERVIEW PARTICIPANTS		
	Wimmera-Mallee region	**Policy and institutional level**	**All participants**
Input provider	1	3	4
Grower	5	0	5
Grower group	4	4	8
Research & consulting	1	2	3
Logistics & trading sector	1	1	2
Local government	2	0	2
State government	0	2	2
Totals	**14**	**12**	**26**

Interviews were generally one hour in duration and nine were conducted face-to-face in the Wimmera-Mallee region, while the remaining 17 interviews were conducted via telephone. The interviews started by covering some background information on individual participants. This was followed by questions about their place within the grains industry supply chain and their views on information flows and trust relationships among key players. The specific questions in this section were:

- What does the supply chain look like for your business? For instance, who are the main players and how are they connected?
- How does information move between your business and others across the supply chain?
- From your perspective, how do you establish and maintain trust between your business and others you work with?

The next section explored perceptions of and experiences with digital agriculture and big data initiatives. The key interview questions in this section were:

- When people talk about digital agriculture and big data, what does that mean to you?
- How much is big data part of your current business or future strategy?
- What benefits or opportunities do these digital technologies and big data applications provide?
- What problems or risks do they present?

The final section explored ideas about how these risks might be managed or reduced and some final reflections on the future of digital technologies and big data in the grains industry. The specific questions in this section were:

- What do you think are the main challenges or changes in relation to digital agriculture and big data that are likely to impact on the grains industry in the next 5-10 years? What are the big trends you see coming up?
- Who do you think should be responsible for managing information or data flows along the supply chain, e.g. governments, corporates, farmer groups or farmers?
- What does this mean for current groups or businesses in the grains industry? Are there going to be winners and losers?
- What types of processes, rules or incentives might help to manage or reduce some of these risks (e.g. protocols, practices, partnerships, support etc.)?

The interviews were digitally recorded and professionally transcribed. We used the qualitative data analysis software QSR NVivo® (QSR International, version 10) to aid the coding, analysis and management of the data. Interview data were categorised into a hierarchical structure of themes and sub-themes through multiple rounds of coding, informed by (and informing) our analytical framework.

4 Findings from the study

4.1 What does 'big data' mean to grains industry stakeholders?

One of our key interview questions was: "When people talk about digital agriculture and big data, what does that mean to you?"[1] Interviewees' responses to this question are represented schematically in Figure 2. A large number of interviewees connected big data with precision agriculture (see Figure 2 for an overview).

> Well, definitely the precision farming but also the use now of, or the access of satellite data and the ability to monitor crops on an almost real-time over large areas, I mean, for me, that's the main focus. (Input provider 2)[2]

Big data was also commonly connected with the idea of improving on farm decision-making.

> Marrying the data along with some of the decision tools to give growers the ability to make better decisions on farms. (Grower group 8)

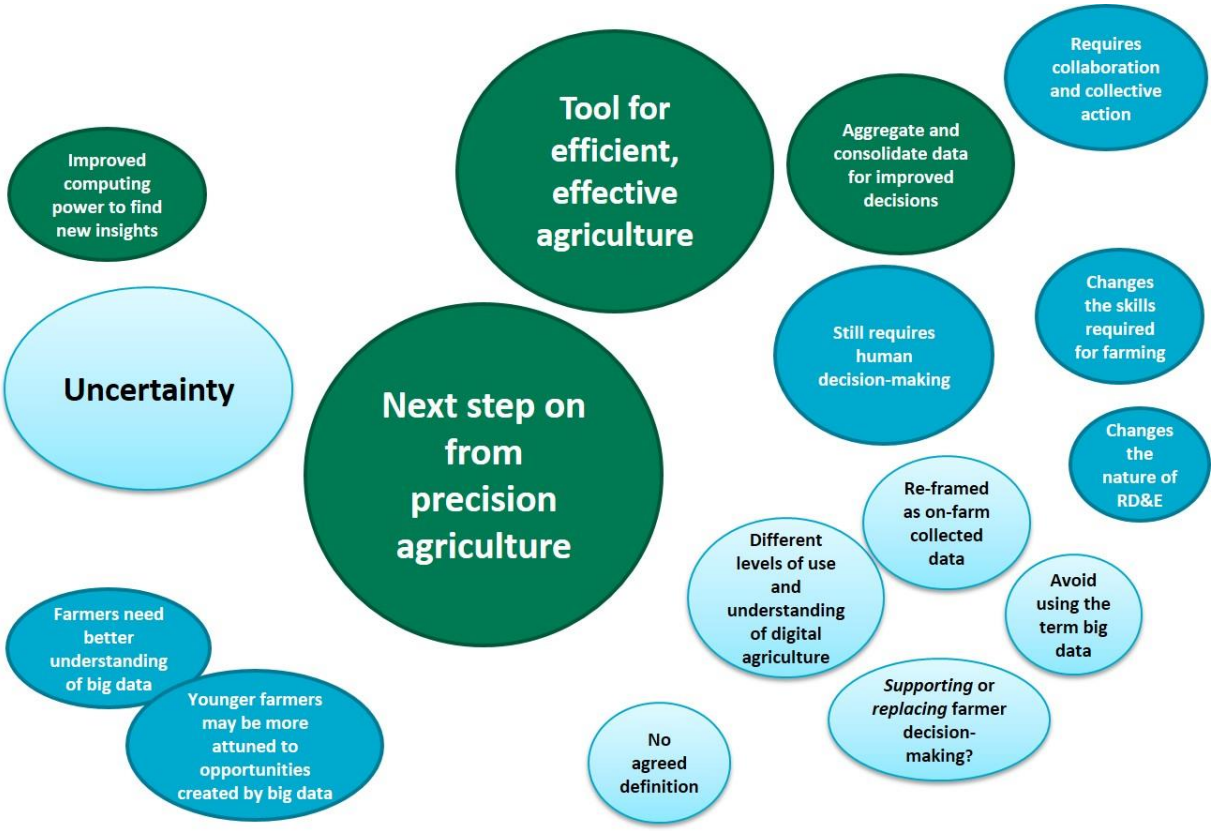

Figure 2 Overview of how participants talked about big data, based on a cluster analysis created in QSR NVivo. The shapes represent sub-themes within our data clustered according to similarity (green: perceptions; light blue: framing; dark blue: social implications). The larger the shape the more frequently it was mentioned by participants.

The emphasis of most participants was on big data being useful to inform growers to make better decisions, and provide a background of evidence to make the decision-making process clearer and

[1] We provided our participants with a project information sheet, however this did not include any definition of digital agriculture or big data applications, to avoid influencing participant responses.

[2] Interview participants are coded according to their stakeholder category to protect their confidentiality (see Table 1).

easier. For instance, one of the input providers described the way in which digital agriculture can help growers make better decisions:

> So we know that technology can help them make better decisions increasing the yield today. (Input provider 1)

Others also saw big data as offering the potential for new insights and learning and answers to specific agronomic questions, as described by this interviewee from one of the grower groups:

> It can solve a very simple problem for me, which is should I put nitrogen on today and how much. (Grower group 2)

The potential for gaining new insight from big data was largely recognised as coming from a new way of processing the data, rather than access to new types of data. Processing larger amounts of data and connecting more data sets was seen as beneficial to allow new insights:

> It's just a matter of having the computing power or having the ability to actually sort - physically sort through it all, isn't it? That's the trick, and I suppose it's trying to find little things, little things that possibly we wouldn't have focused on before. (Grower 2)

Slightly contrary to the perspective that big data was just about new ways of processing data was the idea that it takes new skills to properly apply and interpret the results of big data systems and analysis, as identified by this grower:

> It will change the skills, over time, required to be a successful farmer. (Grower 1)

Developing new skills would require collaboration, to access and build the necessary capability. Improving collaboration was generally recognised as an issue to address across the whole industry. Existing structural, institutional and individual differences and associated low levels of trust were identified as barriers to such collaboration. This interviewee from a grower group highlighted the challenges around working together in the grains industry, given the recent history of deregulation:

> While broad-acre grains is so deregulated, there needs to be some work to actually tackle why people might want to work together. (Grower group 5)

In general, big data was viewed positively, although there was a high level of uncertainty about exactly what the positive effects would be, as highlighted by this input provider:

> I don’t doubt that for our business here, that big data’s going to be good. I just don’t know what it’s going to be good for. (Input provider 4)

However, some interviewees were concerned that big data could potentially have a negative effect. For instance, this grower pointed to concerns about the complexity of big data applications:

> I think, being able to access big data for the sake of being able to access it, there is no benefit and it will add complexity to people’s lives. (Grower group 4)

This was in part because of some confusion around what big data was. It was seen as a hyped up term with no agreed definition, with the result that there was uncertainty around what it might mean in practice. One participant even joked that big data was like teenage sex because everyone was talking about it but no one was doing it.

The differing levels of understanding and engagement with big data was noted by a number of interviewees and there was a perception that the "younger generations" (Grower group 7) were more likely to be engaging with big data, but that this was currently a minority of growers and that more information and support would be required to ensure industry wide benefits. An important aspect of understanding big data was around seeing it practically applied:

> The best way people will learn and understand the value of it is if they can see some examples. (Research & consulting 3)

There was a difference of opinion about whether big data applications should *support* or *replace* farmer decision-making, which was associated with ideological positions related to how they saw farming and being a 'good' farmer (Carolan 2016). Some interviewees were concerned that everyone would be farming the same way in the future and noted that diversity in farming approaches was a positive and necessary thing for the industry to maintain:

> I'm getting a bit philosophical here, but in agriculture you have a bit of a tussle between, sort of, industrialised, highly efficient, high capital agriculture and your very artisanal approach to agriculture, and there's a lot of emotion built up around that. (Input provider 2)

> So we're complete polar opposites with the way they farm. And they're happy and they make money and that's all good... It's like have you got the formula right yet? Is that the formula you're using forever? And it's like no, no, no. You don't understand. (Grower 3)

Differences in farming styles and motivations may need to be considered by proponents of big data to explain and demonstrate the practical implications of these technologies in a way that supports individuals and organisations to develop an informed view that fits with their worldview.

> I don't think you'll ever get, like, equal participation from growers, but I think you'll find that all growers will participate in some way. (Grower group 1)

4.2 Big data in the context of other major industry trends

When asked about future trends in the grains industry, an increasing focus on digital agriculture was the biggest future trend discussed by participants, as illustrated by this interviewee:

> I think, that digital agriculture, particularly precision-ag, that's the new frontier from my perspective, it's about the only trend that I can really see. (Grower group 4)

Closely tied to this trend was the perception that information and data were becoming more valuable, although their value was yet to be fully realised.

> I don't think that growers are actually accessing the value yet. (Grower group 5)

The key trend of digital agriculture was seen to be linked to other future trends too, such as changes to farming and rural communities and new markets developing. Big data potentially creates changes to farming and rural communities by supporting farms getting bigger in the future (by enhancing off-farm management).

> Big data and automation and all that…will absolutely drive up farm sizes, because growers will be able to do more with less time. (Grower group 4)

Increasing farm sizes also relates to potential demographic and labour issues in farming. On the one hand, technology might make farming more attractive by adding interest and increasing profitability. On the other hand, it could act as a deterrent, if infrastructure limitations become a

barrier and farming moves away from more “artisanal” (Input provider 2) approaches. Other participants were confident that farming would always have a range of different motivations and ways to farm, and engagement with the latest technology is only one aspect of that.

Big data was also seen as enhancing the development of new niche markets for specific grain varieties – which in the past would have been unidentifiable and amalgamated with other grain:

> The consumers themselves may want to buy food according to attributes of the whether it’s got health attributes or whether it’s from a sustainable production system, and so on. And so, again, the processing sector is moving into this realm of big data and the use of unique IDs, like livestock numbering systems, and so on, they’re becoming increasingly important. (State government 2)

This was seen as an important opportunity for Australian growers because of high demand as well as increased competition for the international markets in Asia and the Middle East:

> So, you know greater share of the Australian grain crop is actually going into a domestic market for animal feeds and human consumption rather than export. Those sort of international market factors drive a lot of change. (Grower group 3)

Related to the development of new markets is the opportunity for improved marketing, in terms of understanding and predicting market trends through data analysis.

> Well look, I definitely see the marketing aspect of – it’s going to become more digitalised. (Grower group 7)

Other future trends that were seen to be related to big data included genetic modification and the focus on integrated management, incorporating biological, chemical and operational pest management.

Another future trend relates to changes within public and grower-funded RD&E agencies. Several interviewees remarked on what they saw as an increasing focus of public R&D agencies (e.g. GRDC, CSIRO, government departments and universities) partnering with and enabling market actors, such as large agribusiness corporations. For some stakeholders this orientation raised concerns about capture of the public RD&E sector by private interests that might lead, in their view, to increasing the imbalance of influence of larger corporations in the supply chain.

Perceptions around whether the supply chain would change in the future were mixed, with some interviewees predicting a consolidation of the supply chain and others seeing largely a similar supply chain structure into the future. Similarly, there were mixed views on whether farming costs would increase, or drop as a result of uptake of big data.

However, continued concerns about the limitations of digital infrastructure and digital literacy in rural and regional Australia was highlighted as factors that could work against the uptake of big data applications.

4.3 Perceptions of benefits or opportunities

Interviewees discussed a diverse range of benefits or opportunities that may be created by digital technologies and big data applications, including on-farm benefits, industry level benefits and other broader benefits and opportunities. The themes emerging from this part of the interview are represented in Figure 3 below.

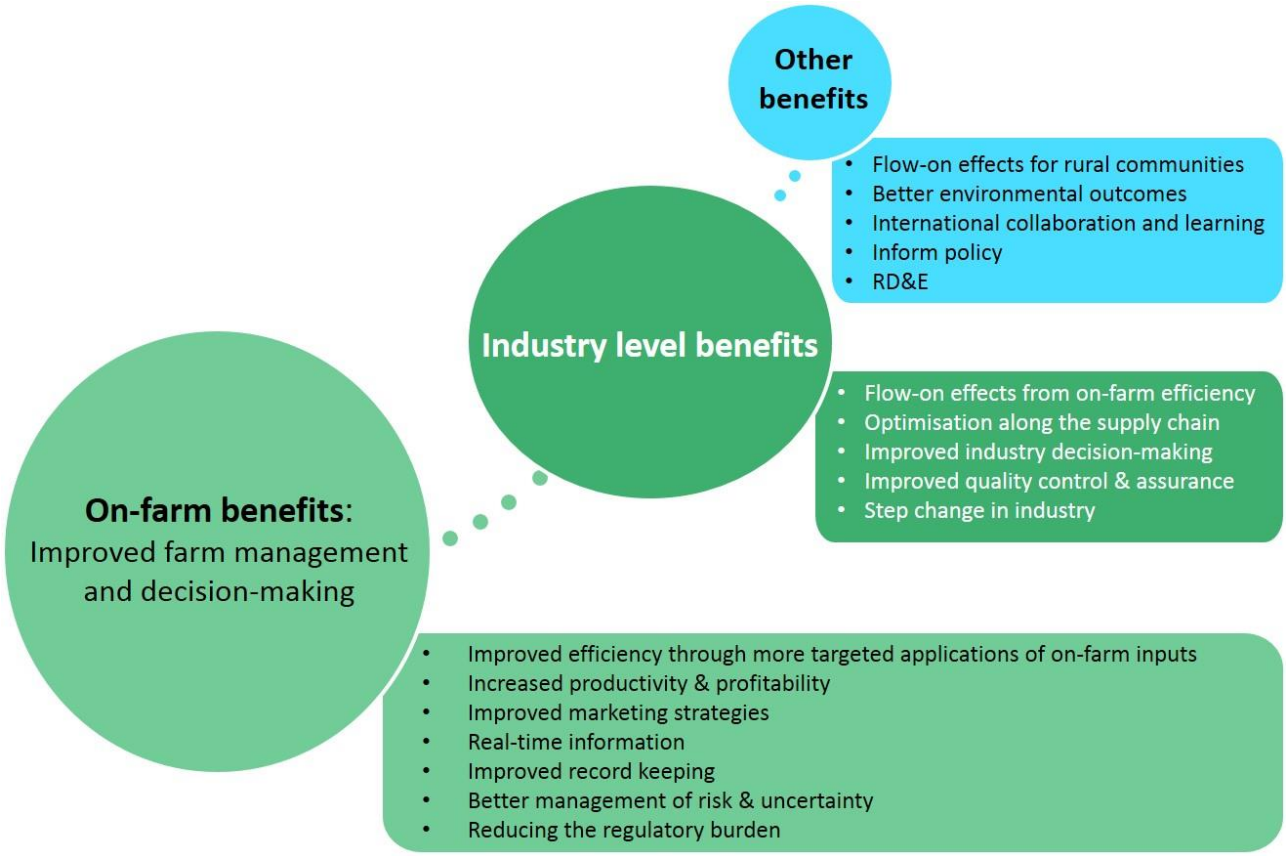

Figure 3 Benefits and opportunities of digital agriculture and big data reported by stakeholders (many of these benefits overlap across categories)

On-farm benefits

On-farm benefits were the most frequently mentioned type of benefits, with interviewees outlining a range of ways in which digital agriculture and big data could improve farm management and decision-making, focusing on improved efficiencies through more targeted applications of on-farm inputs:

> Well, benefits are more targeted application of inputs across our farms, so if we have the data to be able to aid in decision making then we can match our inputs to the potentials of the season. Not only on a paddock scale but down to a pixel scale or a particular point on the farm. (Grower group 8)

A related theme was the increased productivity and profitability that improved farm management and decision-making could bring:

> …farmers make lots of decisions through the life of their crop on a farm, and if they can make better decisions…they are able to improve their efficiency and productivity out of that. (Input provider 3)

The value of real-time information for decision-making was also highlighted as a potential benefit associated with advances in digital agriculture, especially sensing technologies:

> So having a system - it might only be one or two weather stations on a property - that feeds in almost real time data to the farmer; would be really useful. (Grower group 6)

Key future benefits of big data were seen to come from being able to link up current or potential data sets, such as developing a national soil database to be overlaid with climate projection data, weather forecasts, water models and crop information on an individual farm basis.

> There's one dataset that I would regard as a big dataset that, in and of itself, would probably provide little benefit, but if you merge it with other things would significantly increase research and even decisions for growers on farm, is the soils. (Grower group 4)

Industry-level and supply chain benefits

Interviewees also identified a number of industry-level or supply chain benefits, particularly those related to optimisation along the supply chain and the improved industry-level decision-making that this could facilitate.

> I think, the supply chain will streamline itself and will be able to drive efficiencies from the use of big data, so there'll be a commercial benefit for the business. (Grower group 4)

> Certainly through logistics…actually moving transport, being able to track, maintain, record is important for supply chain optimisation. …So at every level it will drive improved performance. (Grower group 3)

Another important benefit associated with big data was improved predictive and analytical capabilities for storage and transport logistics providers. For example, more accuracy of tracking and predictions of yield would allow for better optimising of decisions and resource allocation related to transport, logistics, labour, timing and price points. One participant referred to this as visibility along the supply chain where there may have been unknowns before, such as when grain was transported or combined with other growers' grain:

> The marketers want to keep data separate to get commercial advantage whereas [from a logistics and handlers' supply chain perspective]…greater visibility and accuracy around that data is what we're chasing. (Logistics and trading 2)

Big data applications would also increase the traceability of grain in the supply chain creating value for consumers, retailers and processors as well as growers, as explained by one of the input providers we interviewed:

> Traceability is the one that everyone talks about, so traceability is a good example because we're seeing increasing demand for people who understand where their food came from. The digital technology will enable that. (Input provider 1)

Similarly, one grower described how information on varieties of grain (including GM varieties, provenance, quality) could now be traced by customers, creating premium products and niche markets with potential to grow demand for specialist products (e.g. grain for craft brewing).

> At some stage, traceability's going to be key. It's either going to come in a rush and it's going to be a huge cost for the farmers to implement and hard to do…Or we can start putting in place systems and processes now, which is actually going to lower the cost of implementation, so that traceability - so when the Japanese buyer goes, "Actually, I want to know which paddock this grain was grown in that's making my beer," or whatever. Or that Australia - the supply chain can actually say, "Actually, we're pretty good at actually being able to do that." (Grower group 5)

Bulk handlers in particular described what they saw as considerable opportunity for value generation that would rely on collaboration between companies involved in grain storage and

transport. One handler described the benefits associated with the types of data driven predictive modelling of the location, timing, volumes and quality of grain yields for informing decisions on rolling stock and road transport. However, the efficiency of the system overall, including managing grain flows into the port terminals, could be improved by co-investment across grain handling companies in a given region in generating a 'complete' picture of where and when grain was moving. Investment in such a system by one company alone was seen as unviable.

Several participants expected that the efficiencies enabled by big data would translate to better farm gate prices for growers, although this perspective was not necessarily supported by growers themselves.

> So digital agriculture, for me, is the automation of a lot of management processes for farmers largely, I don't think that you could necessarily automate much more of the supply chain. So it, for me, is the next productivity gain pre-farm gate, it means that growers more take a role of managing their farm and putting prescriptions in place to automate those processes, whether it be a sprayer going out and spraying without a human actually sitting in it, et cetera, if that makes sense. (Grower group 4)

Interviewees also discussed crop forecasting data as a potential future benefit offered by big data. The ability to gather and analyse data on variety, quantity, location, quality, weather events, management decisions and market prices offers a whole new way of understanding the grains industry. In some cases there is still work to be done to ensure visibility and accuracy of data. Furthermore, support will be required to improve the capacity to interpret the data in order to answer specific questions, for example to compare years and management decisions, as well as to look at non-traditional indicators such as pasture availability for the dairy industry influencing the potential demand for hay crops (and conversion from cereal).

Marketers and traders expected that big data would allow them to better predict export demand and prices, however again growers expressed concerns that this would, they believed, exacerbate the commercial advantage these groups currently exercised over growers.

Although most of the benefits were seen to accrue to farmers and other industry actors, some broader benefits and opportunities were also identified. These included opportunities for international collaboration and learning, informing policy and improving research and development, as explained by this grower group interviewee:

> There's certainly some key examples in the US, in New Zealand - there's some key case studies we can draw from. And what I'd also say is I guess when you look at data and how Australia fits in that context, some of our data sets and platforms actually underpins some decision support tools internationally. So we actually help, for example in New Zealand, some of the grain research initiatives over there are actually underpinned and powered by our decision support tools. (Grower group 3)

Some interviewees also discussed the possible far-reaching consequences that digital agriculture and big data could have for the Australian agricultural sector more broadly:

> Step change is something that will be required in the Australian agricultural sector to remain internationally competitive. So looking at, you know, revolutionising the way we do things and not just finding those one, two percent gains around the fringes, which digital agriculture will help us with, but it could also help us make step changes in the way we farm and in the way we undertake business day to day. (Grower group 3)

Despite big data being helpful in aiding decision-making, the greatest financial returns on implementing big data approaches were generally seen to be most clearly tied to businesses upstream and downstream of the farm gate (i.e. input suppliers and manufacturers, traders and marketers), rather than farmers themselves.

4.4 Perceptions of costs and risks

We also asked interviewees for their views on the costs or risks associated with big data applications in agriculture. Their responses can be grouped into three main categories: social and institutional, technical and financial costs or risks (see Figure 4).

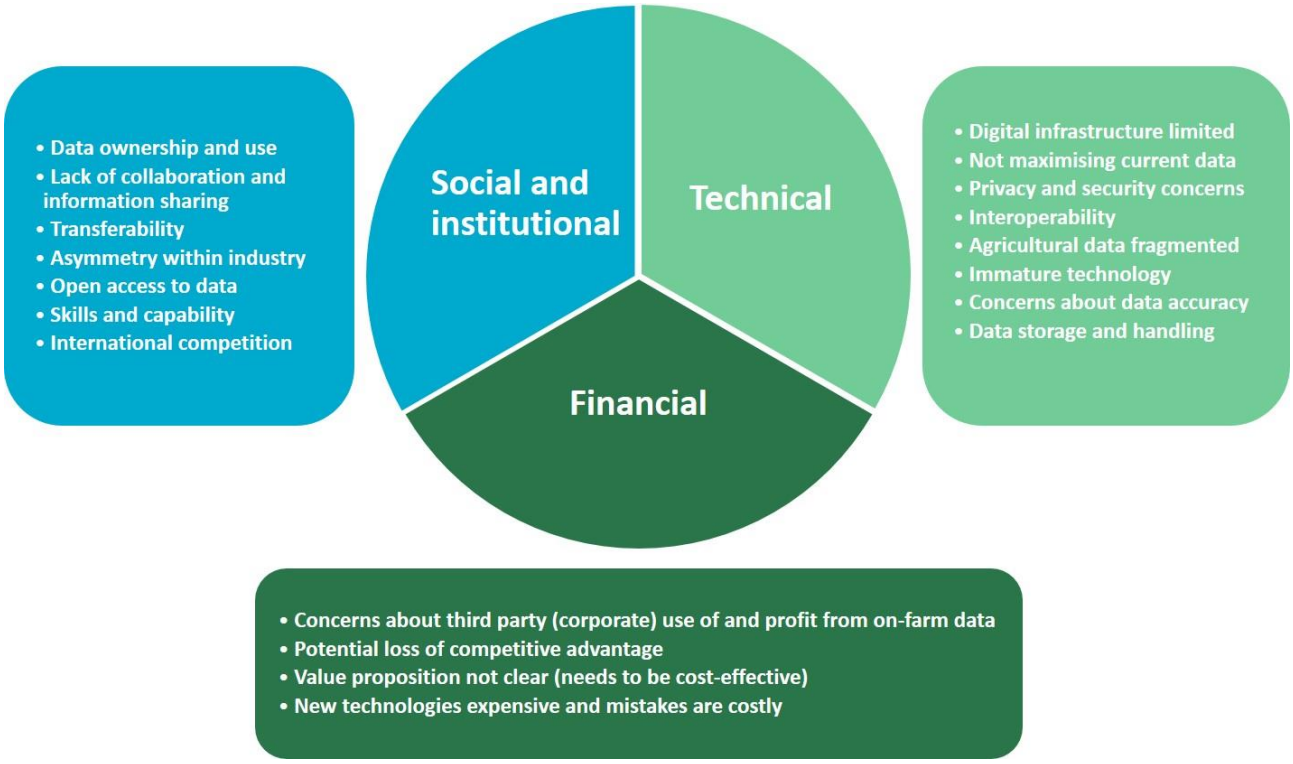

Figure 4 Costs and risks associated with digital agriculture and big data applications

4.4.1 Social and institutional risks

By far the largest area of concern related to the potential risks surrounding third party use of and benefit from farm data. This was frequently discussed in relation to issues surrounding data ownership, however the underlying concern here often related to the issue of who would be using the data and what they would be using it for. Data was understood as a valuable commodity, hence data ownership was important:

> I have to admit everyone seems caught up in that data will be valuable therefore I should focus on owning it and extracting insight from it. (Input provider 1)

Many growers were concerned that large corporations could capture this value, possibly at the expense of local growers, based in part on observations about how these issues are playing out in the United States:

> Now, if there is value in it you kind of want to make sure that if we're doing all this, we want a little bit of something back and I guess the fear is the big players swoop down, grab it, run off and make some big business model and they make a good living off it and the

> guys that generate it all miss out. …I guess I'm of the thinking that we're probably at the bottom of the food chain. We've got something that maybe someone wants collectively and if they get it for nothing it just doesn't feel right. (Grower 4)

> I guess if we have a look at the example of what happened in the US with Monsanto and Climate Corporation, their prescription farming model, you know over time there was a kick back against a commercial operator owning it and farm groups wanted to own it. ...[W]e've [a grain industry organisation] owned these decision support tools for a while and been building up these systems and looking at acquisition of other, competitive products over the next few years and building on our platforms, [because] if we don't do that there will be international players that come into the Australian market, and Australian farmers will be at the whim of whatever the commercial incentive and the commercial imperative of those organisations is rather than what's in the grower's best interest. (Grower group 3)

Discussions of the issue of data ownership were characterised by both uncertainty and competing views. In terms of uncertainty surrounding data ownership and use, many interviewees expressed uncertainty about rights to data ownership and use.

> It would be…really good to know how the information could be misused…actually that's probably as relevant as anything, to be honest, the risk side of it, how could it be misused, so then we can make an informed decision about where it goes and how it's used. (Grower 2)

Competing views were particularly evident regarding the interpretation of the principle that growers own their on-farm data. Digital agriculture service providers seek to address concerns about privacy and data ownership through written contracts, which specify the terms and conditions regarding data ownership and use (Keogh and Henry 2016). Some interviewees accepted digital agriculture service providers' assurances that growers' retained ownership of their on-farm data under emerging big data opportunities. For example, this interviewee discussed the approach taken by Climate Corp to ownership of farm data:

> But effectively what Climate Corp and therefore Monsanto has said is that if data is generated by a farmer or from their farming equipment on their farm, that that data is owned by the farmer. … And…if a farmer brings their data to Monsanto or they generate it through their equipment and it's used as part of Monsanto systems, if the farmer wants to leave, they can take their data with them, and we don't own that data. …That's why I do really like the guiding principles that the Climate Corp have put in place. (Input provider 3)

However, other interviewees expressed a more critical view regarding data ownership, focusing instead on how that data may be used and who it might be used by, suggesting a lack of trust in digital agriculture service providers' assurances that growers own their data:

> They [digital agriculture service providers] say the farmer owns the data, the farmer, legally that's true but practically what does it mean? Almost nothing. A far more interesting and pertinent question is what are they doing with that farm data? (Grower 2)

This lack of trust is in part due to the way in which some user agreements "bury exclusions deep in the document which in effect give free reign to the software providers…to use the data in many different ways, including via the sale or transfer of the data to a third party" (Keogh and Henry 2016: 37). For some interviewees, this included an explicit recognition of unequal power relations:

> But it depends on how the information is going to be disseminated once it's collected as well and who has control of it. And that's one of the areas that really worries me is that it seems to me that most farmers are still reasonably small and most of the businesses they deal with are reasonably large so there's going to be an inequity in the data. (Local government 1)

Concerns around data ownership and use also related to the boundaries around what data growers are comfortable with sharing and what data they want to protect:

> I'd be more probably worried about that…when you sign the dotted line to buy that tractor you lose control of the data without really realising it. … Well I think one farmer versus John Deere, we've got Buckley's. But…okay, the information about how many hours our tractors do, what sort of conditions do they work in, what problems they have, that's all great information to have. John Deere needs that information to build better tractors, more efficient, which is going to benefit us. I think the data that we have that's most value to other people is our yields, our varieties that are much more specific to our farms. Our gross margins, our business information. And that we should be more able to keep control of. (Grower group 6)

As a consequence, some interviewees raised doubts about the willingness of growers to share their on-farm data, even with other growers:

> But I can't see people openly sharing their data. I can see people giving you a bit of something that you might need, or sitting down with your agronomist, giving them some stuff. But I can't see me and you, being farmers that are 100km away, really, openly sharing. We might talk on basics, but I'm never going to let you take my yield maps and you're never let me take yours. We might look at them together and talk about different farming methods and the physical, but you're never going to walk away with that data, I wouldn't have thought. (Input provider 4)

This in turn raises potential doubts about how willing some growers might be to collaborate in digital agriculture or big data applications that involve data sharing:

> I think the risk lies in farmers being confident that they don't need to lock up their data and make it absolutely unavailable to anyone except a very narrow limited range of providers. (Grower group 2)

One interviewee pointed out that the industry needed to better explain the rationale for and potential benefits of access and use of on-farm data:

> …the industry has done, frankly, a terrible job of explaining why they want access to farm data. Not so much an issue probably here in Australia yet, it's probably just starting to happen now, but in the US it's been going on for quite a few years, and it's even more so. ….So it's this weird thing where they don't want to tell us exactly what they're doing with it but if they don't tell us what they do with it, why would we trust them? …[P]robably mostly they are doing the right thing but that's not explained anywhere and we're certainly just trusting that's what they say they're doing, there's no way of verifying it…and that's what's holding more farmers back from adopting it, but we miss out on the benefits of it then as well. (Grower 1)

Thus, issues of trust and transparency are central themes underlying concerns surrounding perceptions of the risks and costs associated with ownership and use of on-farm data, which in turn have the potential to limit the adoption of digital agriculture and big data applications.

4.4.2 Technical costs and risks

Interviewees also identified a diverse range of technical risks and costs associated with digital agriculture and big data applications. One of the most significant technical risks mentioned by interviewees related to the fundamental limitations of Australia's digital infrastructure, especially in rural and regional areas. There was widespread recognition that the mobile phone network and internet access in rural Australia was not currently at a level that would support some of the potential advances in digital agriculture:

> …another risk is actually not having the ability to download all this data and actually upload stuff and have good internet coverage. …If we want this to happen in the country we've got to have our mobile phone working pretty much, and that's a major concern. (Grower 2)

Although one interviewee acknowledged that "there are work arounds" the limitations to digital infrastructure (Grower 1), there remained a degree of scepticism about how much the rural and regional digital infrastructure would improve in the near future, which some interviewees linked to the further widening of the city/country divide:

> And our other big problem that's going to become more pronounced is just lack of Internet access… I'm not sure what's going to come out of the rollout of the NBN but…we're going to be left off the end of that and a lot of this sort of stuff is going to be quite data hungry that we should and could be using. So I'm not sure what the answer to that is but it's certainly going to create a bigger city/country divide. (Grower 5)

In addition to limitations of the digital infrastructure, interviewees also suggested that Australian digital agriculture data is highly fragmented and people are not currently maximising existing data.

> I think there's a whole lot of data that's out there being collected, but it's all in various different firms and business and stuff. … So to me that opened up some different questions about, well, crikey, how much data have we got sitting out there that we're just not making use of? (State government 1)

A related issue here is the challenge of interoperability (the ability of information technology systems to exchange and make use of information), which is compounded by the fragmented nature of Australia's digital agriculture data landscape.

> …it's like different railway systems. In the end, it's sometimes easier to do it your own way than find a compromise. And I think that goes back to trust and everything like that. It's how much are you willing to give up and how much are you willing to drive forward? (Research & consulting 3)

Data privacy and security were another area of technical risk identified by interviewees. The social and institutional dimensions of this issue have already been covered, but there are also technical dimensions to the challenge of ensuring that data privacy and security measures provide appropriate levels of protection. There were differing levels of concern about data privacy and security. Some interviewees were satisfied that privacy and security measures would be adequate:

> So we have privacy policies that are inserted into our licensing agreements with growers on an annual basis. And they obviously take into account federal and state requirements. And we update them as there are any changes in local requirements in Australia around privacy. (Input provider 3)

However, other interviewees expressed more concern about privacy and security issues:

> …All that privacy stuff, it's just can of worms. And it's got the potential to completely explode. But we are so reliant on our technology nowadays, that we can't really stop it. …So yeah, definitely some healthy scepticism and concern about how that sort of privacy can go. And I think people just need to become more and more aware of it - me included. And making those safeguards to make sure that you can protect your data. (Grower group 6)

Furthermore, one interviewee explained that even with privacy and security measures in place, breaches are always going to be a risk:

> Probably the other risk is just about data security in itself and that is an ongoing concern. It's an ongoing concern…across the globe that malicious people will always try to break the systems that are in place. And we've seen that time and time again. And even big companies and organisations that presumably had good security in place have found breaches. And I think that it is incumbent upon organisations that are storing data that they need to be doing their very best to maintain that security, but at the same time the consumers and the farmers need to understand that there can be breaches that happen from time to time even with the best intentions. And that's always going to be a risk. (Input provider 3)

There was also a bundle of concerns related to technical risks associated with new technologies. These revolved around perceptions that the new digital agriculture and big data applications are immature technologies, with all the teething problems often associated with new technologies, combined with concerns about data accuracy.

> But given this is…a relatively new field, it is going to take some time to get that validation and to get the systems working at a high level of accuracy. So that's I think one of the challenges over time that farmers are going to need to be able to work with systems that might not be perfect, but as they work with them, they will get better. (Input provider 3)

A related risk here was the challenges of data storage and handling in the context of a new and emerging technology:

> So we've got a lot of data that we've been collecting. And where we can use it, we do. But we really haven't found an easy outlet for that. And I think that's one of the things that the big data problem's created. There's just lots of information, which we know we need to collect to be able to get enough to be useful, but we don't know what to do with it and we should have enough by now to be useful. So it would be good to see what could come out of this as well. (Grower 3)

The transferability and applicability of the new technologies were another related area of concern, including the difficulty of making judgments about competing technologies in this domain.

> …there's at least half a dozen companies [in the United States] offering precision, prescription farming services for farmers to deal with, typically nitrogen in corn. Now everything starts out over there because that's where all the money is but once you develop the system for corn it's pretty easy to adapt it for wheat in Australia or canola in South Australia or whatever. So those sorts of services are going to come here eventually, and how does a farmer evaluate whether the Pioneer solution is better than the Monsanto solution…? (Grower 1)

4.4.3 Financial costs and risks

Interviewees also discussed a range of financial costs and risks that could potentially be associated with digital agriculture and big data applications. The most frequently mentioned financial risk related to the concern that private companies could try and profit from on-farm data collection. This is closely linked to the concerns surrounding data ownership and use that were discussed earlier.

> There's a risk that these huge data sets end up in the hands of agribusinesses and marketing companies and they use that against farmers in restricting supply or increasing price or decreasing price. (Grower group 8)

Some interviewees suggested that concerns that the data sharing could potentially lead to a loss of competitive advantage could limit the uptake of big data applications:

> The big one is commercial sensitivity. Some companies have put a lot of money into this and quite understandably, they're not going to share that information. (Logistics & trading 1)

Another financial risk that growers in particular raised concerns about were unanticipated impacts on the land market. As data and information about farm productivity and profitability become increasingly accessible and 'joined-up' this could enable financial and agronomic service providers to become more significant players in the agricultural land market, to the disadvantage of growers operating in that market.

Some interviewees also expressed doubts about the value proposition of big data applications, especially from a grower's perspective.

> …I just can't see how the benefit is going to get passed to us …when you push it a bit harder, that's the whole supply chain, it's nothing to do with the farmer. (Grower 5)

One interviewee elaborated on the dilemma surrounding the value proposition of big data applications:

> I think one of the ironies of big data applications is that…for a start, the collection of data that an individual farmer, for example, would have available will only bring limited benefits, but over time and across industries as data gradually accumulates, then the benefits start flowing and flowing back to decisions on the farm. So it's quite an ironic or complicated issue because if you said to farmers, "Start recording that data," I think a lot of the response would be, "It's not much use to me," and it's not until you've got a body of that data accumulated that benefits start to flow and then they all flow back to the farmer. (Grower group 2)

Digital agriculture technologies were also seen by many growers as an expensive investment that they may not necessarily be able to afford:

> …we've got manual rain gauge. …I know [a local grower group] is rolling out the automatic ones which I'd love to have but I just can't justify three and a half grand this year to buy one for the farm 30ks that way and one for that way. So if it was a better year I'd sign up and grab a couple but, yeah, this year is going to be a bit tight so we won't. (Grower 5)

Decisions about adopting the precision agriculture technologies that underpin the advances in digital agriculture need to be integrated into farm machinery purchasing decisions:

> …for us it revolves around machinery purchase and so I reckon we just need to make sure that we're very careful about how we go about that basically. …Because you wouldn't want to spend half a million dollars and then two years later or five years later go, "I wish I had actually foreseen that." So we have to be really well informed about where we want to go, how we want to get there basically because when we make that next big machinery purchase it's got to be the one that will last us 10 years and lets us get where we want to go. (Grower 2)

This supports findings from other studies that growers often take a 'stepwise' approach to gradually integrate digital agriculture technologies into their farming system, to allow them to manage the costs of adopting these new technologies (Robertson et al. 2012).

4.5 The role of trusted information and advice networks

In previous sections we have described how trust (or the absence thereof) between growers, whose business operations generate data, and corporate and other parties, as consumers of that data, is a central concern for the acceptability of big data enabled technologies and services. In this section we focus on the role that existing trusted relationships play in supporting growers business planning and decision-making, and their role in facilitating informed decision-making in relation to big data.

The most important factor in how interviewees across the supply chain talked about trust related to the role of reputation built through interpersonal relationships over extended periods of time. While trust was most often ascribed to individuals, it was also associated with organisations or other parts of the supply chain. Maintaining or indeed losing trust in business or advice relationships was intimately connected to reputation, and neither of these 'commodities' were seen as permanent:

> …we often trust people and things on face value and give it the benefit of the doubt, but over time if that's not reinforced, the trust and the reputation decline very quickly. (Grower group 2)

Existing trusted relationships were identified as important mechanisms for decision making. These decision-related relationships come in a variety of forms, from agronomists, to researchers, to input providers, to grower groups. An important aspect of maintaining trust for growers was that it could be 'proven' or observed, such as through demonstrated results of advice leading to a noticeable gain in business performance.

The view that trust was built over time through interpersonal contact was widely held, including beyond the agricultural production sector in Wimmera Mallee, with other service providers commenting on possible implications of a growing digital divide between service providers and rural communities:

> …trust still comes down to what's the personal relationship…we have with residents and with the farmers? So that's probably going to be a challenge with this digital age going forward as people become more digitally-isolated, how that trust continues. (Local government 2)

Concerning advice and information flows, the conditions that create trust, from growers' perspectives were seen to be: independence of the source of the information; that interests and

benefits of the exchange are transparent; and, that there is clear mutual benefit to parties in the relationship. Conversely perceptions of hidden or vested interests in an information exchange relationship were seen to erode trust:

> When talking to farmers about [digital agriculture and big data], the attitude, you get the whole spectrum including I don't care what they do with it because I'm not using it, it's no use to me, if they can use it, good luck to them, right through to the opposite extreme, which is not helpful either, which is I don't know what they're doing with my data, if I can't benefit from it, they shouldn't either. So we need to be somewhere in the middle, but they're trying to develop products using farm data with fertiliser application and new tractors and whatever. So it's this weird thing where they don't want to tell us exactly what they're doing with it, but if they don't tell us what they do with it, why would we trust them? (Grower 2)

Grain farming businesses reported they rely on resellers for 'general' advice but on their own independent private agronomists to interpret and translate that information into a workable, tailored tool for the farm (e.g. variable rate application map for fertiliser or chemicals). Growers may access several advisors for advice covering a range of topics, but some may also still rely strongly on one or two key personal relationships.

Interviewees described the growing diversity of sources of advice related to farming business. In some instances this diversity reflected deregulation of parts of the industry or gaps left with the withdrawal of public sector extension. However, it was also due to existing players in the supply chain or information chain diversifying their roles (e.g. grower or industry groups are now involved in advocacy, extension, training, and commercialisation of R&D and commercial services).

5 Discussion

5.1 Farm businesses and changing knowledge networks: a varied response

The growing number and diversity of information service providers is also in part a response to an increasingly complex farming environment where multiple objectives are pursued (e.g. increasing productivity, profitability, and environmental protection). Each of these objectives is requiring increasingly specialist expert or professional advice. Recent research is pointing to the influence of these inter-professional advisory relationships (that is the relationships between professional advisors themselves) in shaping the character of advice to farming businesses (Phillipson et al. 2016). The demands of digitally enabled agriculture is only likely to add to this trend in the short to medium term.

We observed however that there is something of a contradiction when looking at the effects of digital technologies within advice relationships. On one hand, while growers, and other actors such as local machinery dealers, emphasised the importance of trusted interpersonal networks, they also described their growing use of digital sources of information to validate, verify or expand on those personal sources. On the other hand, the demands presented by these emerging sources of information see growers place increasing weight on the capacity of their advisors to synthesise and interpret these multiple information sources to the specific problem at hand. This suggests

that digital information and data sources are in different ways augmenting or altering existing knowledge networks, rather than replacing them.

It is also apparent that information using and sharing patterns of businesses, including farm businesses, are increasingly interwoven with the value-chain strategies of those businesses and the sector more widely. From this perspective the interviews also suggest that the quality of information networks accessed by farm businesses and the degree of active integration with the value chain are two characteristics that may shape how those enterprises respond to digital disruption (Figure 5). Those farming enterprises that have greater levels of value chain integration and higher quality information and advice networks may be more likely to benefit. For example, farming businesses that are high information users and that are targeting specific market segments or developing specialised relationships with processors and consumers might be considered as embedded or 'networked'. Businesses that are high information using but perhaps less embedded into specific supply relationships may still be able to anticipate and respond flexibly to changes in the market or seasonal conditions 'opportunistically'.

Conversely, businesses with low quality advice and information networks may lack these responsive capacities and are therefore potentially constrained within inflexible, low value, supply relationships. Lastly those businesses that are neither networked into the value chain nor emerging information networks may become increasingly disengaged and exposed to risk. We argue that digital disruption has the capacity to both enhance and exacerbate these differences in sectors such as the grains industry.

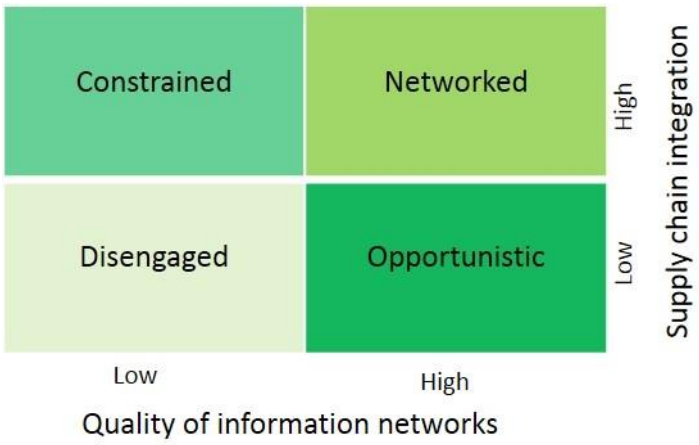

Figure 5 How different farm business models may respond to or benefit from digital disruption is highly varied

From the above it could be argued that gaps that currently exist between the capabilities of different farm businesses to realise benefit from the existing digital technologies may widen as these technologies further emerge. If the intention is for benefit to be more widely realised across the industry as a whole then there are important questions about how to ensure that businesses can access the support needed in an equitable way. At least part of the answer to this question may be in some of the emerging roles and governance arrangements in the sector, which we discuss briefly below.

5.2 Emerging roles, gaps and governance

Interviews with a range of grains industry stakeholders touched on issues of roles in governing the emerging arrangements around digital agriculture. While very few interviewees described a clear picture of what effective or appropriate governance arrangements might look like, several observations about current trends and their implications for different public and private actors were described.

Also clear from the investigation, and consistent with international experience in this domain to date, was recognition of the emergence of new, multiple and sometimes competing service and data governance models. These models included but were not limited to: several proprietary models associated with specific farm machinery suppliers or other input suppliers; commercial service models being developed by industry organisations; and collective, place-based models proposed by grower cooperatives to broker access with third parties and finance improved service provision to members. This diversity of service models reflects the circumstances described above (in section 4.5) about the diversification of information service providers and products within this space. In the Australian context at least, many of these models are still embryonic or untested for their ability to meet the needs of transparency, equity of and access to value-generation that have been identified in this research. What is also clear, when we consider the different levels of responsiveness of farm businesses to digital disruption (see Figure 5), is that it is unlikely that any single type of model will be suitable or appropriate across the range of needs. However, given this difference in responsiveness, and the widespread recognition of possible trust issues with the corporate-run models, there appears to be a need for service models that act as an intermediary between farm businesses and corporate users of farm data, and that assist growers in managing that interface.

A recurrent theme of discussion in the interviews was the role of government, or the public sector more broadly, in any emerging set of governance arrangements. There was general agreement amongst those interviewed that there was a significant role for governments to 'help set up a framework' for big data in the grains industry. This role involved establishing necessary 'regulatory safeguards' and rules around data security and privacy, but also more broadly by helping to create a policy environment that would encourage more collaborative approaches to data sharing and integration, improve accessibility, minimise fragmentation of efforts in the current RD&E system, and investing in the foundational data that would drive future services. Some of these contributions are captured in the words of one interviewee:

> …I think that there's a role for government to create mixed governance systems [at the regional level] – so that the government supports some of the underlying platform and then allows the private sector…at either a big vendor level or at a service provider level to create value-added activities based on the underlying platform of standards and governance. (State government 2)

The conditions of independence, transparency and mutuality that characterise what many grain farming businesses and other stakeholder see as necessary for establishing trusted information and data sharing relationships, suggest an important and ongoing role for public sector organisations.

6 Recommendations

Responding to the concerns and opportunities identified by our research requires working both individually (with businesses and farming enterprises) and collectively (across the sector and value chain). Identifying the underlying values and assumptions about the benefits and risks of these potentially transformative technologies is a critical first step that can help with (i) collectively defining what success looks like and (ii) collaboratively developing effective strategies for the successful deployment of these technologies on farms and within value chains. Understanding expectations and needs of different members in the value chain is also necessary in designing appropriate and acceptable governance responses. This includes dealing with concerns of transparency and trust and uneven benefit.

The primary recommendation from this study is the need to:

> *Invest in building the capability of growers and farm businesses to be both informed data **consumers** as well as **co-creators** and **curators** of data, by involving growers and their trusted information and advisory networks in the cooperative development and trialling of these systems.*

The input from our interview participants suggests some actions that are likely to help build this capability, and serve to empower stakeholders in their future engagement with big data. We list these below (in no particular order):

1. Conduct and communicate case studies showcasing experiences with big data applications across the supply chain, to provide other stakeholders with better insight into how big data works in practice. Ideally these case studies would identify potential "easy win" high impact data integration initiatives that would capitalize on existing data sets (that are currently underutilized) and demonstrate the value of collaborating to join up data. These case studies should reflect the diversity of practice or businesses within the relevant sector and provide a balanced view of benefits and costs associated with big data. By providing these case studies online and via trusted organisations, there might be potential to share learnings and develop an online community of practice.

2. Improve the availability and accessibility of plain English advice to farming businesses about the practical and legal issues surrounding data privacy, security and ownership in Australia and the rights and obligations of different parties under existing arrangements.

3. Encourage industry level dialogues via farmer groups, industry associations or cooperatives that identify shared expectations or possibly best practice principles for data sharing, reporting that support transparency and equity of outcomes derived from big data.

4. Evaluate the suite of emerging cooperative, commodity based and/or private sector led data service and governance models for their capacity to meet the types of expectations identified through point 3 above and their transferability.

5. Identify opportunities to situate new training or advisory services for digital agriculture within the context of broader initiatives and programs about bridging the digital divide in rural and regional communities.

7 Conclusions

7.1 Digital agriculture and big data as transformative technologies

Amongst the grains industry stakeholders that we interviewed, big data applications were considered to be one of the most important developments in agriculture, offering the potential to transform Australian agriculture through significant and substantial productivity gains. Given the emergent nature of these technologies, it is understandable that many interviewees were uncertain about the practical implications of developments in big data. Nevertheless, interviewees were aware of the need to monitor developments in this space, with some already engaging with the technology. Different stakeholder groups had different perspectives on the benefits associated with big data. Overall, there was a common assertion across all stakeholders that growers *should* be important beneficiaries of big data applications, since they would be able to make better decisions through the insights enabled by this technology. However, many growers were somewhat sceptical about the *actual* benefits to growers and some growers feared that the benefits would be more likely to accrue to up-stream or down-stream actors in the supply chain. Other stakeholders seemed to be more optimistic about how growers would benefit. Many interviewees also described how benefits would accrue across the supply chain, since consumers would be more informed (about the provenance of their food), transport and logistics groups would have more information to support their planning and resourcing and sellers would have better insight into supply and demand. This confluence of benefits has the potential to be harnessed to support the collaboration required for effective use of big data, so long as potential barriers (outlined below) are addressed.

7.2 Trust, transparency and the distribution of benefits

Concerns were widely held, particularly amongst growers, that the benefits and risks of big data related developments will be unevenly distributed throughout the supply chain, with disproportionate benefit accruing to businesses upstream and downstream of the farm gate (i.e. input suppliers and manufacturers, traders and marketers). The capacity of different grains supply chain actors to engage with or benefit from digital agriculture (including big data applications) is presently highly varied, especially amongst farm businesses. For the majority of growers we interviewed the benefits they receive are likely to be realised longer term or 'down the track' and in many cases appear uncertain. While in the short to medium term concerns about transparency, equity (in terms of the distribution of benefits) and access dominate. Indeed, trust and transparency are central themes underlying concerns surrounding perceptions of the risks and costs associated with the use of on-farm data, which in turn have the potential to limit the informed and consensual participation of all stakeholders in digital agriculture and big data applications. Trusted information and advice networks are important mechanisms for growers in

mediating the benefits and risks of engaging with these opportunities. As such, alignment of these new opportunities with existing (or re-negotiated) trust relationships is a critical enabling condition.

7.3 RD&E and governance directions

This study suggests there are both significant opportunities and challenges for the RD&E system. In traditional models of information delivery, researchers and funding agencies viewed adoption of a new technology or technique 'on farm' as the desirable and logical end point. It is increasingly apparent in the new and emerging data and information networks that are developing, that information flows are multi-directional with value being realised by a broader group of actors beyond the farm gate. This means that where previous work has often focused on the significance of trusted *sources* of information in agricultural production, producers are increasingly concerned with questions of trusted *sinks* of information (i.e. whom is their data going to and for what use and benefit). In realising the full value from digital agriculture and particularly big data, this implies more thought is required into not only facilitating improved data *capture*, but also the enabling conditions, processes and institutions required to facilitate data *contributions* from diverse stakeholders.

It is tempting, for simplification, to suggest that there is an emerging choice or tension between (i) creating open systems based on sharing data through trusted multi-party collaboration that empowers growers and other agricultural stakeholders to make better decisions and improve performance; or (ii) allowing proprietorial systems developed by global corporations to dominate, potentially limiting growers' decision-making freedom (Poppe et al. 2015). However, this study found that there are instead multiple, emerging initiatives and hubs of activity that, at least in the short term, constitute the institutional fabric of data governance in Australian agriculture across a range of scales and interests.

Some of the key remaining questions however include: what are the implications of these emerging and diverse models of services and governance, and how adequate are they at meeting the requirements of transparency, shared benefit and access raised in this study? Furthermore, since advances in digital agriculture are also likely to converge with a variety of information-based compliance processes (e.g. food safety and environmental regulation), it will also be necessary to understand how this convergence is likely to impact on farm productivity related developments and the regulation of agricultural production and supply chains at the enterprise level.

There is an important role for social researchers working in a participatory way with industry, corporate and RD&E stakeholders to identify and evaluate these emerging models. Such research will support their ongoing improvement, assess their transferability between sectors or growing regions and ultimately help to ensure that the application of these technologies has the widest possible benefit in Australian agriculture.

8 References

ABS, Australian Bureau of Statistics. 2013. Summary of IT use and innovation in Australian business, 2011-12. .

Brynjolfsson, E. , and L. M. Hitt. 2003. "Computing productivity: Firm-level evidence." *Review of Economics and Statistics* 85: 793-808.

Carberry, P.S., Z. Hochman, R.L. McCown, N.P. Dalgliesh, M.A. Foale, P.L. Poulton, J.N.G. Hargreaves, D.M.G. Hargreaves, S. Cawthray, N. Hillcoat, and M.J. Robertson. 2002. "The FARMSCAPE approach to decision support: farmers', advisers', researchers' monitoring, simulation, communication and performance evaluation." *Agricultural Systems* 74:141–177.

Cardona, M. M., T. Kretschmer, and T. Strobel. 2013. "ICT and productivity: Conclusions from the empirical literature." *Information Economics and Policy*.

Carolan, Michael. 2016. "Publicising Food: Big data, precision agriculture, and co-experimental techniques of addition." *Sociologia Ruralis*:1-20. doi: 10.1111/soru.12120.

Eastwood, C., and I. Yule. 2015. "Challenges and Opportunities for Precision Dairy Farming in New Zealand." *Farm Policy Journal* 12 (1):33-41.

Griffith, C., G. Heydon, D. Lamb, L. Lefort, K. Taylor, and M. Trotter. 2013. Smart Farming: Leveraging the impact of broadband and the digital economy. New England: CSIRO and University of New England.

Jakku, E., and P. J. Thorburn. 2010. "A conceptual framework for guiding the participatory development of agricultural decision support systems." *Agricultural Systems* 103 (9):675-682. doi: http://dx.doi.org/10.1016/j.agsy.2010.08.007.

Kaloxylos, Alexandros, Aggelos Groumas, Vassilis Sarris, Lampros Katsikas, Panagis Magdalinos, Eleni Antoniou, Zoi Politopoulou, Sjaak Wolfert, Christopher Brewster, Robert Eigenmann, and Carlos Maestre Terol. 2014. "A cloud-based Farm Management System: Architecture and implementation." *Computers and Electronics in Agriculture* 100:168-179. doi: 10.1016/j.compag.2013.11.014.

Keogh, M., and M. Henry. 2016. The Implications of Digital Agriculture and Big Data for Australian Agriculture. Sydney, Australia: Australian Farm Institute.

Kitchin, R. 2014. *The Data Revolution: Big Data, Open Data, Data Infrastructures and Their Consequences*. London: SAGE.

LonerganResearch. 2013. Digital literacy report. Lonergan Research.

Mason, Claire, Beth O'Brien-McInally, and Sharon Dane. 2014. "High-level stakeholders' insights on readying Australia for Next Generation Broadband." *Australian Journal of Telecommunications and the Digital Economy* 2 (2). doi: 10.7790/ajtde.v2n2.39.

Patton, M. 1990. *Qualitative Evaluation and Research Methods*. 2nd ed. ed. Thousand Oaks, CA: SAGE.

Phillipson, Jeremy, Amy Proctor, Steven B. Emery, and Philip Lowe. 2016. "Performing inter-professional expertise in rural advisory networks." *Land Use Policy* 54:321-330. doi: 10.1016/j.landusepol.2016.02.018.

Poppe, K., S. Wolfert, C. Verdouw, and A. Renwick. 2015. "A European Perspective on the Economics of Big Data." *Farm Policy Journal* 12 (1):11-19.

Robertson, M. J., R. S. Llewellyn, R. Mandel, R. Lawes, R. G. V. Bramley, L. Swift, N. Metz, and C. O'Callaghan. 2012. "Adoption of variable rate fertiliser application in the Australian grains industry: status, issues and prospects." *Precision Agriculture* 13 (2):181-199. doi: 10.1007/s11119-011-9236-3.

Rogers, E.M. 1995. *Diffusion of innovations*. 4th edition. ed. New York: The Free Press.

Sensis. 2013. Yellow Pages Social Media Report. Sensis.

Sonka, S. 2015. "Big Data: From Hype to Agricultural Tool." *Farm Policy Journal* 12 (1):1- 9.

Stiroh, K. J. 2002. "Information technology and the U.S. productivity revival: What do the industry data say?" *American Economic Review* 92:1559-1576.

Taylor, B. M., and M. Van Grieken. 2015. "Local institutions and farmer participation in agri-environmental schemes." *Journal of Rural Studies* 37:10-19. doi: 10.1016/j.jrurstud.2014.11.011.

Vines, Richard, Michael Jones, and Gavan McCarthy. 2013. "Collaborating across institutional and jurisdictional boundaries: enabling the emergence of a national innovation system through public knowledge management." *Knowledge Management Research & Practice* 13 (2):187-197. doi: 10.1057/kmrp.2013.41.

Yamine, M, N. Ellis, F. Pedic, and B. Tan. 2014. SMEs and Digital Communication Technologies: A qualitative market research report based on consultation with Small and Medium Sized Enterprises. Sydney: GfK Australia Pty Ltd for Australian Communications and Media Authority.

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