

Framing Agri-Digital Governance: Industry Stakeholders, Technological Frames and Smart Farming Implementation

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Abstract

Meso-scale actors – such as farm advisors and other extension agents – are increasingly recognised as playing a critical role in managing farmer uncertainty associated with smart farming implementation. However, there has been limited research to date on how these actors navigate smart farming implementation within specific industries or commodity sectors. This article applies theoretical insights from the technological frames literature to investigate how meso-scale actors in the Australian rice industry frame smart farming technology implementation, and the ways in which relationships between frames variously afford and/or constrain industry sovereignty over implementation of technological change. Through analysis of our data, we reveal a complex relationship between participants' technological frames involving *frame incongruence*, *frame ambivalence* and *frame switching*. We argue that while development of a more integrated approach to enhancing the digital capacities of meso-scale actors advocated in the literature provides a way of addressing frame incongruence, more flexible strategies may be needed to address frame ambivalence and switching. Furthermore, we contend that those frame relationships supporting industry sovereignty – namely frame ambivalence and switching – may not always be conducive to the promotion of digital agency among meso-scale actors, and could in fact impose limits on smart farming implementation.

Key words

agri-digital governance, meso-scale actors, smart farming, sovereignty, technology implementation, technological frames

Introduction

Smart farming refers to the application of information and communication technologies (ICTs) for managing more effectively all aspects of the farm

system, including land, water, animals, crops and employees (Smart Farming Thematic Network 2016; Wolfert *et al.* 2017; Eastwood *et al.* 2019b). Encompassing data-driven and data-enabled technologies such as sensors, robotics, drones, global positioning systems (GPS) and the use of Big Data, smart farming extends 'conventional tools (e.g., rain gauge, tractor, notebook) by adding autonomous context-awareness by all kinds of sensors, built-in intelligence, capable to execute autonomous actions or doing this remotely' (Wolfert *et al.* 2017, p. 70). In addition to improving efficiency at the farm level, smart farming is argued to have benefits for more informed and accurate decision-making along the entire food supply chain. This occurs through the production and availability of new data, often available in real time, that enables 'decision-making capabilities at a level that was not possible before' (Wolfert *et al.* 2017, p. 78). In doing so, smart farming technologies are viewed by scientists and policymakers as a win-win solution to diverse challenges such as farm productivity, global food security and the environmental impacts of farming (Bongiovanni and Lowenberg-DeBoer 2004; Oliver 2013; Talebpour *et al.* 2015; Lindblom *et al.* 2017).

Despite the claimed benefits of smart farming technology, rural sociologists have long pointed to the contradictions and problems associated with its application as a form of agri-digital governance. For example, scholars have drawn attention to the implications of smart farming in terms of the development of unequal power relationships between large corporations and farmers (Wolf and Wood 1997; Bronson and Knezevic 2016; Carolan 2017). These unequal relationships can contribute to commodification of information (Wolf and Buttel 1996; Wolf and Wood 1997), transfer of data ownership from farmers to digital agricultural companies leading to associated issues of data access (Bronson and Knezevic 2016; Carolan 2018), and problems with data privacy and security (Rotz *et al.* 2019). Sociologists have also investigated how farmers negotiate asymmetrical power relations and find novel strategies to make smart farming technology locally workable through experimentation (Carolan 2018) and tinkering (Higgins *et al.* 2017). Work by sociologists to date is important in highlighting the macro-level political economic influences on smart farming development and implementation, and the farm-level strategies for adaptation, negotiation or contestation. Nevertheless, missing from these analyses is a focus on meso-scale actors, such as agri-service providers, agronomists, researchers and other extension agents, who are tasked with the implementation of smart farming technology in specific commodity sectors or farming industries.

Meso-scale actors – and farm advisors in particular – are increasingly recognised as playing a potentially central role in smart farming, especially in managing farmer uncertainty associated with its implementation (Eastwood *et al.* 2017; Rijswijk *et al.* 2019). Smart farming technology, however, represents a substantial shift from routine practices for those in farm extension and advisory positions (Nettle *et al.* 2018) and this poses challenges in providing effective support to farmers. Such challenges coalesce around what Ayre *et al.* refer to as 'symbolic practices of digiware' – 'managing the proliferation of and multiplicity of digitised forms and effects that characterise digital innovation' (Ayre *et al.* 2019, p. 11). In this context, rather than conceptualising extension and advisory roles as principally a promoter

or a barrier to technology uptake, it is argued that advisors play an important role as ‘sensemakers’ (Eastwood *et al.* 2019a) in helping farmers achieve greater value from smart farming tools. As such, supporting agricultural knowledge providers’ ‘digital agency’ or ‘digi-grasping’ capacities through processes of co-design and collaboration is considered to be a priority so that they are better able ‘to both recognise and act upon the systemic nature of digital innovation in smart farming’ (Ayre *et al.* 2019, p. 9; see also Rijswijk *et al.* 2019). Research to date is valuable in documenting the different ways in which meso-scale actors engage with smart farming technology, the challenges involved in doing so, and how the digital agency of these actors can be supported accordingly so as to enable them ‘to adapt to be successful components in a smart farming future’ (Eastwood *et al.* 2019a, p. 2). However, this research has not yet engaged in a systematic way with existing sociological debates concerning the ways in which actors seek to navigate and negotiate smart farming implementation within specific industries or commodity sectors, and how facilitating or constraining individual agency is linked to broader questions of *sovereignty* for those industries.

Applying insights from the literature on technological frames, this article contributes to sociological knowledge on the significance of meso-scale actors in smart farming, and agri-digital governance more broadly. It does so through addressing two research questions: (1) how do meso-scale actors frame smart farming technology implementation; and, (2) in what ways do those frames variously afford and/or constrain industry sovereignty over how technological change is implemented? We define *sovereignty* in this article as being the capacity of farming industries or communities to exercise ‘democratic control of datascares so as to empower [them] to chart their own futures and define their aims’ (Carolan 2018, p. 759). A theoretical focus on frames and framing provides a conceptually coherent approach for engaging with these questions by enabling researchers to identify the interpretative schemas through which meso-scale actors develop ‘particular assumptions, expectations, and knowledge’ of smart farming technology, ‘which then serves to shape subsequent actions toward it’ (Orlikowski and Gash 1994, p. 175). While there are numerous theoretical approaches to the construct of framing (see e.g., Dewulf *et al.* 2009), we have selected a *technological frames* approach as it accords with a more sociological ‘interactional’ approach to framing (Dewulf *et al.* 2009), and it explicitly recognises technology as a core component in the construction of interpretative schemas across different domains. These domains include: the *nature of technology* including its capabilities and functionality; *technology strategy*, which includes the likely value of the technology to the organisation or industry; and, *technology in use*, which refers to the likely or actual conditions and contexts associated with how technology will be used (Orlikowski and Gash 1994, pp. 183–184). As such, the application of technological frames enables us to identify and examine the relationship between frames across different domains of technology implementation. In developing our arguments, the article draws upon qualitative data from 20 meso-scale actors – including managers, consultants, agronomists and researchers – involved in the planning and implementation of smart farming technology across the Australian rice industry. Throughout this article we refer to these actors as ‘industry stakeholders’ or ‘stakeholders’.

Technological frames

Framing is largely attributed to the work of Goffman (1974, pp. 10–11) who proposes that frames are the schema that individuals develop and draw upon to interpret and make sense of social settings. Frames enable individuals to ‘render events or occurrences meaningful and thereby function to organize experience and guide action’ (Benford and Snow 2000, p. 614). As Kwan (2009, p. 26) argues, exploring frames is ‘not just about the frames themselves and the interplay between competing and complementary frames ... they are also about the relationships between frames and agents’. In other words, frames are used not only as a way of interpreting social settings, they can also be used to convince others of a particular interpretation within a social context, or as a way of mobilising action in others.

Technological frames are widely recognised as a useful conceptual tool for understanding how members of social groups understand and attribute meaning to technological artefacts within organisations (e.g., Bijker 1995; Klein and Kleinman 2002; Davidson and Pai 2004; Lin and Silva 2005; Khoo and Hall 2013) and, significantly for this article, farming industries (Jakku and Thorburn 2010; Thorburn *et al.* 2011). Technological frames were originally developed within a social construction of technology (SCOT) approach (Pinch and Bijker 1987; Bijker 1995), in which emphasis is placed on the socio-cultural processes through which members of a social group develop interpretive schema around an artefact. For a SCOT approach, frames provide a shared ‘vocabulary for social interaction, the forming of social groups, and the constitution of a world’ (Bijker 1995, p. 195). Despite their origins in the SCOT approach, technological frames have been applied and developed most extensively in the information systems literature (e.g., McLoughlin *et al.* 2000; Davidson and Pai 2004; Lin and Silva 2005; Khoo and Hall 2013). From this perspective, technological frames are conceptualised as:

... that subset of members’ organizational frames that concern the assumptions, expectations, and knowledge they use to understand technology in organisations. This includes not only the nature and role of the technology itself, but the specific conditions, applications, and consequences of that technology in particular contexts. (Orlikowski and Gash 1994, p. 178)

Technological frames operate in the background and work to guide individuals in making sense of taking action in organisations and industries. They possess two key characteristics. First, technological frames are used by individuals ‘to organize and make sense of, and to ascribe meaning to, a technology’ (Lin and Silva 2005, p. 50). Second, frames are ‘interpretative, flexible, and context-specific’ (Lin and Silva 2005, p. 50). In turn, technological frames can be both facilitating and constraining in their effects, enabling change or helping to preserve the status quo and preventing adaptation to a changing environment (Orlikowski and Gash 1994).

Central to the technological frames literature is the notion of frame congruence, which refers to alignment of frames of different groups ‘on key elements or categories’ (Orlikowski and Gash 1994, p. 180), or ‘closure in respect of openness to alternative interpretations and arguments’ (McLoughlin *et al.* 2000, p. 21). Frame congruence is argued to be central to the successful implementation of technology in organisations

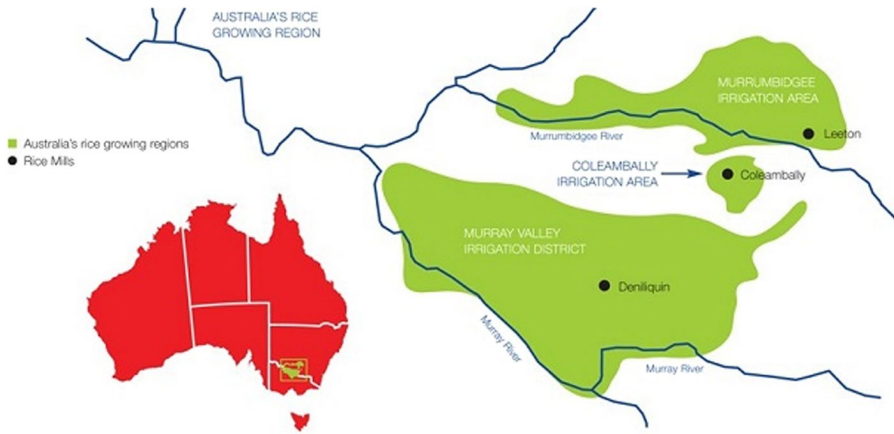
and industries (e.g., Lin and Silva 2005; Davidson 2006; Jakku and Thorburn 2010; Olesen 2014) by creating a set of 'similar expectations around the role of technology in business processes, the nature of technological use, or the type and frequency of support and maintenance' (Orlikowski and Gash 1994, p. 180). Congruence is typically achieved in one of four ways, through: (a) effective communication among organisational stakeholders (Orlikowski and Gash 1994); (b) reframing stakeholder's existing technological frames (Lin and Silva 2005); (c) conceptualising technologies as 'boundary objects' that can facilitate co-learning so that those involved 'arrive at an increasingly shared understanding of the problem' (Jakku and Thorburn 2010, p. 677); and, (d) the imposition of a dominant frame that persuades other groups into accepting the dominant viewpoint (Davidson 2006; Olesen 2014). In contrast, frame incongruence can inhibit implementation of technology by causing 'difficulties and conflicts around developing, implementing, and using technologies' (Orlikowski and Gash 1994, p. 180). Differences in interpretation are typically 'shaped and constrained by various groups' purpose, context, power, knowledge base, and the artefact itself' (Orlikowski and Gash 1994, p. 179). However, McLoughlin *et al.* (2000, p. 21) note that there is often a tendency to interpret 'new technology through frames associated with existing "old" technologies'.

Identifying frame incongruence within organisations and industries shows that congruence of meaning among different groups involved with smart farming technology cannot be taken for granted, and we argue that recognition of differences between technological frames needs to be the starting point of sociological analysis. However, we also acknowledge Davidson and Pai (2004, p. 486) who observe that 'merely noting that different groups think differently about information technologies, and that differences can cause problems, is not very satisfying in the long run'. To contribute to this body of knowledge we argue that while identification of frame incongruence is an important starting point, it is not enough to understand the complex ways in which meso-level actors navigate the challenges in implementing smart farming technology. As such, through our analysis we build on the work of Carolan (2017, 2018) to investigate, (a) other effects, in addition to incongruence, that may be possible from different technological frames, as well as (b) how these effects variously restrict or afford industry sovereignty over technological change, including smart farming technology implementation.

Research methodology

This article focuses on the Australian rice industry, which is located predominantly in the Murrumbidgee and Murray valley regions of New South Wales (NSW). Specifically, the irrigation districts of Murrumbidgee (MIA), Coleambally (CIA) and Murray are situated within this area (see Map 1).

These districts are characterised by hot summers and cool winters. There are approximately 1,500 farms across these regions, which since 2011 have collectively produced an average of 900,000 tonnes of rice per annum (Clarke 2016). Rice production is highly dependent on the availability of irrigated water, and annual production can change dramatically depending on flows into the irrigation system. Water availability



Map 1: Australia's rice growing regions at the time of the research

Source: Ricegrower's Association of Australia Inc. <http://www.rga.org.au/the-rice-industry/rice-community.aspx> [Colour figure can be viewed at wileyonlinelibrary.com]

for rice growing is managed by the NSW state government. Rice is generally grown as part of farming system that can include irrigated winter cereals and canola, summer crops such as maize, soybeans and cotton, and irrigated pasture for livestock production.

The data discussed within this article form part of a larger research project that investigated social interactions with smart farming technology. Specifically, the project sought to understand barriers to more widespread adoption of smart farming technologies. As the project was focused specifically on social interactions with technology, we adopted a social constructionist approach in which the focus is on understanding how 'human action and interaction constitutes reality' (Richey and Ravishankar 2017, p. 3). As such, a qualitative approach was used in which our focus was on investigating the experiences and interpretations of participants who were involved in the planning and implementation of smart farming technologies across the Australian rice industry. To achieve this aim, we conducted semi-structured interviews with 20 participants from across the rice industry. Participants were categorised across four occupational groups (see Table 1), which was done for two specific reasons. First, the rice growing regions in Australia are located in southern New South Wales and are geographically confined, which meant that categorising into four occupational groups would be more likely to ensure anonymity as compared with the risk of describing individual roles.

Participants were recruited for this research through a mixed sampling strategy. First, purposive sampling was used to identify key informants across the different occupational groups (Patton 2015). Each of the key informants then provided opportunities to snowball sample through identification of further participants (Ritchie *et al.* 2014). Each participant took part in a semi-structured interview of approximately one hour in length, all of which were digitally recorded and transcribed for analysis.

Table 1: Stakeholder participant information

Participant code	Gender	Position/Occupation	Role in Change Process
1	M	Management	Development of broader change strategies across the industry
2	M	Management	
3	M	Management	Private consultancy in relation to technology (such as precision agriculture)
4	M	Consultant	
5	M	Consultant	
6	M	Consultant	Broader farming advice including technology adoption but also related to farming processes and business (e.g., agronomy and extension personnel)
7	M	Consultant	
8	F	Agri-service delivery	
9	M	Agri-service delivery	Research and development of new technologies; development and implementation of policy
10	M	Agri-service delivery	
11	M	Agri-service delivery	
12	M	Agri-service delivery	
13	M	Agri-service delivery	
14	M	Agri-service delivery	
15	F	Agri-service delivery	
16	F	Agri-service delivery	
17	M	Research/Policy	
18	F	Research/Policy	
19	M	Research/Policy	
20	M	Research/Policy	

As appropriate to the social constructionist approach, the interviews were treated as ‘reality-constructing and interactional events’ (Koro-Ljungberg 2008, p. 430) in which the interviewer and participant act as co-constructors. Within the interview setting, participants were asked about their roles and backgrounds in the rice industry, what they believe to be the most important technologies for the industry, enablers and barriers to change, perceived gaps between current and desired technology use across the industry, levels of support for change adoption, change recipient input into change processes, and ways in which technology changes were communicated to recipients.

Data from the interviews were initially analysed using open coding, followed by axial coding to seek out possible contextual relationships between open codes (Miles *et al.* 2014). Finally, a thematic analysis (Hennink *et al.* 2011) was conducted across the 20 interview transcripts to derive a set of themes. Three broad themes were derived

from this analysis – technology extension, technology priorities, and technology adoptability – which, similar to Orlowski and Gash (1994, p. 183), were identified as forming ‘core domains of the participants’ technological frames’.

Technological frames in the Australia rice industry

Technology extension

The first theme derived from the data analysis related to the role of private sector agronomists and advisors in supporting growers to implement and use smart farming technologies. Cuts to publicly funded personnel within the NSW State Government as a result of the creation of Local Land Services in 2013 mean that the numbers of regional agronomy and extension staff available to assist growers for free with implementing technology on-farm have been significantly reduced. The rice industry responded to this decline in publicly funded personnel by establishing their own industry-controlled and funded rice extension network. The rice extension network was attributed to providing solutions to low resources by better positioning commercial agronomists to assist in smart farming technology implementation. As two stakeholders observed, the rice extension network was set up to ‘rely on agronomists’ (stakeholder 14), ‘and really upskill our agronomists because agronomists are working a lot more with growers now than they used to’ (stakeholder 15). According to one report, this reliance is important for the future of the smart farming in the rice industry because agronomists are engaged directly with growers:

Agronomists, they’re number one [for communicating changes]. We started running breakfast and morning meetings last season and I think they were much more effective, and they were much better targeted, the whole thing was tightened up under the new extension network and so I think it’s functioning much better. (stakeholder 13)

Some stakeholders judged that this strategy had been reasonably successful in engaging growers in smart farming, and technological change more broadly. For example: We’ve [now] got a lot of younger agronomists who are really stepping up to do that [technology] extension side of things a lot better (stakeholder 11), and ‘Commercial agronomists are now much more important than they were. They’re going out and they’re talking much more to farmers about what’s going on on their farm... They’re not just out there selling chemicals or fertiliser’ (stakeholder 19).

However, other stakeholders raised doubts about the capacity of commercial agronomists and advisors to provide quality technological advice to growers. According to one participant, ‘There is a constraint there that a lot of agronomists aren’t really pushing their clients down this path [smart farming], they’re not encouraging them at all to look at this. So it’s mainly been the farmers dragging the agronomists along’ (stakeholder 5), while another judged that agronomists ‘don’t understand [the technology] so they don’t push it so hard’ (stakeholder 6). Further, ‘I think that most of the support is coming from the retail agronomist, who’s selling [growers] all the products. I suspect they’re probably giving farmers a fair bit of technology recommendations. But I don’t think we really know’ (stakeholder 4).

These reports are supported from some agronomists themselves with several stakeholders reporting that if they do not support particular types of smart farming technology being used in the rice industry, they are less likely to encourage growers to adopt it. For example: 'I think the [smart farming] technology is difficult. I don't think it's been thoroughly demonstrated yet that there is an advantage ... I don't think we quite know how to make use of the technology' (stakeholder 19). Another agronomist believed that it was not his role to assist growers with smart farming technology implementation:

I am a bit of a dinosaur as in I'm not interested in computers ... I suppose I've been down the track a bit with the satellite imaging and we were aware of the whole process of the grower taking an image of his rice paddock and so on ... but I'm pretty much a hands-on service provider and there are others now who are starting to come into the field who specialise in that side of it. (stakeholder 12)

The technological extension domain highlights two competing frames – one in which commercial agronomists are viewed as a solution to the implementation of smart farming technology in the context of declining public resources, and the other where agronomists have a limited role, or none at all, in providing smart farming advisory services and technological support to growers. These competing frames provide clear evidence of *frame incongruence* among rice industry stakeholders. This conclusion is consistent with technological frames research in which frame incongruence is argued to inhibit technology implementation. However, as analysis of the next two core domains shows, not all competing technological frames are characterised by incongruence. In fact, we contend that there is a far more complex relationship between frames that also includes frame ambivalence and frame switching.

Technology priorities

A key second theme that emerged from the interviews was in relation to which technologies were of most importance, and that the rice industry should prioritise. The majority of stakeholders reported that new varieties were the most important technological priority for the rice industry. This is consistent with the primacy of 'Rice breeding – varietal and quality improvement' in the 2012–17 Rice R&D Plan, which at the time of the research was the key document guiding research, development and extension investment in the industry. The strong emphasis by stakeholders is perhaps not surprising given the significance of new varieties in responding to changing market demands as well as in delivering improved stress tolerance, grain quality and water productivity. For example, as one stakeholder argued, 'far and away the most important technology is delivering improved varieties to growers. The reason that is so fundamentally important is that there is enormous competition for water' (stakeholder 1). Another stakeholder emphasised that the industry needs:

to keep making step changes in varieties ... I think the other one is probably, we talk about aerobic rice and cold tolerance ... And I know it's related to varieties, but if we can improve the cold tolerance ... once we get to that, we may open up a whole lot more area that can be cropped and also marry in with other farming systems. (stakeholder 17)

Another reason why stakeholders emphasised the importance of new varieties is because they are in most cases straightforward for growers to adopt and are taken up quickly. For example, 'The most visible technologies and the one that we put the most money into is varieties, so new varieties. And growers take those varieties up very quickly ... There's a great degree of trust that [a new] variety shall deliver' (stakeholder 20). Further, '[growers] are always interested in varieties and that's where the bulk of the research dollar goes, into development of varieties. And so anything to do with varieties [growers] are always very interested in and they're always pretty quick at adopting (stakeholder 9). Growers were also reported as being motivated to adopt new varieties due to the vertical integration of the rice industry. The primary commercial rice company located in the region (SunRice) annually contracts growers to trial new varieties on their farms, providing seed that is deemed to be clean and quality assured (Clarke 2016). This means according to one stakeholder that '[the company] provide the seed; they do the pure seed program so they're providing the seed and passing in information about quality. That really helps the uptake of technology' (stakeholder 19).

However, not all stakeholders viewed new varieties as the most important technology. Several indicated that smart farming technologies such as precision agriculture, laser levelling, and satellite mapping were a greater priority for the industry. For example: 'the number one technology, after autosteer, would be imagery ... levelling [and] GPS guidance' (stakeholder 5); and, 'Laser-guided machinery [is important] ... because that gets right to the farmer's bottom line; if they've got efficient layouts, laser levelled, they'll make significant water savings and they'll have reduced labour inputs as well (stakeholder 2). Further, 'GIS is the most important [technology] ... I think precision ag is probably the main driver at the moment' (stakeholder 11). One stakeholder judged that 'the future's in digital technologies ... that's where we've got to start looking at improving what we do. I think what we have done in the past has worked reasonably effectively but I can see that that's not going to continue to work as effectively (stakeholder 19).

At the same time, some stakeholders raised serious concerns around the extent to which these technologies were likely to be adopted by growers. For example: 'Mapping is [a priority] but whether it's being used is another thing' (stakeholder 6); and, 'Part of [the] challenge is that a lot of [growers] are collecting information but just not utilising it to make their next management decision and ... it's mainly [to get people to] a) be available to analyse the information, and b) to get all their different implements talking to each other' (stakeholder 14). As a consequence, there was considerable *ambivalence* amongst stakeholders over the extent to which the industry should focus on technologies – such as varieties – that are adopted quickly by growers or increase investment in promoting uptake of smart farming technologies that would take more effort. This ambivalence is illustrated well by one stakeholder who initially was of the view that 'anything to do with simple adjustments to the growing system, as long as they're simple, I think [growers] are likely to adopt that faster than they're likely to adopt a big change [such as smart farming]' (stakeholder 17). Later in the same interview this stakeholder conceded that despite the need to focus on easily adoptable technologies, '[transitioning to precision ag] is a step we're going through and it's not easy to transition but we're going to have to have to help [growers] get in there with this precision ag world' (stakeholder 17). While frame ambivalence is evident among stakeholders over

technology priorities, the third domain – technology adoptability – highlights further complexity in the relationship between different technological frames.

Technology adoptability

A third key theme that emerged from the data analysis was over what factors are important in determining whether smart farming technologies would be adopted. On the one hand, participants framed grower attitudes towards technology as well as demographics such as age as key constraints and enablers to smart farming adoptability. One participant reported that uptake of technology in general was slow across the rice industry, which is reflected in the following comment: '[Growers] are slow to pick up on [technology]. Initially ... [changes to] farm layout would be something that they would pick up straight away [but] ... very slow in taking up precision ag and other technologies' (stakeholder 18). Yet, other participants argued that refusal to engage with new technologies in general highlighted that adoption of smart farming technology was highly unlikely: 'I've got a couple of guys that don't have computers and refuse to use computers ... They can't do anything without having to ring someone up and get them to do what they need on their computer ... They are resistant to change' (stakeholder 8); and, 'One of the things becoming more obvious is that [growers] are sticking to traditional practices ... It frustrates me 'cause they could have a new bit of gear, it doesn't break down ... yet they choose to keep fixing the old one (stakeholder 3).

Reluctance to adopt technology was attributed primarily to age. Age was viewed as having a major influence on adoption with older growers in particular seen as lacking interest in new technology. For example, 'The sort of people who take up technology, they're probably the ones who are more familiar with using an iPad and they're probably the younger generation' (stakeholder 15); 'the older guys, I think they're just used to being in the field more and they don't want to be behind a computer' (stakeholder 10). Such arguments are further articulated in the following comment:

I think age is the biggest barrier, the demographics of ages. I'm not sure what the average age of a rice grower is, but it's probably in the 60s, late 50s anyway and that's old enough. We've been holding major field days and some young grower days ... and the young ones that are coming are just willing to adopt technology really quickly, whereas, you get the field days where a lot of older growers will turn up, and they're still doing the same old thing and they haven't changed a great deal. But they've done pretty well out of it for 20 or 30 years and they're happy ... There are some good older growers, but there are some that are starting to get left behind (stakeholder 17).

Whereas older growers were argued as being less likely to embrace technological change, participants viewed younger farmers as early adopters of change. Specifically, early adopters were reported as being more inclined to embrace new technology: '[Technology] is attracting younger farmers, those toys, new toys. Keeps the son on the farm possibly, a lot of farmers like to buy those toys to keep their son interested in staying on the farm' (stakeholder 15). Younger growers were also described as being pivotal to the longevity of the rice industry through being more open to innovation than older growers and developing sustainable change. For example, 'I think there's a percentage of older guys that are very tuned in, but I think we're looking for a

younger generation to come through and actually see what opportunities there are' (stakeholder 3).

On the other hand, within their reports, stakeholders also framed structural and biophysical constraints as having a significant impact on the ability of growers to successfully implement technological change. First, the availability of assistance in implementing more advanced technologies was reported as being a constraint to growers:

[If] a farmer wanted to do some precision ag, they want to have someone local, and in many cases, there just isn't anyone in their [location] so they've got to look further afield and engage [someone] like us – we might be two or three hours away – which does limit the way you can work with them. You can't afford just to be on their doorstep all the time. There'd be less than five businesses in Australia offering independent precision agriculture consulting; that's restricting the growth. (stakeholder 5)

Similar views are evident in the reports of two agri-service delivery stakeholders. For example, 'something like precision ag, there's a limited amount of consultants, whereas something like [adopting] herbicides and nutrition, then you've got agronomists giving advice and support (stakeholder 16)'; 'I reckon there's a small amount of support out there but not a lot. If I were a grower, I'd be frustrated ... They either have to go and read a fair bit ... but if you don't read a lot then there's not a lot you can do, not a lot of help out there' (stakeholder 17).

Second, stakeholders identified the climate in which rice growing takes place in Australia as a constraint on technology adoptability. For example, 'drought has a big impact in the sense that it dictates what R&D levies are likely to be; the Millennium drought really cut through the R&D network' (stakeholder 13); 'Water is the most limiting factor of growing rice. There's plenty of land, plenty of skills to grow it ... there's market demand ... we just haven't got the water' (stakeholder 14). Another stakeholder suggested that recent ongoing drought had forced many growers to sell their water allocations, restricting their ability to grow crops, let alone invest in new technology:

Sometimes [growers] were told to [sell water]; the banks told them they had to [and] they're struggling now to get enough water to grow anything ... So these are important issues that I don't think from a research point of view that we understand really well yet ... I don't think researchers yet understand ... the range of experiences the farmers have and what they need to [do] address that. (stakeholder 19)

While the presentation of reports above suggests that stakeholders frame adoptability of smart farming as either an individual or a structural issue, this was not the case in the interviews. Indeed, in their reports, stakeholders *switched between* technological frames, framing adoptability of smart farming technology as both an individual and a structural issue. This contrasts to the technology priorities domain where frame *ambivalence* was evident, and stakeholders were unclear on the extent to which research and development investment should continue to prioritise rice varieties or give greater emphasis to smart farming technologies. It also contrasts to technology extension where there was clear *incongruence* among stakeholders over the role of commercial agronomists in the promotion of technology to growers and providing assistance with implementation.

Discussion

This article has drawn upon a technological frames theoretical approach to investigate two research questions: (1) how do meso-scale actors in the Australian rice industry frame smart farming technology implementation; and, (2) in what ways do those frames variously afford and/or constrain industry sovereignty over how technological change is implemented? In addressing these questions, we have sought to connect the growing literature on the role of meso-scale actors in smart farming to rural sociological scholarship on how actors negotiate technology implementation, and the ways in which individual agency is interconnected with questions of industry sovereignty.

In addressing Research Question 1, our analysis has identified three frame domains within which rice industry stakeholders construct interpretative schemas around smart farming implementation – technology extension, technology priorities, and technology adaptability. Each domain is characterised by the use of different technological frames. Thus, under the *technology extension domain*, stakeholders frame commercial agronomists as playing either a central or a very limited role in smart farming implementation; under the *technology priorities domain*, participants' frames emphasise easily adoptable technologies – such as new rice varieties – as well as the need to increase investment in smart farming technology; under the *technology adaptability domain*, increasing smart farming adoption is framed as an individual and a structural issue. Each of the technological frames drawn upon by participants reflect particular 'assumptions, expectations and knowledge' of smart farming technology and its users, as well as local understandings of the contextual factors that are likely to influence specific uses of the technology (Orlikowski and Gash 1994, p. 178). Identification of these frames provides further evidence of the challenges experienced by meso-scale actors in 'managing the diversity, complexity and uncertainty' (Ayre *et al.* 2019, p. 2; see also Nettle *et al.* 2018) associated with smart farming technology. However, it is the relationship between frames that is most significant in building on existing scholarship on the role of meso-scale actors in smart farming.

In identifying the different ways in which industry stakeholders frame smart farming implementation, we have shown that differences between technological frames do not necessarily engender frame incongruence. Within the technological frames literature, a dominant focus is how different interpretations of technology between relevant groups lead to frame incongruence, and in turn impose constraints that need to be managed to ensure frame alignment and effective implementation of technology (e.g., Orlikowski and Gash 1994; Davidson 2006; Jakku and Thorburn 2010; Khoo and Hall 2013). An emphasis on frame incongruence is also evident in the literature on meso-scale actors in smart farming, in which understandings of and responses to smart farming are characterised as ad-hoc (Rijswijk *et al.* 2019) and lacking in a shared and strategic vision (Fielke *et al.* 2019). From this perspective, the development of a more systematic, integrated and strategic approach to smart farming is argued to be critical so that meso-scale actors can more effectively translate digital innovations into better farm management decisions (Eastwood *et al.* 2017; Ayre *et al.* 2019; Rijswijk *et al.* 2019). Our analysis reveals that incongruence, while important, is only evident within one of the domains that we have discussed – the technological extension domain. In this domain, commercial agronomists and advisors

are interpreted on the one hand as being central to smart farming implementation at a regional scale, while on the other they are viewed as having a limited and in some cases counter-productive role in promoting technological change. For the other two domains – technology priorities and technology adoptability – a more complicated relationship between frames is evident characterised by what we have termed *frame ambivalence* and *frame switching*.

Frame ambivalence refers to equivocal interpretations over which technologies industry should prioritise in its research, development and extension work. Ambivalence is already recognised as an important part of framing processes (Nijland *et al.* 2013). However, to date it has received limited attention in the smart farming literature. Frame switching involves stakeholders switching between individual grower-centred and structural or climatic explanations of smart farming adoptability. Switching has not previously been observed in research on technological frames, or framing more broadly, and as such provides a novel contribution. In the framing literature, different frames are typically viewed as incongruent (Orlikowski and Gash 1994), conflicting (Keenan *et al.* 2019) or contrasting (Dewulf 2013). From this perspective, the values, norms and interests of relevant groups are associated with a specific frame, and this only changes once interpretative flexibility is reduced and frame congruence achieved. We argue that research on the role of meso-scale actors in smart farming needs to give greater attention to frame ambivalence and frame switching. While the development of a more systematic and integrated approach to smart farming advocated in the literature provides a way of addressing incongruent, conflicting or contrasting frames, it may not be as effective in managing frame ambivalence or switching. For these frame relationships, more flexible and diverse approaches are likely to be needed in enabling meso-scale actors to engage with smart farming services in the context of industry-defined technological priorities and drivers of adoptability, that are mixed, multiple, and sometimes contradictory.

In addressing Research Question 2, we build on current research that explores the possibilities for enhancing the digital agency of farm advisors, by reflecting on the broader effects that each frame relationship engenders for the sovereignty of the rice industry to ‘chart their own futures and define their aims’ (Carolan 2018, p. 759) in relation to technological change. Our analysis shows that the different relationships between participants’ technological frames have mixed effects for industry sovereignty. First, the effects of *frame incongruence* are consistent with what scholars of technological frames have already observed, namely impeding the capacity of the industry to implement technological change unless appropriately managed through, for example, imposing a dominant frame or finding other ways for actors to reach a shared understanding of the problem (e.g., Lin and Silva 2005; Davidson 2006; Jakku and Thorburn 2010). From this perspective, if commercial agronomists and advisors are not promoting, or have doubts about, the use of specific technologies, the Australian rice industry will face growing ‘knowledge fragmentation and information asymmetry’ (Sutherland *et al.* 2013, p. 97) that is likely to be counter-productive in enabling more widespread implementation of smart farming technology. Such information asymmetry is likely to also lead to confusion among growers as to who they should turn to for technological support, a particular concern in an institutional environment characterised by declining public extension and limited commercial businesses offering specific smart farming technology support.

Second, *frame ambivalence* has two possible effects for rice industry sovereignty. On the one hand, it allows 'interpretation of ambiguous situations' (Orlikowski and Gash 1994, p. 176). Here, frame ambivalence can promote technology implementation by legitimating industry support of smart farming technology within a qualified framing of technology priorities. Such qualified framing allows scope for uncertainty around grower adoptability and caution over the costs and benefits associated with transitioning to a new mode of working for growers (Eastwood *et al.* 2017; Nettle *et al.* 2018). On the other hand, ambivalence can lead to industry stakeholders hedging their bets (see e.g., Sillince and Mueller 2007) on new and unproven technology, adhering to existing priorities of improving productivity through the promotion of new, and easily adoptable, rice varieties, which have worked well for the industry in the past. In these circumstances, falling back on known technological frames ensures ongoing industry control over research and development priorities. Yet it can also 'reinforce unreflective reliance on established assumptions and knowledge, distort information to make it fit existing cognitive structures, and inhibit creative problem solving' (Orlikowski and Gash 1994, p. 177).

Third, *frame switching* involves reframing of who or what is (or should be) responsible for driving grower adoptability of smart farming technologies. This is not so much a switch from one strategic perspective to another, as described by Sillince and Mueller (2007), but an ongoing *switching between* technological frames where both individual and structural or climatic factors are interpreted as important in influencing adoptability. Switching not only allows 'wide scope for interpretation of responsibility' (Sillince and Mueller 2007, p. 155), it also enables growers to be positioned as critical to technological change outcomes within the rice industry. In this instance, growers are positioned as the key agents in enabling or preventing technological change, despite not necessarily being involved in its design or implementation. This is particularly evident in participant reports in which grower characteristics such as age are attributed to an ability or willingness to adopt smart farming technology. However, growers are also positioned as being constrained by structural and climatic forces beyond their immediate control. The seemingly contradictory positioning of growers enables industry stakeholders to differentiate between those aspects of technological change over which they have control, and those they do not. In this sense, positioning enables industry stakeholders to draw upon 'their experience in relation to identity, power ... [and] ideology' (Scarduzio and Geist-Martin 2010, p. 424) to shift the focus to others in the event that change outcomes may not be as planned.

We argue that of the three frame relationships, frame ambivalence and frame switching are the most likely to *afford* sovereignty by enabling the rice industry to exercise control over technological priorities, and to define the scope of industry influence in managing technological change. However, affording sovereignty does not necessarily enhance the digital agency of industry stakeholders to implement smart farming technology. For example, one of the possible effects of frame ambivalence is that industry stakeholders stick to tried and trusted technological priorities, which may discourage the research, development and extension work that is important in translating smart farming technology to meet farm level needs (Eastwood *et al.* 2017; Eastwood *et al.* 2019a). This in turn can have negative implications for the capacity of growers in experimenting and tinkering with new technology, which is

central for working with and working ‘around technology to make it adoptable on-farm’ (Higgins *et al.* 2017, p. 201). While frame ambivalence and switching afford industry sovereignty, this is not necessarily the case for frame incongruence in which industry extension priorities are clearly at cross purposes with the availability of smart farming technology support and the existing priorities of commercial agronomists. This imposes limits for the industry in promoting more widespread and systematic implementation of smart farming technology. Yet, perhaps paradoxically, such incongruence may also be a key reason why the corporate control observed by some sociologists is not evident to date in the implementation of smart farming in the Australian rice industry.

One significant implication of our analysis for smart farming research is that frame relationships supporting industry sovereignty may not always be conducive to the promotion of digital agency among meso-scale actors, and could in fact impose limits on smart farming implementation within particular industries. This also means – although not explored in this article – that efforts at enhancing the digital agency of industry stakeholders could inadvertently undermine industry sovereignty by promoting technological solutions ‘that empower corporate actors rather than supporting independent farmers to make informed ecological decisions under their management’ (Rotz *et al.* 2019, pp. 19–20). However, enhancing industry sovereignty does not necessarily need to run counter to the promotion of digital agency among meso-scale industry stakeholders. Future smart farming research underpinned by Responsible Research and Innovation (RRI) principles – anticipation, inclusion, reflexivity and responsiveness (Bronson 2018; Regan 2019; Eastwood *et al.* 2019b) – will be critical in ensuring that industry sovereignty is taken into account by researchers *as part of efforts* to support agricultural knowledge providers’ digital agency.

Conclusion

This article shows that technological frames provide a promising analytical direction for sociologists in exploring the role of meso-scale actors in implementing smart farming technology, and agri-digital governance more broadly. In particular, it enables greater emphasis on (a) how meso-scale actors who provide services to specific industries frame smart farming implementation in the context of existing technology priorities, extension and advisory capabilities, and interpretations regarding the main drivers of technology adoptability, and (b) the ways in which framing processes enhance industry or commodity sector sovereignty over the direction and nature of technological change within those industries. In focusing on these areas, the article contributes to and builds on the literature on the role of meso-scale actors in smart farming in two important ways. First, we argue that this literature implicitly assumes frame incongruence among meso-scale actors. The finding that other frame relationships – such as frame ambivalence and switching – are equally relevant, raises critical questions over whether and to what extent seeking integration of diverse meso-scale actor perspectives will be effective in enhancing industry-level implementation of smart farming technology. Second, the current literature focuses on enhancing the digital agency of meso-scale actors so that they are better able to ‘realise the value of digital tools and services’ (Ayre *et al.* 2019, p. 11) and thereby support more

effective uptake of smart farming innovations. We argue that while supporting the digital agency of meso-scale actors is important, researchers also need to give attention to agency at an industry scale – what we have termed ‘sovereignty’ following the work of Carolan (2018). However, building industry sovereignty is not necessarily conducive to researcher efforts to enhance the digital agency of meso-scale actors. We contend that future research incorporating RRI will be critical in ensuring that questions of industry sovereignty are considered alongside those of digital agency in determining how best to support meso-scale actors in ways that do not undermine industry sovereignty in controlling the course of technological change.

We have argued in this article that the application of a technological frames approach, and its extension through the concepts of frame ambivalence and switching, is highly applicable in making sense of smart farming technology implementation in the Australian rice industry. Nevertheless, we recognise that further research in commodity sectors within Australia and internationally, and especially in contexts where smart farming implementation is more advanced, will be crucial in assessing the extent to which technological frames provide a conceptually coherent way forward in studying the role of meso-scale actors in smart farming. In doing so, other theoretical approaches to framing based upon interpretative or cognitive paradigms (Dewulf *et al.* 2009) might be applicable in teasing out aspects of meso-level actors’ role in smart farming implementation that have been touched on only briefly, or not considered at all in this article. Regardless of research context or theoretical approach to framing, understanding the diversity of relationships between frames, and the complex political ontologies they engender, will need to be a central focus of inquiry for social researchers as they seek to further understand how to enhance farmer ‘access to outcomes and opportunities from digital innovation in smart farming’ (Ayre *et al.* 2019, p. 11).

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Conflict of interest statement

No conflict of interest is declared.

Data availability statement

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

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