Digital technology in the agrifood sector: a review on the business impact of digitalization in the agrifood sector

How is digitalization affecting agrifood?

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2 Digital technology in the agri-food sector

A review on the business impact of digitalization in the agri-food sector

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Introduction

Organizations in all fields are now increasingly making use of digital technologies, which has resulted in a new phenomenon defined as "Industry 4.0."

Following the "4.0 era," the agricultural industry is also on the verge of a digital transformation, with a growing number of organizations, both established and start-ups, and investors devoting enormous resources to R&D, adoption, and diffusion of new technologies in agriculture (Deloitte, 2016), resulting in "Agrifood 4.0" (Miranda et al., 2019). "Digital agriculture" is defined by Shepherd et al. (2018) as "the use of detailed digital information to guide decisions along the agricultural value chain." Within agriculture, the use of Precision Agriculture Technologies (PAT), or Smart Farming Technologies, are mostly applied on the farm in the form of digital input. Nonetheless, Agrifood 4.0 innovations can apply to different actors in the value chain, as in the case of marketplace technologies. Smart technologies and 4.0 are showing extensive benefits, with a potential large impact both on economics and on social and environmental issues since it is enhancing the efficiency of operations by reducing the overuse of inputs (i.e., water, fertilizer, pesticides, seeds, etc.). When applied to several actors in the value chain, these technologies consistently reduce waste and costs, be it on the farm, in retail, or in consumption, as they provide new and valuable information for decision making (FAO, 2013). Within the food industry, the adoption of robots in the production line and the use of automations have become very attractive in light of the drop-in production costs. Adopting these technologies will be necessary for an industry like food, which has vast competition and significantly lower labor costs abroad (Masey et al., 2010).

While effects on the whole value chain are important, we focus specifically on agriculture. Despite the significant benefits and the efforts of many institutions to pave the way for Smart Agriculture by providing consistent public funds and introducing policies to support innovation, there are still many farms coping with challenges in adopting digitalization. This chapter focuses on the digitalization of agriculture and refers to existing literature to summarize the main challenges faced by agri-food firms when adopting digitalization. By not making use of new technologies while other firms do, a business might fall behind amongst the vast competition (Rao, 2003). Additionally, fast growing industries are moving on to a "5.0 era," while the agricultural sector still has difficulties in adopting "Industry 4.0" technologies (Zambon et al., 2019).

Based on these earlier studies, there are concerns about the speed of adopting digital technologies in the agricultural sector and the lack of a clear overview of the problems that agricultural firms face in adopting digitalization in their operations. Moreover, there is also a relevant research gap that needs to be examined and which will be essential for decision makers in this area, and given its immense potential economic and environmental impact, studying the factors affecting technology adoption is crucial.

Digital technologies in agri-food

In Chapter 1, we highlighted the main trends related to digitalization, which are extending to the agricultural industry driven primarily by four megatrends: First, the need for sustainable production as well as to find alternative and innovative ways to feed the growing global population, which is expected to increase to 8 billion by 2025 and 9.7 billion by 2050 (FAO, 2013). Second, consumer-specific demand for safety, traceability, ecological footprint, and health properties of food, as demonstrated by the rapid growth of the organic and slow food market (IFOAM EU Group, 2016). Third, the emphasis on potentially polluting effects, biodiversity loss, and reduction of soil fertility in relation to agri-food operations, as well as the quest to reduce the impact of climate change and to increase the optimization of resources (e.g., water and land scarcity following urbanization) (World Business Council for Sustainable Development (WBCSD), 2008). Lastly, the technological shift that has enabled the development of agri-food applications. These include the explosion of smartphone capabilities and the diffusion of the internet and Wi-Fi, which serve as catalysts for this change, as well as the development of technologies related to Artificial Intelligence (AI), Big Data Analytics, Cloud Computing, Cyber-Physical Systems (CPS) (mechanisms controlled or monitored by computer-based algorithms), and the Internet of Things (IoT). More specifically, in this chapter, when discussing "Digital Technologies in Agri-food" or "Agriculture 4.0," we are referring to the application of such technologies in farming and the implementation of Smart Farming (also defined as Precision Farming), following the "Fourth Agricultural Revolution" (Deloitte, 2016). We describe the main technologies below:

- *Smart Greenhouses*: self-regulating, climate-controlled environments for optimal horticulture growth with minimal human intervention. Within a smart greenhouse, moisture, humidity, and light are constantly monitored and any divergence from the predetermined conditions is automatically adjusted.

- *Smart Irrigation Control Systems*: IoT and AI systems are used to minimize water usage in irrigation. Such systems combine technologies monitoring soil moisture, wind, and rain, as well as remote sensing controllers and AI algorithms (Shitu et al., 2015). Thus, Smart Irrigation optimizes water consumption according to soil data and through variable rate technologies (VRT).
- *Drones and Robots*: the former is an unmanned aerial vehicle used in farming to help monitor crop growth. Farmers can monitor fields from the sky and gather richer pictures through sensors and digital imaging, which is helpful for detecting potential problems in cultivation, pests, and other crop diseases. Robots, on the other hand, are "intelligent farm machines" that automatize and perform diverse farm tasks and can be remotely controlled.
- *Soil, Plants, and Yield Monitoring Systems*: in these systems, several smart sensors are used to gather data, increase efficacy, and prevent problems. They are used to monitor various physical, chemical, and biological soil properties, plant compositions, mass flow, and harvest.
- *Software and Data Analytics*: following the need for data-driven insights, organizations might use software to track, manage, and maximize the use of resources and production, as well as data analytics, information collection, and management to gather not only real-time insights but, more importantly, predictions. Software can also be used to increase collaborations with other actors along the supply chain.
- *Precision Livestock*: just like in the case of precision farming, technologies can be used to optimize operations and deliver better results in livestock farming. For example, technologies allow farmers not only to monitor the health and welfare of livestock, but also feeding, heat stress, milk harvest, and breeding patterns.
- Lastly, technologies can act as enablers and drivers for commercialization by providing *marketplaces*, connecting organizations to suppliers or consumers, even bypassing intermediation.

Methodology

In order to collect data about the challenges related to digitalization in the agri-food industry, we performed a systematic review of the literature, following the method laid out by Tranfield et al. (2003) described in Chapter 1 (Par "Systematic literature review: the methodology" in Chapter 1, ibidem).

We performed the research with Scopus, using search terms associated with the 4.0 era (digit*, big data, Artificial intelligence) in relation to "agri-food," "agriculture," "farm*," and "smart farm*." We restricted the search to the "social sciences," journals, peer reviewed articles, and documents written in English. Additional filters included the number of citations (if the paper did not fit in any of the three groups described below) and outlet (only ABS 2, 3, 4 and 4* journals). We followed the grouping method described by Crossan and Apaydin (2010) and divided the papers into three groups: the first group containing 28 reviews and meta-analysis, the second group consisting of 47 frequently cited papers (at least five times per year), and the third group comprising 433 more recent papers (published between 2009 and 2019). We excluded review articles and filtered the remaining ones. We were left with 17 papers after filtering, most of which were empirical, summarized in Table 2.1.

Discussion

We analyzed the papers to identify the challenges faced by agricultural firms. We started by classifying the challenges highlighted by the different papers and the theories connected to each type of challenge. Based on the available literature, several features could be significant in the adoption and diffusion of a technological innovation, some of which are found at the individual level, like a farmer's educational background and his/her capability to perceive an opportunity. Others are at the firm or environmental level, and relate to factors such as finance, access to physical infrastructure and business services, institutional support, and the socio-cultural context (Long, Block and Poldner., 2017; Annosi et al., 2019).

Individual factors, such as education and cognitive capacity, may influence the decision to adopt and use a technology. These capabilities allow an individual to identify a match between the opportunities and threats and internal resources, skills, and capabilities (Shane and Venkataraman, 2000), since they relate to the ability to evaluate benefits and costs, identify needs and opportunities (i.e., turning a farm into a "smart" one) (DeTienne and Chandler, 2004), and act on them, using the technologies (Annosi et al., 2019). In this light, education and training enhance an individual's own cognitive abilities to identify the quantity and characteristics of technologies to adopt (Fernandez-Cornejo, Beach, and Huang, 1994; Daberkow and McBride, 2003; Paxton et al., 2010). At the same time, farmers who perceive net benefits and possess the education and training needed to use PAT showed a greater propensity to adopt them (Adrian et al., 2005). An additional role of cognitive capacity might be the one played by socio-cultural norms and culture, such as peer pressure, which might drive or hinder decisions to adopt Smart Agriculture. For example, in his study of innovation adoption in India, Abdullah (2015) identified elements such as access, level of education, knowledge, quality, and landholding as potential features that have an impact on adoption. Specifically, he analyzed the level of education and landholding as proxies for caste to verify how individual and socio-cultural factors influenced the adoption and use of farming technology. Several of the analyzed papers focus at these cognitive factors. Bello-Bravo et al. (2018) built a study to verify the impact of diverse learning tools on rural populations. While the scope of their experiments ranges from health to agricultural issues, their approach highlights some interesting insights into factors such as access, education, costs of Information and Communication Technology (ICT) transfer, and learning. Chandra et al. (2017) analyzed climate-resiliency field schools (where the practice of organic farming and community seed bank

Table 2.1 List of articles analyzed

Year	*Authors*	*Title*	*Journal*	*Themes*
2003	Cecchini, S. and Scott, C.	Can information and communications technology applications contribute to poverty reduction? Lessons from rural India	*Information Technology for Development*	Access; Infrastructure; Institution
2009	Richards, P., de Bruin-Hoekzema, M., Hughes, S. G., Kudadjie-Freeman, C., Kwame Offei, S., Struik, P. C., and Zannou, A.	Seed systems for African food security: linking molecular genetic analysis and cultivator knowledge in West Africa	*Technology*	Institutions; Policy
2010	Mokotjo, W., and Kalusopa, T.	Evaluation of the Agricultural Information Service (AIS) in Lesotho	*International Journal of Information Management*	Access; Services
2011	Islam, M. S., and Grönlund, Å.	Bangladesh calling: farmers' technology use practices as a driver for development	*Information Technology for Development*	Age and Generation
2011	Soomai, S. S., Wells, P. G., and MacDonald, B. H.	Multi-stakeholder perspectives on the use and influence of "grey" scientific information in fisheries management	*Marine Policy*	Complexity; Services
2014	Hay, R., and Pearce, P.	Technology adoption by rural women in Queensland, Australia: women driving technology from the homestead for the paddock	*Journal of Rural Studies*	Access; Age and Gender; Education
2015	Abdullah, A.	Digital divide and caste in rural Pakistan	*The Information Society*	Access; Level of Education; Infrastructure; Socio-factors
2015	Tanure, S., Nabinger, C., and Becker, J. L	Bioeconomic Model of Decision Support System for farm management: proposal of a Mathematical Model	*Systems Research and Behavioral Science*	Complexity

(*continued*)

Table 2.1 Cont.

Year	*Authors*	*Title*	*Journal*	*Themes*
2016	Hennessy, T., Läpple, D., and Moran, B.	The digital divide in farming: a problem of access or engagement?	*Applied Economic Perspectives and Policy*	Access; Farm characteristics
2017	Chandra, A., Dargusch, P., McNamara, K. E., Caspe, A. M., and Dalabajan, D.	A study of climate-smart farming practices and climate-resiliency field schools in Mindanao, the Philippines	*World Development*	Access; Knowledge
2017	Panagiotopoulos, P., Bowen, F., and Brooker, P.	The value of social media data: integrating crowd capabilities in evidence-based policy	*Government Information Quarterly*	Knowledge; Policy
2017	Pant, L. P., and Hambly Odame, H.	Broadband for a sustainable digital future of rural communities: a reflexive interactive assessment	*Journal of Rural Studies*	Access
2018	Bello-Bravo, J., Tamò, M., Dannon, E. A., and Pittendrigh, B. R.	An assessment of learning gains from educational animated videos versus traditional extension presentations among farmers in Benin	*Information Technology for Development*	Access; Education; Knowledge
2018	Coble, K. H., Mishra, A. K., Ferrell, S., and Griffin, T.	Big data in agriculture: a challenge for the future	*Applied Economic Perspectives and Policy*	Access; Data Management; Policy
2018	Khanna, M., Swinton, S. M., and Messer, K. D.	Sustaining our natural resources in the face of increasing societal demands on agriculture: directions for future research	*Applied Economic Perspectives and Policy*	Incentives; Finance; Institutions
2018	Saggi, M. K., and Jain, S.	A survey toward an integration of big data analytics to big insights for value-creation	*Information Processing and Management*	Complexity; Finance
2019	Rotz et al.	Automated pastures and the digital divide: how agricultural technologies are shaping labor and rural communities	*Journal of Rural Studies*	Institutions; Policy

establishments are taught) and noticed that since climate-smart interventions are traditionally knowledge-intensive processes, a lack of education and previous experience can hamper the adoption of such technologies. One peculiar finding is that of Islam and Grönlund (2011), who, in their research about farmers in Bangladesh, showed that education and income did not represent barriers to adoption, but rather demographic factors such as age or having young children were.

These innovations are often costly and complex (Tanure et al., 2015; Saggi and Jain, 2018). Therefore, not only do individual factors play a role, but so do factors at the firm or environmental level, which can have an impact on the likelihood of innovation adoption and usage (Annosi et al., 2019). Among them, access to finance, institutional support, infrastructure and services, and cultural and social context. With regards to finance and costs, it is important to note that the higher the effective – or perceived – cost of digital technologies in the agri-food sector and the more difficulties there are in accessing financing, the lower the probability that farmers, entrepreneurs, or firms will adopt and use such technologies. Richards et al. (2009) accurately underlined this problem when they analyzed the challenges faced by African countries in terms of lack of support in funding and direct links between farmers and researchers (Richards et al., 2009). Institutions also play a role, especially through policies that stimulate farmers' investments in digital solutions or help them use such technologies (Khanna et al., 2018; Rotz et al., 2019). Another relevant issue, given the nature of these technologies, is the access to infrastructure, such as broadband internet and the cloud, which are required for Smart Agriculture to be used effectively and offer successful results. This was highlighted by Pant et al. (2017) in their study of examining Canadian farms. Similarly, services in commercial, legal, financial, and, most importantly, IT and digital consultancy could offer proper support to farmers deciding to adopt certain innovations (Hay and Pearce, 2014; Long et al., 2016). Mokotjo and Kalusopa (2010) noticed that the use of agricultural information services is related to weak promotion and training in the use of these services. For example, Soomai et al. (2011), in their study of fisheries, noticed that institutional support could help entrepreneurs cope with the high technical content. From a different perspective, Panagiotopoulos et al. (2017) noticed that in the UK, farmers have also successfully used digital platforms to influence policy making. Other authors specifically focus on these issues. For instance, Cecchini and Scott (2003), focusing on how technologies support farmers in rural India and their connection to markets, analyzed the digital divide and identify access to a proper infrastructure as a necessary, but not sufficient, prerequisite for adopting and using technologies, recalling the importance of incentives and support. Coble et al. (2018) also mentioned how infrastructure is a critical bridge in the use of technology. Thus, access and availability of an infrastructure result in a comparative advantage for firms that have it. Hay and Pearce (2014) confirmed this in their study of the lifestyle of rural women in Queensland.

At the firm level, the adoption of smart farming technologies was found by Hennessy et al. (2016) to be dependent on a business's characteristics and not simply on the access to digital technologies; indeed, in their study, farmers with access to computers did not necessarily adopted ICT technologies.

Conclusion

In this chapter, we provided an overview of existing literature to assess the challenges previously highlighted regarding the adoption of digitalization in agriculture.

While there has been abundant literature on Precision Agriculture (e.g., Cox, 2002; Grogan, 2012; Kaloxylosab et al., 2012), it is evident that the contributions to management literature related to digitalization and agri-food are still limited, and a great deal remains to be done to further understand the factors that influence farmers' decision to adopt smart solutions. So far, management scholars have focused on the impact of new technologies on a farm's business model (e.g., Long, Blok, and Poldner, 2017) or firm performance following adoption, rather than focusing on the relationship between the decision to invest in smart technologies and the various factors that impact such a decision (Annosi et al., 2019). Nonetheless, despite the scope and variety of topics analyzed, the purpose of this chapter is to lay the groundwork for the following chapters, where some of these issues are discussed in detail.

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