Chapter 6
Digitalization in the EU Agricultural Sector: Seeking a European Policy Response

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6.1 Introduction

Agriculture has always been distinct in regard to other national economic activities, and thus it has always been treated as such. More particularly, the importance of agricultural production, and consequently of the food industry, not only for the population's nutrition needs but also for the rural areas of a country, remains critical. As a result, it has traditionally been the subject of the policy process, in order to be appropriately regulated. Furthermore, various specific sectoral features have also been incorporated into the notion of the multifunctionality of agriculture which can be broken down into the idea that agriculture has multiple functions in addition to food products such as environmental protection, rural employment and food security. In that sense, farmers go beyond their traditional role and become the core of a broader plan for the development of rural areas (Doukas, 2012).

Thus, the agricultural sector holds a particular and strategic position in the process of a country's economic development, not only due to its vitality as a food supply sector, but also due to its interconnection and linkages with various activities in the food industries' supply chain. Within an era where the "evolution of socio-economic systems objectively implies periodic radical changes in the technical and technological base of the social reproduction system and the development of the system of economic and social relations" (Ulez'ko et al., 2019), the agri-food sector strives for a sustainable path towards digital transformation.

On the other hand, technological advancement plays a crucial role in building circumstances of sustainable economic development and innovation as a significant driver of growth. Even so, technology adoption and use are still in the initial stages in

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the case of the agricultural sector; some scholars support the idea that digital technologies will lead to the next agricultural revolution. That potentially will reverse some of the most harmful effects of the "green revolution" witnessed by the sector a few decades ago (Kosior, 2018; Walker, 1969). Furthermore, the issue of digital transformation and the need to reform the agricultural sector of a country towards this direction has unfolded multiple times during the last years in the public discourse. That happened mainly through public discussions and conferences, signaling a bottom-up process, where various stakeholders seek to bring this issue into the public policy agenda. Nevertheless, no robust action has been taken. In the meantime, numerous European countries are making significant efforts to adjust their agricultural sectors in the digital era.

Using the agricultural innovation systems (AIS) approach, we will emphasize specific EU policy means, such as the Green Deal and the Farm to Fork Strategy under the new CAP, which will go into force in 2023, aiming at contributing to the digitalization of the agricultural sector, in practice. In other words, the paper intends to highlight specific parameters of the AIS, focusing on relevant initiatives undertaken by an involved actor of major special weight, namely the EU, for the purposes of the digitalization of the agricultural sector.

6.2 Digitalization of the Agricultural Sector in a Nutshell

Generally, "the change of technological structures allows the society to resolve the accumulating development controversies, to ensure the growth of labour productivity and the efficiency of processes of economic benefit production necessary to meet the growing needs of society, and to improve the living standards of the population" (Ulez'ko et al., 2019).

On the other hand, this technical and technological modernization of the processes of socio-economic development and improvement of the system of social reproduction, as well as digital expansion in all stages of economic activity, produces not only positive effects but also potential threats. For instance, the development of socio-economic systems may be affected negatively. Therefore, not only awareness and identification are needed, but also the creation of tools to deal with their manifestations effectively (Ulez'ko et al., 2019).

Consequently, the exponential growth of digital technologies is reshaping the way various economic sectors operate and perform. As digitalization has entered the agri-food sector, the new technologies create the context not only for improving agricultural productivity, but also for how to deal effectively with some of the most pressing international problems related to climate change and the gradual loss of biodiversity. Current technological innovations in the sector are based upon the precision agriculture concept, but at the same time, they go far beyond it.

For example, with the emergence of Big Data, i.e. massive volumes of digital data coming at high speeds from a wide range of sources and in different formats, new opportunities for the agri-food sector have opened. Thanks to the Internet-of-Things, cloud computing and machine learning, Big Data can be analyzed in real or near-real time to extract new insights and economic value for the benefit of virtually all actors in the agri-food chain. These opportunities might change farming into smart farming and other agribusiness operations into smart businesses. Nonetheless, various barriers may impede digital transformation in the agri-food sector. Besides, questions about the ethical and social consequences of digitalization also arise as new smart technologies are—to no small extent—based on artificial intelligence and systems beyond direct human inspection. Therefore, a discussion about all the fundamental opportunities and challenges related to digitalization processes is essential to avoid possible lock-in effects on the road to a smart, data-driven agri-food sector (Kosior, 2018).

Within a world of globalization and dynamic digitalization, led by new consumer trends and the fast pace of technology and innovation, the agri-food sector has been challenged like never before. Shifting the agri-food sector to digitalization seems to be a significant challenge. Critical transformations of agricultural systems, rural economies, communities and the sustainable management of natural resources will be required for the emerging digital agri-food sector to achieve its full potential.

It is a common belief that increasing food demands, exhausting natural resources and risks to agricultural productivity comprise elements of crucial future trends in the broader area of food and agriculture (OECD, 2015). Beyond the latter, the estimated increase in the world's population from 7.6 billion in 2018 to over 9.8 billion in 2050 should be seriously taken into consideration as the primary source of global demand for food (UN DESA, 2017). In parallel, a rapid rate of urbanization is expected in the following years, as estimations show that approximately 66% of the world's population is estimated to live in urban areas by 2050, compared with 54% in 2014. As a result, it seems very difficult to cover 40% of water demand in 2030, while more than 20% of arable land is already degraded (Bai et al., 2008).

Within the above-mentioned framework, it is expected that "Industry 4.0" will cause several dramatic changes in the agri-food system in the next decade. Advanced digital applications and innovations (blockchain, Internet-of-Things (IoT), Artificial Intelligence (AI) and Immerse Reality), changing consumer trends and demands, the influence of e-commerce on global agri-food trade, climate change, and other factors are dynamically formulating the current socio-economic framework. In line with the UN's Sustainable Development Goals (SDGs) and moving ahead to a "world with zero hunger" by 2030, FAO calls for more productive, efficient, sustainable, inclusive, transparent and resilient food systems (FAO, 2017). As far as the EU response is concerned, in its Communication on the Future of Food and Farming (EC, 2017b), among others, the European Commission has recognized the essential role of the CAP in fully connecting farmers and rural areas to the digital economy.

The CAP, in parallel to European Structural and Investment Funds, offers great potential to support digital solutions to these challenges for the farming sector, rural areas and the bio-economy. The Commission Communication for Artificial Intelligence for Europe (EC, 2017a) has identified agriculture as one of the key application areas where targeted investments are necessary to achieve those objectives. The EU

Coordinated Plan on Artificial Intelligence (EC, 2018) also provides for investments in platforms and large-scale pilots integrating AI and robotics in agriculture.

Lastly, in its declaration on the 4th of April 2019, the member states "...recognize the importance of addressing without delay the economic, social, climate and environmental challenges facing the EU's agri-food sector and rural areas. We highlight the necessity to encourage an evolution of farming systems towards more resilience and resource efficiency in the long term and note the potential of digital technologies to help tackle such challenges" (EIP-AGRI, 2019).

6.3 The AIS as a Key Concept Towards Digitalization: Theoretical Background

In an attempt to examine and explain the enabling factors and hurdles towards digitalization of the agricultural sector, emphasis is laid on the concept of the "system of innovation". The Systems Innovation (SI) approach has been an important area of scholarship and has been widely used in academic and policymaking circles. SI emphasizes "all important economic, social, political, organizational, and other factors that influence the development, diffusion, and use of innovations" (Edquist, 1997). Initially focused on the national level (National SI), it has been complemented by sectoral and regional variants (Breschi & Malerba, 1997; Mowery & Nelson, 1999). The origins of the concept of a national system of innovation (NSI) may be attributed to Freeman (1987) and Lundvall (1992), to trace the critical role of government in a country's technological infrastructure, as well as the interdependence between technical and institutional change via the interdependence of various actors, namely enterprises, government, national bureaucracy, higher education institutes etc. Since the first appearance of the term "national system of innovation" in the literature, it has found widespread acceptance. The meaning of the term and the connotations it carries have far-reaching implications for public policy choices in science and technology.

In more detail, NSI is described as a network of economic agents and/or interrelated institutions that, together with the institutions and policies, influence innovative behaviour and performance. This constitutes an evolutionary system in which enterprises in interaction with each other, supported by institutions and organizations such as industry associations, R&D, universities, technology transfer mechanisms and institutions, play a key role in bringing new products, new processes and new forms of organization into economic use (Niosi et al., 1993; Patel & Pavitt, 1994; Mytelka, 2003). A critical parameter to this is the fact that his holistic approach also determines the rate and direction of technological learning, as well as the volume and composition of change-generating activities that takes place in a country (Metcalfe, 1995).

An analysis of the above definitions reveals several central themes in the manner in which the NSI is conceived and employed among scholars. These themes comprise a variety of institutions, interactions and technological learning; at the same time, the NSI refers not only to organizations, but also to a set of habits, routines, rules, norms and laws, which regulate the relations between people, and shape social and technological/innovative interaction (Chrysomallidis, 2012). This aspect underlines the importance of system governance and the efficiency of both the written and unwritten rules of engagement that characterize the nature of interactions among the components of the NSI.

Therefore, the analysis will also take into account a more sectoral approach, based on the concept of the sectoral system of innovation (SSI) that was developed initially in 1987 within the studies of the "Centre for Research on Innovation and Internationalization (CESPRI)". Pavitt (1984), who classified industries according to the sources of innovation, has an essential place in the development of this particular approach. In more detail, SSI can be defined as an integrated structure, made up of the interactions of the actors in the market and non-market, actors who are inclined to develop, produce and market a product group, as well as these products for specific use (Malerba, 2002).

A sectoral system has a structure consisting of information infrastructures, technologies, inputs and demand. The main advantage of the sectoral system of approach is that it provides a conceptual framework for a better understanding of the structure and the limits of the sector. Yet, it more deeply examines the actors and their interactions with each other, specifically on a sectoral level; it contributes to the understanding of learning, innovation and manufacturing processes, specifically for a sector, examining its transformation dynamics and the factors leading to differences in the performance of the companies in the sector or the internationally competitive countries in specific sectors (Malerba, 2005). This conceptual framework paves the way for the development of the technology policy, as in the case of NSI, but for specific sectors, by revealing the unfavourable aspects of the approaches, claiming that all sectors are similar and they can be organized and supported with macro-policies.

As already stated in the analysis of NSI, innovation is the result of a complex, interactive and dynamic process, totally different from the approaches that argued about linearity from research to technology, and then to innovation, since involved actors are engaged simultaneously in various, different, and complementary ways that go beyond the more static domains of research and development (R&D). In other words, valuable input for this analysis is that an innovation systems approach highlights, on the one hand, the importance of technology, when focusing on innovation, but is not limited to that, as it follows a rather inclusive approach, taking into account parameters such as a wider scope of actors, the institutional framework, the socio-economic context or the dominant interests (Rajalahti et al., 2008). Thus, the agricultural innovation systems (AIS) approach may prove to be valuable for analyzing technological, political, social and institutional developments that are innovative for the agricultural sector, as in the case of digitalization.

Actually, the Agricultural Knowledge and Information Systems (AKIS), as a concept initially discussed in the OECD and FAO, may be regarded to be a predecessor of the AIS, since its origin is to be found in the need for more

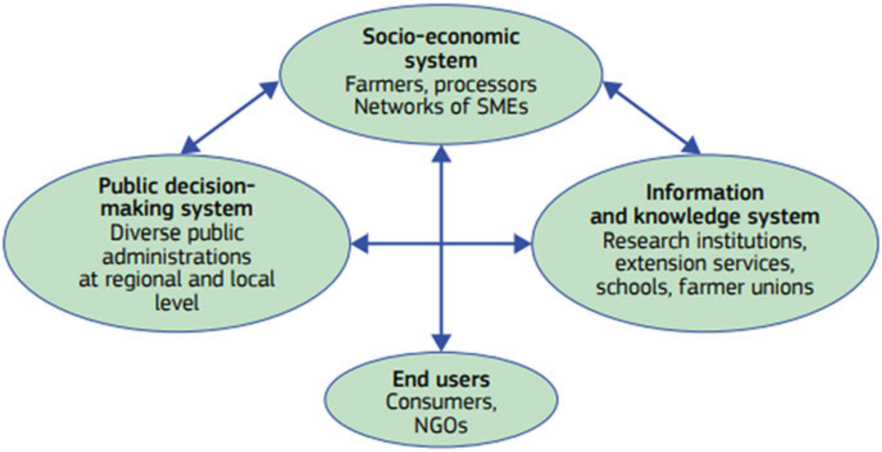

Fig. 6.1 Main categories of involved actors in AIS/AKIS. Source: Dockes et al., 2011

agricultural advice and extension, contributing to evidence-based and documented professional practices, policymaking and intervention. Emphasis on information systems came about from the result of the large-scale introduction of information technologies and computers as early as in the 1960s and 1970s. This was also the time the CAP was introduced, as the EU planned and implemented a rather interventionist policy that sought to coordinate knowledge and innovation transfer, in order to accelerate agricultural modernization. This general direction has led to a policy trend that combined interactively and integrated public research and education on the one hand, with extension bodies on the other. These initiatives were often designed by national Ministries of Agriculture. It is interesting that gradually—and silently—“innovation” replaced “information” in the AKIS acronym (EU SCAR, 2012). Nowadays, one may argue that the more generic reference to “innovation” definitely includes information technologies, but in a more modern way, through the digitalization process, also highlighting the need for introducing digital technologies, applications and means to the agricultural sector and production.

In practice—as in the case of NSI—the AIS analytical framework provides insight into governance and involved actors’ interactions for introducing and promoting innovation. Particular emphasis is laid—amongst others—on public policy and national bureaucracies, epistemic communities, the scientific community, businesses and the broader productive sector (World Bank, 2012). Furthermore, interactions between different involved actors in AIS are crucial for agricultural innovation. These interlinkages include actors from research, education, extension, farms, policymakers and regulators, NGOs, consumers and brokers (Fig. 6.1), combining potentially different fields of science (OECD, 2013). Innovation niches that may arise can facilitate actions and interactions among different (groups of) actors and stakeholders which may lead to transitions towards new modes of production, organizational systems and even to institutional arrangements that contribute to (collective) learning, adjustment and transformation in the agricultural sector (Meynard et al., 2012; Wigboldus et al., 2016; Pigford et al., 2018). This perspective implies that aspects and dimensions of innovation in the agricultural sector, such as digitalization, may be analyzed through the lenses of AIS.

Digitalization contributes—amongst others—to: (i) more precise production (precision farming) to foster resources and efficiency, (ii) digitalization of the agro-food chain that brings producers and consumers closer and (iii) knowledge exchange that enables and improves training and advisory services. All these are directly related to aspects of AIS, in terms of involved actors, interlinkages between them, supporting initiatives and relevant activities etc. In other words, the priority and final aim of this approach are to provide the means and the explanatory parameters to achieve higher added value, which is at the heart of using digital technologies and tools in the agricultural sector. An additional challenge here is that this has to be achieved in a way that benefits small and medium-sized farms, which are not well placed to make profitable use of such systems (EC, 2019a); thus, digitalization taking AIS into account will ideally promote equity and interactivity between the different actors involved.

Analysis following the AIS approach is feasible for the purposes of our study for an additional reason: its main elements and features can be taken into account for the overview of the agricultural sector at a national level (including the EU); at the same time, it may prove to be useful when examining the application of a particular new technology in the agricultural sector. In this case, the approach is closer to that of the technological innovation system. This may especially be an interesting interpretation for examining enabling factors and hurdles of digitalization in the agricultural sector, theorizing the technological innovation system as a kind of sub-sectoral analysis, in order to examine the case of digitalization within the auspices of the more generic AIS approach.

A fruitful area for studying and examining AIS is in terms of the innovations that are developed for general or other purposes, such as Information and Communication Technology (ICT), nanotechnology or biotechnology, and their application to the agricultural sector (OECD, 2013). Thus, when examining digitalization in the agricultural sector within the scope of AIS, analysis on this specific innovation process needs specific elaboration, beyond examining just actors (either from the public or private sector) that start the process, as well as factors (either from public policy or the market) that trigger innovation. Therefore, an innovation system is a useful framework for analyzing different issues (e.g. economic growth and agricultural development); at the same time, it may be used as the appropriate theoretical background for analyzing the means, enabling factors and hurdles of the digital transformation of the agricultural sector.

Certainly, digitalization may be regarded to be such an area of activity. It may prove to be the tool for and the result of a more conducive environment that will enable quicker innovation and better valorization of existing knowledge (EC, 2019a, b, c, d). Examining, thus, the case of digitalization in the agricultural sector, and following Polt's (2008) argumentation, we may discern the three dimensions to priority-setting processes. As far as the type of priority is concerned, it may be characterized as generic (and not thematic), the level of priority setting is to a larger or lesser degree a national one (instead of institutional or project-based), and the nature of the priority-setting process may be regarded to be both top-down/expert-based and bottom-up/participatory, in terms of formation and implementation (OECD, 2013).

In any case, some of the main functions and interconnections that are developed in any innovation system and should be examined in more detail in the case of introducing the digital transformation of the agricultural sector are: (i) transformation of new knowledge, technologies, networks and markets into specific entrepreneurial actions that contribute to new business opportunities, (ii) development of knowledge that drives innovation, beyond research centres' and universities' research activities, as this may also be the result of initiatives taken by other actors within the AIS, (iii) network formation that will enable knowledge diffusion and technology transfer (e.g. the AIS approach highlights the significance of platforms and networks for upscaling and outscaling innovation in the agricultural sector), (iv) the need to select or choose among different functions of various technological options, a function known as guidance of search, (v) initiatives and measures to boost the introduction of new technologies in established markets, for instance through 'subsidizing' demand for new products, (vi) achieving leverage of resources that are crucial for the operation of AIS, such as funding research, subsidies for further development of technologies, applications and innovative market niches etc. and (vii) the need to take action, in order to address inertia and resistance from established actors. Advocacy coalitions having this goal may prove to be catalysts promoting a particular agenda on innovation and lobbying for funding, as well as for the development of necessary institutions (Hekkert et al., 2007; World Bank, 2012). These parameters either support the process of innovation or hinder it, in the case where they are missing or there are no interconnections among them.

Thus, within the framework of this analysis, the role of bureaucracy, public administration and governance is significant for determining progress (or even inertia) regarding the operation and further development of AIS. Actually, even the EU considers policymakers, farmers, researchers, advisors, associations and the media as part of a potentially broader AIS that needs to step up efforts to develop new knowledge and innovative solutions. Thus, the role of public funding is of great interest, as well as direct and indirect support for private investment in R&D, which partly constitutes a kind of public–private partnership (PPP) in the AIS. Public intervention and policy measures also play a crucial role in providing all potential different kinds of knowledge infrastructure, as well as enabling parameters for fostering knowledge flows through networks and markets. In terms of digitalization, interactions among different actors of AIS and the facilitation of adopting agricultural education, training, information and extension may also be key pillars of public policy in the agricultural sector (OECD, 2013).

Specifically for the purposes of digitalization, the role of political action and policy measures by national or supranational institutions and policymakers may prove to be vital in several blocks of activity for a number of reasons: the support of research and technology; the formation of platforms that would provide advisory services in order to boost innovation, or even more specifically, the digitalization process; the implementation of policy initiatives that could provide incentives for forming or strengthening partnerships and collaboration among the different actors; and finally, policy measures to support smallholders, especially for empowering their innovation capacity, as well as for cultivating the conditions and environment that are necessary for flourishing innovation and digitalization in the AIS as a whole (Hermans et al., 2019). In this context, the role of national governments, and the EU through CAP, is a major parameter that should be examined more closely in the case of EU countries. As a matter of fact, according to the OECD (2013), agricultural policies are particularly important in a number of ways: for agricultural innovation, especially in terms of removing distortions in input and output markets; fostering structural adjustment towards farm-level innovation; provision of services in rural areas that are directly or indirectly relevant to agricultural innovation; agricultural education, new knowledge dissemination and extension in order to enable the adoption of innovations by farmers; the provision of (knowledge) infrastructure including ICT and the digitalization process; and finally, the cultivation of conditions for promoting partnerships and interactions between various actors, including public–private partnerships.

6.4 Discussion on EU Policy Response Towards Digitalization

Within the document: "The EU budget powering the recovery plan for Europe" (EC, 2020a), the Commission proposes the "Next Generation EU" as the tool to develop new means of intervention and strengthen critical programmes to direct investment quickly to where it is most needed, strengthening the single market, and stepping up cooperation in areas such as health and crisis management. Furthermore, it may contribute to a long-term budget to drive the green and digital transitions and build a more equitable and resilient economy.

The so-called "twin transitions" to a green and digital Europe remain the generation's defining issues. This is reflected in the Commission's proposals. Investing in a large-scale renovation wave, renewable energies and clean hydrogen solutions, clean transportation, sustainable food and a smart circular economy, among other things, offers significant potential to boost Europe's economy. The support should be in line with the EU's climate and environmental goals. Investing in digital infrastructure and skills will assist in increasing competitiveness and technological sovereignty (EC, 2020a).

In line with this framework, the Commission acknowledges that the CAP must be at the forefront of the transition to more sustainable agriculture. In times of crisis, the CAP must help strengthen the sector's resilience while still supporting farmers' income and viability. The CAP must completely embrace digital technologies that make farmers' jobs easier and promote the sector's generational rejuvenation. Public engagement in research and innovation is required to bridge the gap between rural regions in demand for advanced technologies and better connections. Sensors, for example might identify and prevent animal illness early on, reducing the need for treatment. Farmers could make better and faster decisions by having real-time access to sunlight intensity, soil moisture, markets and herd management, among other areas of interest. For the successful completion of the above, cooperation on research and innovation at the EU level is needed, as more excellent knowledge is developed, and innovation adaptation is faster through efficient knowledge transfer between the different EU regions (EC, 2017b).

The CAP 2021-2027 intends to promote a sustainable and competitive agricultural sector that can support farmers' livelihoods while providing society with healthy and sustainable food and dynamic rural communities. Agriculture and rural regions are at the heart of the European Green Deal, and the new CAP aspires to be an essential tool in realizing the Farm to Fork and biodiversity goals.

The document: "2030 Digital Compass: The European way for the Digital Decade" states that digital technology may substantially contribute to the fulfilment of the European Green Deal's goals, as the adoption of digital technologies and data will support the transition to a climate-neutral, circular and resilient economy. At the same time, digital technologies enable greener processes in agriculture, energy, buildings, industry, city planning and services, all of which contribute to Europe's proposed goal of reducing greenhouse gas emissions by at least 55% by 2030 and better environmental protection. For example, applications for intelligent-edge computing in "Smart Farming" will facilitate the deployment of edge capacity connected to farm machinery and allow for real-time collection of agricultural data, enhanced services for farmers like harvest prediction and farm management, and the optimization of food supply chains. Moreover, agriculture is one of the five key ecosystems for digital transformation, as it is recognized that digital farming technologies can help the agricultural industry produce more precisely and effectively, improving the sector's long-term viability and competitiveness. Agriculture has been recognized as a significant industry in which digital technologies may aid in the reduction of global GHG emissions and pesticide use (EC, 2021).

Therefore, implementing the European Green Deal requires rethinking policies for clean energy supply across the economy, industry, production, consumption, large-scale infrastructure, transportation, food and agriculture, building, taxes and social benefits. It is critical to raise the importance of maintaining and restoring natural ecosystems, ensuring resource sustainability, and promoting human health to accomplish these goals. The EU should also encourage and invest in the required digital transformation and technologies, critical facilitators of the reforms.

It is a common belief that, in many different areas, digital technologies are a vital facilitator for achieving the Green Deal's environmental targets. Digital technologies like artificial intelligence, 5G, cloud and edge computing, and the Internet-of-Things can help policymakers cope with climate change and preserve the environment more effectively. Digitalization also opens up new possibilities for remote monitoring of air and water pollution and tracking and optimizing energy and natural resources. At the same time, Europe requires a digital industry that prioritizes sustainability: the agriculture sector is at the heart of that effort.

Precision agriculture, organic farming, agro-ecology, agro-forestry and stricter animal welfare requirements are examples of sustainable methods. Eco-schemes, for example, should compensate farmers for improved environmental and climatic performance, such as controlling and storing carbon in the soil, and enhanced fertilizer management to improve water quality and cut emissions, by moving the focus from compliance to performance. According to the Commission's recommendations for the CAP from 2021 to 2027, climate action will receive at least 40% of the overall budget. Thus, European farmers play a critical role, as their efforts to deal with climate change, safeguard the environment and preserve biodiversity will be reinforced by the Farm to Fork Strategy (EC, 2019b).

The Farm to Fork Strategy recognizes that Research and Innovation (R&I) are critical drivers in expediting the transition from primary production to consumption of sustainable, healthy and inclusive food systems. R&I may assist in the development and testing of solutions, the elimination of hurdles, and the discovery of new market opportunities. The Commission has made an additional call for proposals for Green Deal goals under Horizon 2020, with a budget of approximately EUR 1 billion. Additionally, Horizon Europe plans to invest EUR 10 billion in research and development in food, the bioeconomy, natural resources, agriculture, fisheries, aquaculture and the environment, as well as the use of digital technologies and nature-based solutions in the agri-food sector (EC, 2020b).

Through specific cooperation on agro-ecology living laboratories, new knowledge and innovations will also scale up agro-ecological practices in primary agriculture. Pesticides, fertilizers and antimicrobials will be used less as a result of this. The Commission intends to engage with the Member States to increase the role of the European Innovation Partnership "Agricultural Productivity and Sustainability" (EIP-AGRI) in the strategic plans to boost innovation and knowledge transfer (EIP-AGRI, 2019). In addition, the European Regional Development Fund will invest in food value chain innovation and collaboration through smart specialization.

It is widely acknowledged that all farmers and rural communities need full Internet access, as this is a critical enabler for rural jobs, business and investment and increasing quality of life in sectors like healthcare, entertainment and e-government. Precision farming and artificial intelligence will become more widespread with access to faster broadband Internet. Moreover, it will enable the EU to fully capitalize on its worldwide satellite technological superiority. Farmers are expected to reduce their cost of production, improve soil management and water quality, limit the use of fertilizers, pesticides, and GHG emissions, increase biodiversity and create a better environment for farmers and people. The Commission intends to accelerate the deployment of high-speed broadband Internet in rural regions so that everyone has access by 2025 (EC, 2020b).

However, given the agriculture sector's specific characteristics, all food system participants must gain expertise and guidance to become sustainable. Farmers need practical, expert guidance on long-term management solutions. As illustrated, the Commission intends to encourage participation in Agricultural Knowledge and

Innovation Systems by all food chain stakeholders. To accomplish the Green Deal's objectives and targets in their CAP Strategic Plans, Member States will need to improve support for AKIS and raise resources to build and sustain suitable advisory services by the above-mentioned framework (EC, 2019c).

To support those goals, the Commission plans to propose legislation to transform the Farm Accountancy Data Network into the Farm Sustainability Data Network, intending to collect data on the aims of the Farm to Fork and Biodiversity Strategies and other sustainability indicators. The network will allow farmers to compare their performance to regional, national or sectoral averages. Farmers will receive feedback and support through personalized advisory services, and their experiences will be linked to the European Innovation Partnership and research programmes. It is estimated to increase the farmers' long-term viability, as well as their revenues (EC, 2017b, 2021).

Additionally, the common European agriculture data space, as part of the European data strategy, aims to improve the EU agriculture's competitive sustainability by processing and analyzing the production, land use, environmental and other data, allowing precise and tailored application of production approaches at the farm level and monitoring sector performance, as well as supporting the carbon farming initiative. The EU's Copernicus and European Marine Observation and Data Network (EMODnet) programmes intend to decrease investment risks and support sustainable fishing and aquaculture operations (EC, 2020b).

It is important to note that a cross-cutting objective (Article 5) (EC, 2019d; EU—Court of Auditors, 2020) is included in the Commission's proposal for the future CAP regulation 2021–2027, which seeks to modernize the sector through the promotion of knowledge, innovation and digitalization in agriculture and rural areas, in particular through the use of the CAP Strategic Plans developed by Member States. This includes a description of "the organizational set-up of the AKIS, designed as the combined organization and knowledge flows between persons, organizations, and institutions that use and produce knowledge for agriculture and related fields", as well as a description of "how the advisory services, research, and CAP networks will work together in the framework of the AKIS, and how advice and innovation support services are provided". Furthermore, support for EIP-AGRI Operational Groups is being maintained, with the inclusion of new features such as advance payments and collaboration between current EIP-AGRI Operational Groups. In addition, support for innovation provided through CAP-funded networks will be maintained and strengthened. In brief, whereas the focus in 2014–2020 was on funding meaningful innovation projects, the focus in 2021–2027 is on the entire innovation ecosystem, including project funding and stimulating supporting services (EC, 2019a).

Lastly, agriculture has always been an innovative industry, adjusting to changing conditions and new environments. Precision agriculture, often known as Farming 2.0 (or Agriculture 2.0), is a whole-farm management procedure that incorporates information technology, satellite positioning data, distant sensing and proximate data collection. These technologies maximize input returns while potentially lowering environmental consequences (EC, 2017b). With around €10bil available under the Horizon Europe programme for research and innovation, and €1.7bil for Information and Communication Technologies under EAFRD 2021–2027, in order to advance the development and uptake of digital technologies in agriculture and rural areas and anticipate the impacts of the digital revolution, digitalization in agriculture seems to be high on the European Union's agenda.

6.5 Conclusions

The AIS approach may be considered crucial for analyzing technological, political, social and institutional innovations in the agriculture sector. For introducing and promoting innovation, the AIS analytical framework gives insight into governance and the interactions of multiple groups. Public policy and national bureaucracy, epistemic communities, scientific communities, corporations and the more significant productive sector are all given special attention.

The emergence of innovation niches can facilitate actions and interactions among various actors and stakeholders, leading to transitions to new modes of production, organizational systems and even institutional arrangements that support (collective) learning, adjustment and transformation in the agricultural sector.

It has been stressed that the focus and the ultimate goal of this approach are to provide the means and explanatory criteria for achieving better-added value, which is at the heart of employing digital technologies and tools in agriculture. Another concern is that it should be done to assist small and medium-sized farms, which are not well-positioned to profit from it; consequently, digitalization with AIS in mind will ideally enhance equality and interaction between various players.

Therefore, when examining digitalization in the agricultural sector within the context of AIS, an in-depth examination of this specific innovation process is required, going beyond the analysis of actors (public or private) who initiate the process. Therefore, other parameters, such as public policy and market, which trigger innovation, should be taken into account. The AIS approach regarding public policy deals with the various approaches used to encourage innovation and transformation in the agricultural policy setting. These include more traditional interventions and critical components, such as support for agricultural research and education and other complementary interventions to promote professional skills. In addition, policy incentives and resources for expanding collaboration on the one hand, and productive structures and businesses on the other, are criteria incorporated in the AIS analytical framework. Farmers are at the heart of AIS in this concept, which encompasses natural agricultural research and national education and training systems.

The Commission recognizes that the CAP must be at the forefront of the transition to more sustainable agriculture, as the so-called "twin transitions" to a green and digital Europe remain the generation's defining concerns. The CAP must increase the sector's resilience in times of crisis while also boosting farmers' income and viability. Digital solutions that simplify farmers' tasks and encourage the sector's generational regeneration must be fully embraced by the CAP. Public participation in research and innovation is essential to bridge the gap between rural communities in need of modern technology and improved connectivity.

Cooperation in research and innovation at the EU level is required to accomplish the above since more outstanding knowledge is effectively created and innovative adaption is accelerated through efficient knowledge transfer across EU regions. As previously stated, "Smart Farming" applications for intelligent-edge computing will facilitate the deployment of edge capacity connected to farm machinery, allowing for real-time agricultural data collection, enhanced farmer services such as harvest prediction and farm management, and the optimization of food supply chains. Agriculture is also one of the five essential ecosystems for digital transformation since digital farming is widely acknowledged.

As we move from compliance to performance, European farmers will play a vital role, as the Farm to Fork Strategy will support their efforts to combat climate change, protect the environment and preserve biodiversity. Research and innovation are essential drivers in accelerating the transition from primary production to the consumption of sustainable, healthy and inclusive food systems, according to the Farm to Fork Strategy. These can help with solution development and testing, as well as remove barriers and discover new market possibilities.

Precision farming and artificial intelligence will become more prevalent with access to high broadband Internet. It is commonly understood that all farmers and rural communities require complete internet connectivity. Farmers are expected to lower their production costs, enhance soil management and water quality, minimize fertilizer and pesticide use as well as greenhouse gas emissions, promote biodiversity and improve the environment for farmers and people. The Commission plans to hasten the implementation of high-speed broadband Internet in rural areas to have everyone connected by 2025.

It is recognized that the role of bureaucracy, public administration and governance in determining progress (or even inertia) in the operation and growth of AIS is critical within the context of the AIS study. This paper intended to highlight specific parameters of the AIS towards digitalization of the agricultural sector, laying emphasis on the EU's relevant initiatives. Thus, the role of public funding is of significant importance. Intervention by the government and policy actions are also critical. As shown, the function of national or supranational institutions and policymakers in political and policy actions can be critical in different blocks of activity. As illustrated, the role of political action and policy measures by national or supranational institutions and policymakers may prove vital in several blocks of activity. Interestingly enough, the EU itself recognizes policymakers, farmers, academics, consultants, associations and the media as part of a potentially more significant AIS that requires more effort to create new information and innovative solutions. In this regard, the participation of national governments and the EU through the Common Agricultural Policy (CAP) is a crucial parameter that may prove to be decisive for agricultural innovation.

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