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Smart farming and short food supply chains: Are they compatible?

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ABSTRACT

The challenge of sustainability and the need to secure the production of high-quality, affordable and healthy food, have led to the emergence of alternative food production/distribution schemes that, based on technological or organizational innovation, can increase food production without burdening the environment. Both smart farming and short food supply chains (SFSCs) are considered as promising solutions towards this target. From a theoretical standpoint, the introduction of smart farming technologies into SFSCs could increase the value-generating capacity of short food supply schemes. However, a pivotal question is whether such technologies are compatible with SFSCs. In this study, following a mixed research design, we analyze Greek farmers' and consumers' perceptions of the compatibility between smart technologies and SFSCs, and we examine the extent to which compatibility perception affects willingness to engage in "smart SFSCs." Quantitative results revealed that perceived (in)compatibility is central in predicting this willingness for both farmers and consumers. The qualitative strand of the study uncovered the existence of two different types of compatibility. Actual compatibility refers to the consistency of smart technologies with the technological advancement of farms and the real everyday needs of farmers. Symbolic compatibility relates to the meanings attributed to both SFSCs and smart technologies by farmers and consumers. In sum, the results indicated that smart technologies are viewed as tools that can lead to a conventionalization of SFSCs, thus altering their optimally distinct nature. Policies targeted at the promotion of smart farming should go beyond traditional views of smart technologies as tools that increase farm efficiency, by paying more attention to their compatibility with different "agricultures" and to the ways they can transform farming systems.

1. Introduction

The growing concern over the ability of agriculture to cover the increasing demand for food under the pressure of resource scarcity, along with the interest on the quality of consumed food and the ability of poor consumers to cover their minimum dietary requirements, have led researchers and policy-makers to shift their focus to practices that can increase food production and improve food quality without negatively affecting the environment. However, this task is far from easy. The increase of global population – which is expected to reach 9.8 billion in 2050 (United Nations, 2017) – and the consequent increase in the demand for food (FAO, 2009), the dependence of production on energy prices (Thompson et al., 2019) and market forces (Choi and Entenmann, 2019), and the shifts in land use for the production of biofuels (Ghosh et al., 2019) or housing (Long et al., 2018), rise many questions about the ability of future farming systems to produce enough, nutritional, and healthy food, that will be affordable for poor and food insecure consumers (Rosegrant et al., 2009).

Motivated by such concerns, policies in the developed countries acknowledge the need to move beyond conventional food production and marketing practices, embracing both technological and organizational innovation. Within this framework, the updating of agriculture through "smart" technologies or intelligent decision support systems and the development of short food supply chains (SFSCs) that are based on local cooperation between farmers and consumers are considered as promising alternatives to conventional agrifood systems. For instance, European Union pays special attention to the technological sophistication of agriculture through smart, precision farming technologies (EIP-AGRI, 2015), while simultaneously it promotes the development of alternative food networks, like SFSCs (IPES FOOD, 2018, 2019). Australian policy also sees both alternative food distribution channels and new technologies as opportunities for sustaining the performance of agrifood supply chains (Spencer and Kneebone, 2012), whereas in the USA a wide array of state and federal policies are supporting the expansion of alternative food networks (Martinez et al., 2010), while, in parallel, the United States Department of Agriculture supports smart

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(data-driven) farming through many initiatives (USDA, 2016).

Even though both SFSCs and smart farming have the potential to mitigate the environmental impacts of agriculture, to increase farmers' income and to produce new forms of value, in most cases, they are viewed as separate pathways towards sustainability. Hence, although smart farming has gained considerable momentum over the last few years, the integration of digital technologies and intelligent decision support systems in SFSCs has not yet been achieved. In this work, following a mixed research design, we focus on farmers' and consumers' perceptions of the compatibility between smart technologies and short food supply schemes. The specific objectives of the study are, first, to examine if and how farmers' and consumers' perceptions of the compatibility between smart technologies and SFSCs affect their willingness to participate in "smart SFSCs," and, second, to understand the dimensions that underlie producers' and buyers' views of compatibility.

2. Smart farming and short food supply chains: what are they and why do they matter?

Smart farming – also called digital agriculture (Liang et al., 2002), agriculture 4.0 (Klerkx and Rose, 2020) or data-driven farming (Eastwood et al., 2019a) – emerged as a revolutionary paradigm shift for the agrifood sector, that aims at the optimization of farm management and the improvement of farm efficiency. Notably, smart farming differs from its ancestor precision agriculture, in both logic and scope. Hence, whereas precision agriculture is informed by field-specific data and aims at the fine-tuning of technology and inputs (Lake et al., 1997), smart farming relies on past and real-time data collected through heterogeneous sources (including both on- and off-farm sources) and aims at providing context- and situation-awareness (Wolfert et al., 2017).

Enabled by intelligent technologies (Grogan, 2012) – like connected farm machinery, sensor networks, Internet of Things, automation systems, farmbots and drones – and taking advantage of cloud and granular computing, smart farming can help farmers optimize their planning procedures (Monteleone et al., 2019), save time (Weltzien, 2016; Das et al., 2019), improve input efficiency (Bendre et al., 2016), and increase their decision-making capacity (Mekala and Viswanathan, 2017) and performance (O'Grady and O'Hare, 2017). Importantly, the benefits of smart farming expand beyond the farm level, since the insights offered to farmers and other actors involved in agrifood supply chains by intelligent decision support systems can help to reduce the waste of resources (Tang et al., 2002) and the environmental footprint of agriculture (Walter et al., 2017), improve food quality (Sundmaeker et al., 2016), and increase food security (Ribarics, 2016).

SFSCs, on the other hand, are food supply schemes in which farmers sell their products to consumers directly or with the intervention of only one extra node (Chiffoleau, 2008). In this vein, SFSCs is an umbrella term referring to different food marketing arrangements, like farmers' markets, on-farm sales, direct sales from farmers to local schools or hospitals, community-supported forms of agriculture, box delivery schemes, and so on (Kneafsey et al., 2013). Such alternative configurations gained considerable momentum over recent years in response to the increasing consumers' sustainability (Giampietri et al., 2016) and food quality concerns (Sellitto et al., 2018), farmers' desire to regain a central position in the food networks (Demartini et al., 2017), and both producers' and consumers' willingness to re-establish value-laden connections among them (Giampietri et al., 2018; Chiffoleau et al., 2019).

In spite of their differences, all the above-mentioned food distribution channels share three common characteristics: they are based on trust relationships between farmers and consumers (Charatsari et al., 2018), they are characterized by a proximity between the involved actors – ranging from geographical and organizational to institutional, social and cognitive proximity (Dubois, 2018) – and their value propositions extend beyond the buyer-seller dyad (Charatsari et al., 2020). Indeed, several indications confirm that SFSCs can not only increase farmers' income (Malak-Rawlikowska et al., 2019), but also lessen the environmental impact of packaging (Vittersø et al., 2019) and transportation (Canfora, 2016) associated with long supply chains, whereas they also lead to the creation of new employment opportunities (Mundler and Laughrea, 2016).

3. Smart farming and short food supply chains: can they be combined?

Compatibility is a decisive factor in the innovation adoption process (Kapoor and Dwivedi, 2020). Rogers (1995) defines compatibility as the perceived consistency between innovation and the values, experiences, and needs of potential adopters. Hence, compatibility refers not only to the fit between innovation and the characteristics of an enterprise or a consumer, but also to the congruence between innovation and the values/norms under which a social system (e.g., an organization, enterprise, or market) operates (Banytė and Salickaitė, 2008).

In this work, we use the term compatibility to describe the perceived consistency of smart farming technologies and SFSCs. Although such technologies are considered as flexible tools that have wide applicability (Himesh et al., 2018), some indications confirm that they are better suited to highly intensive forms of agriculture (Carbonell, 2016; Jakku et al., 2016; Fleming et al., 2018) than to small-scale farming or to low-input agriculture (Wezel et al., 2018) – which are usual cases in alternative food networks (Ortmann and King, 2010). In addition, the adoption of such technologies transforms traditional physical-social farming systems to cyber-physical-social systems, thus increasing systemic complexity (Lioutas et al., 2019). Hence, it is questionable whether smart technology can be applied to SFSCs, which are based on a simplified form of food production and distribution.

However, compatibility does not only refer to the economic dimension of smart technologies or the ease of using them in SFSCs. Value compatibility is another determinant of innovation adoption (Bunker et al., 2007) that catalyzes innovation success (Harrington and Ruppel, 1999). In the case of smart farming technologies, this type of compatibility refers to the congruence between established ethics or values and the new ethics associated with smart farming (Eastwood et al., 2019b). Since values and ethics are fundamental in the ontology of SFSCs (Renting et al., 2003; Giampietri et al., 2016), this type of compatibility is of critical importance.

4. Methods

4.1. Participants and procedure

The study was conducted in the island of Crete (Greece). Data were drawn from two samples. The first one consisted of 98 farmers (64.3 % men, mean age = 43.1 years, S.D. = 10.9) who sell their products through farmers' markets. Most of the participants cultivate a variety of crops, including vegetables, orchards, olive trees, potatoes, and aromatic plants. Although all the participants distribute their products through farmers' markets, most of them (92.9 %) use simultaneously other short food supply conduits (on-farm sales, direct sales in local restaurants, and, to a limited extent, box delivery schemes).

The sample included eight organic growers, three agroecologists, and 87 farmers who use conventional production practices. Their majority had secondary education (72.4 %), whereas 15.3 % of the sample had a university diploma. The average yearly farm income reported per participant was about €17,580 S.D. = 5200. The second sample comprises 106 consumers 56.6 % women, mean age = 41.1 years, S.D. = 11.2) who buy food products from farmers' markets and other short food supply schemes. About two-thirds of the sample (65.1 % reported having tertiary education, whereas their mean family income was about €16,500 per year S.D. = 4771.

In the first phase of the study, participants were asked to answer a series of closed-type questions, presented in the section that follows. To ensure that participants were familiar with the terms "smart technology" and "SFSCs," the questionnaire started with two questions asking farmers and consumers to answer whether they know what smart technologies are and what an SFSC is. All participants positively answered the two questions. After questionnaire completion, subjects were requested to participate in a second, quantitative phase of data collection. Those farmers (n = 63) and consumers (n = 77) who agreed to contribute qualitative data were personally interviewed by two trained interviewers a few weeks later.

4.2. Instruments used

4.2.1. Quantitative strand

Attitude toward smart technologies: Farmers' and consumers' attitude toward smart technologies was assessed by the use of five pairs of adjectives that endorse the statement "To my view, smart technologies are…" In this type of semantic differential scales, for each pair, an adjective is used as a sign of a negative attitude and another one as an indication of a positive attitude. The chosen adjectives refer to related but not synonymous attributes, as suggested by Osgood et al. (1975) who developed this methodology, and as used by others (e.g., Bradley and Lang, 1994; Zaichkowsky, 1985) in their studies. Since the aim of the scale was to depict farmers' and consumers' general attitudes towards smart technologies, we avoided using phrases like "for the society," "for farmers" etc. The pairs used were: useless/useful, beneficial/unprofitable, fascinating/boring, interesting/uninteresting, and worthless/valuable. Participants were asked to choose the option that better describes their perception on a five-point semantic differential scale ranging from -2 to 2. In such a scale, the high intercorrelation between different pairs is not a problem, since the ratings are subjected to factor analysis, so as to determine the structure of the scale. In our case, the five items were found to load on a single factor (eigenvalue = 1.85, explained variance = 36.96 %), hence a new variable was computed by adding item scores. Cronbach's alpha for the scale was 0.60.

Perceptions of smart SFSCs: In the next section of the questionnaire, 14 items were added to assess participants' perceptions of smart SFSCs. Items were developed after reviewing theoretical and research papers dealing with both smart farming and alternative food networks. A scale ranging from 1 (completely disagree) to 5 (completely agree) was used. A principal axis factor analysis revealed a four-factor structure for the scale (Table 1). The first factor was labeled "Efficiency" because it consists of four items referring to the ability of smart technologies to improve farm production while reducing work effort, to enhance farmers' decision-making performance and planning capacity, and to help farmers save time. The second is related to the ability of smart technologies to alter the farmer-consumer relationship, and thus it was called "Relational impacts." The factor "Economic impacts" includes three items associated with the ability of smart technologies to increase farmers' income, to reduce farm costs, and to enhance farmers' economic security. Finally, the factor "Environmental impacts" refers to the potential environmental benefits resulting from the adoption of smart technologies by SFSCs. A score was calculated for each subscale by averaging items.

Table 1
Perceptions of smart SFSCs: Factors, item loadings, eigenvalues, explained variance and Cronbach's alphas.

Factor/items	Loading
Efficiency (Eigenvalue = 3.80, Explained variance = 27.14 %, α = 0.85)	
7. Can help farmers produce more with less effort	0.82
13. Can help farmers make better decisions	0.76
1. Can help farmers save time	0.72
10. Can help farmers optimize planning	0.71
Relational impacts (Eigenvalue = 2.43, Explained variance = 17.35 %, α = 0.86)	
5. Will positively affect the farmer-consumer relationship	0.87
9. Can help farmers better respond to consumers' needs	0.83
2. Can positively affect the way consumers see farming	0.77
Economic impacts (Eigenvalue = 2.27, Explained variance = 16.23 %, α = 0.86)	
4. Can help farmers earn a better income	0.82
12. Can increase farmers' economic security	0.78
6. Can help farmers reduce their production cost	0.75
Environmental impacts (Eigenvalue = 1.41, Explained variance = 10.06 %, α = 0.76)	
14. Can reduce the use of pesticides	0.72
3. Can reduce the use of fertilizers	0.70
8. Can lead to more prudent use of agrochemicals	0.67
11. Can increase the environmental performance of SFSCs	0.58

Notes: Items endorse the statement "The application of smart technologies in SFSCs…".
Item numbers refer to their position in the questionnaire.

Willingness to participate in smart SFSCs: To assess farmers' willingness to engage in smart SFSCs we used a single item (To what extent would you be willing to use smart technologies in your farm?). Response options ranged from 1 (not at all) to 5 (very much). Consumers were also asked to indicate their willingness to buy from smart SFSCs by choosing among the same response options for answering the question "To what extent would you be willing to buy from short food supply chains in which farmers use smart technologies?"

Compatibility between smart technologies and SFSCs: Three items, measured on a five-point "completely disagree" to "completely agree" scale, were used to measure the degree to which farmers and consumers believe that smart technologies are compatible with the function ("Smart farming technologies can easily be used in SFSCs"), the philosophy ("Smart farming technologies fit well the philosophy of SFSCs"), and the unconventional character of SFSCs ("The use of smart farming technologies in SFSCs will destroy the alternative character of food production and buying" – negatively worded item). A principal axis factor analysis uncovered a single factor structure (eigenvalue = 2.44, explained variance = 81.20 %). Cronbach's alpha for the scale was quite high (α = 0.88). A new variable was created by averaging item scores.

4.2.2. Qualitative strand

For the qualitative phase of this study, we designed a semi-structured interview guide. To build a conceptual basis for the development of the guide and to collect rich and insightful data we relied upon the relevant literature and the results of our quantitative analysis, as suggested by Kallio et al. (2016). However, to avoid leading interviewees to standardized answers – which eliminate the opportunities to collect unexpected data and to uncover important connections and effects (Kreiner and Mouritsen, 2005) – we left spaces for personal expression by adding "w-questions" (i.e., "why do you say that?" or "why do you believe this is so?"). Such an approach allowed us to gather data depicting concepts we had not predicted before the beginning of interviews. When new concepts that could advance our understanding of farmers' and consumers' perceptions emerged during preliminary analysis (after each set of interviews) new questions developed and introduced to the guide. This way, a process of reflexive iteration (Srivastava and Hopwood, 2009), which facilitated a continuous sense-making and a validation of the latent meaning of data was followed.

4.3. Plan of analysis

For the quantitative part of the analysis, we used descriptive and inferential statistics. Independent samples t-tests were used to detect differences between farmers and consumers. Correlations between study variables were calculated by Pearson's r. To meet our first objective, that is to understand how perceptions of the compatibility between smart technologies and SFSCs affect farmers' and consumers' willingness to engage in smart SFSCs we developed two hierarchical regression models (one for each sample). To gain a more complete understanding of the way compatibility perceptions affect this willingness we added in the models other three sets of variables that might have mediating effects.

Hence, since some studies conclude that characteristics like gender, income, age, and level of education affect farmers' (Ali et al., 2020; Drewry et al., 2019; Zheng et al., 2019) and consumers' (Sun and Chi, 2018; Abayomi et al., 2019) innovation behavior, in the first step we entered participants' demographics to test for moderating effects. Then, to examine if attitude – that has repeatedly found to be associated with intention in both farmer (e.g. Adnan et al., 2017a, 2017b) and consumer studies (Wang et al., 2018; Juric and Lindenmeier, 2019) – has any effect on willingness to engage in smart SFSCs we added attitude towards smart technologies. In the third step, we entered the four variables that depict subjects' perceptions of smart SFSCs, which – according to recent findings – affect the adoption of smart innovation by farmers (Barnes et al., 2019) and consumers (Deliza and Ares, 2018). Finally, following the results of studies indicating that perceptions of the compatibility of innovation are important facilitators of its adoption (Makanyeza, 2017; Lioutas and Charatsari, 2018), at the fourth step, we added the perceived compatibility between smart technologies and short supply chains.

Qualitative data, collected through interviews, were analyzed using the principles of thematic analysis (Braun and Clarke, 2006). The analysis was guided by our second objective, which was to unravel the different dimensions of compatibility. Patterns of data, referring to participants' perceptions, opinions, and feelings, were combined to generate sub-themes, and then these sub-themes were collated into overarching themes (Aronson, 1995). Since our data collection approach was based on a reflexive iteration process, our focus was on the content than on the frequency of sub-themes (Joffe, 2011), whereas we paid equal attention to the manifest and the latent meanings of data.

5. Results

5.1. Quantitative analysis

The summary statistics for the study variables are presented in Table 2. As the table illustrates, although both samples express a rather positive attitude toward smart technologies, their willingness to participate in smart SFSCs and their perceptions of the compatibility between smart technologies and short supply chains received low mean scores. Independent samples t-tests showed that the two samples did not differ in their perceptions of the impacts that the application of smart technologies can have on farm efficiency ($t = 0.17$, $p = 0.867$), the nature of relations within SFSCs ($t=-1.05$, $p = 0.294$), the economic outcomes for farmers ($t = 0.96$, $p = 0.340$), and the environmental performance of SFSCs ($t=-0.75$, $p = 0.452$). Moreover, the difference between farmers and consumers on their attitude towards smart technologies was found to be marginally non-significant ($t=-1.72$, $p = 0.087$). However, farmers express a significantly higher willingness to engage in smart SFSCs ($t = 2.85$, $p = 0.005$) and they evaluate as higher the compatibility of smart technologies and SFSCs ($t = 2.27$, $p = 0.024$) than consumers.

Bivariate analysis revealed that farmers' willingness to engage in smart SFSCs correlates with the perception that the adoption of smart technologies can increase production efficiency ($r = 0.25$, $p = 0.013$), and is associated with positive economic ($r = 0.20$, $p = 0.045$) and relational impacts ($r = 0.28$, $p = 0.006$). On the other hand, for consumers, this willingness correlates with the perception of economic benefits ($r = 0.24$, $p = 0.014$) and the relational impacts ($r = 0.25$, $p = 0.010$) of smart technologies. For both samples, a strong positive correlation was found between willingness to participate in smart SFSCs and the perceived compatibility between smart technologies and short supply schemes ($r = 0.39$ and $r = 0.40$ for consumers and farmers, respectively; $p < 0.001$ in both cases).

Table 2
Mean scores and standard deviations for the study variables.

Variable	Farmers	Consumers
Attitude toward smart technologies	3.79 (1.24)	4.09 (1.23)
Perceptions of smart SFSCs		
Efficiency	3.68 (0.79)	3.66 (0.98)
Relational impacts	2.33 (0.80)	2.45 (0.82)
Economic impacts	3.67 (0.93)	3.53 (1.03)
Environmental impacts	3.93 (0.60)	3.99 (0.70)
Willingness to participate in smart SFSCs	2.64 (0.82)	2.25 (1.04)
Compatibility between smart technologies and SFSCs	2.21 (0.71)	1.94 (0.98)

Note: Standard deviations are in parentheses.

Table 3
Standardized coefficients for the hierarchical regression analyses predicting farmers' and consumers' willingness to participate in smart SFSCs.

	Farmers			Consumers		
	ΔR^2	β	p	ΔR^2	β	p
Set 1	0.03		0.567	0.04		0.437
Gender		0.05	0.558		0.02	0.821
Age		0.02	0.826		0.07	0.486
Education		0.16	0.122		−0.06	0.573
Income		−0.08	0.459		−0.07	0.492
Set 2	0.01		0.782	0.02		0.900
Attitude toward smart technologies		−0.07	0.474		0.03	0.720
Set 3	**0.17**		0.002	**0.16**		0.001
Efficiency		**0.22**	0.039		0.11	0.288
Relational impacts		**0.24**	0.015		**0.32**	0.001
Economic impacts		0.07	0.478		−0.05	0.611
Environmental impacts		−0.08	0.365		0.17	0.095
Set 4	**0.10**		0.01	**0.04**		0.023
Compatibility		**0.34**	0.01		**0.23**	0.023

Note: Significant coefficients are in boldface.

Our regression analyses (Table 3) indicated that willingness to engage in smart SFSCs is not affected by farmers' and consumers' demographics or their attitude toward smart technologies. When the four variables referring to participants' perceptions of the smart SFSCs were entered in the models some significant associations emerged. In the case of farmers, the regression revealed that the most important predictor of the dependent variable is the perceived compatibility between smart technologies and short supply schemes ($\beta = 0.034$, $p = 0.001$), followed by the perceptions of the potential impacts of smart technologies on the relational structure ($\beta = 0.29$, $p = 0.004$) and the efficiency ($\beta = 0.24$, $p = 0.032$) of SFSCs. In all cases, the signs of beta coefficients are positive, revealing a positive influence of the predictors to the dependent variable.

For consumers, the model showed that the sets of variables referring to perceptions of smart SFSCs and the compatibility were responsible for statistically significant R squared changes. In the final model, beta coefficients for the relational impacts ($\beta = 0.32$, $p = 0.001$) and the compatibility ($\beta = 0.23$, $p = 0.023$) were significant at the 0.05 level. Consumers' perception of the environmental benefits associated with the combination of smart technologies and SFSCs were found to be marginally non-significant.

5.2. Qualitative analysis

The thematic analysis of qualitative data revealed two different meanings attributed to compatibility by farmers and consumers: actual and symbolic compatibility. In the sections that follow we discuss these aspects.

5.2.1. Actual compatibility

Farmers express serious concerns about the ability of smart technologies to be effectively used in their farms. Most of the interviewees noted that smart technologies are better suited to big farms. Quite surprisingly, the investment cost was not found to be the decisive factor in the judgment of smart technologies' compatibility with a farm. On the contrary, most farmers noted that such technologies have a positive cost/benefit ratio. However, they perceive that such technologies are not really designed to offer solutions to their actual needs. The application of multicultivation practices – which is imposed by consumers' demand for as many as possible products – makes the use of sophisticated technologies that are tailor-made for specific crops practically impossible. As a farmer who seriously examined the opportunities to install sensing systems in her farm commented:

> Such (smart) systems are better suited to monocultivation. We (the farm family) have so many crops; from herbs to lemons and avocado trees. Sensors can offer valuable information, but not for all these plants. In case I was a corn producer, then, yes, sensors would be a very good choice. (Dorothea, 41 years old, farmer)

On the other hand, farmers dispute the ability of smart technologies to reduce the physical effort needed to work on a farm, which, according to them, is one of the major difficulties they face in their everyday farm routine. One of the main concerns for farmers is minimizing physical effort without losing in terms of quality. Notably, many interviewees believe that smart technologies cannot help them reduce their long working hours while in parallel keeping the quality of their products high through, for example, harvesting the right products at the right time. The following extract from an interview illustrates this perception.

> Antonis (farmer, 46 years old): Let me describe to you a typical day on the farm. Yesterday, my wife picked tomatoes, cucumbers, eggplants, peppers, and pumpkins. All these were done manually. Then, she harvested fresh onions, parsley, and mint; manually. Meanwhile, I picked carrots, I washed them, and I put them into boxes. It's not easy, you know. I have 46 years in my back, and my body complains when stooping for hours. Honestly, do you know any smart machine that can harvest the right carrots and then wash them?
> Interviewer: Well, to be honest, I'm not sure.
> Antonis: Me either, but I don't believe that such a machine exists. So, what these technologies can offer me?

The low levels of familiarity with technology also affect farmers' perception of the compatibility between smart and short food production systems. Some farmers noted during the interviews that they do not have a computer at home. Irrigation systems are also outdated in many cases. This lack of baseline equipment makes the transition to the use of smart, high-tech tools almost unrealistic. In addition, farmers – even those who stated that they have an adequate level of technological competence – are afraid that they lack the skills needed to use and exploit smart technologies. Consumers also agree that the farms from which they buy foods are technologically incompatible with smart farming systems, as the following comment exemplifies.

> The farm I buy from is owned by a man who has an old Bautz tractor and a self-made irrigation system, consisting of plastic bottles tied above the vegetables. I cannot see how this man can combine smart technologies with all these, or how he can unlearn the old way of producing vegetables. (Katerina, 38 years old, consumer)

Interestingly, when the discussion shifts from tangible technologies to the data collected through smart sensing and other data collection devices or to big market data farmers express mixed opinions. Although most interviewees agree that the use of weather and environmental data can help them make better decisions, farmers who follow alternative food production practices (organic or agroecological farming) see such data as an absent benefit. In other words, having limited opportunities to intervene by applying fertilizers or by spraying their crops, organic growers and agroecologists denote that they cannot get advantages from data-based predictions. Finally, both producers and consumers agree that the structure of SFSCs permits the communication and exchange of information between them, thus limiting the value of (big) market data.

5.2.2. *Symbolic compatibility*

Symbolic compatibility refers to the fit between smart technologies and the symbolic meaning of SFSCs. Our interviews revealed that, for consumers, SFSCs correspond to their beliefs about "the farming as it should be," as an interviewed put it. For SFSCs buyers, farmers who distribute their products through SFSCs work hard, show respectfulness to nature and have as a top priority the production of high-quality foods. Most of the consumers participating in the study believe that the introduction of smart technologies in farm practice will irreversibly change this image. However, as the following conversation derived from an interview indicates, the conceptual basis of such a belief is rather fuzzy.

> Thomas (consumer, 44 years old): Why somebody to use, for example, drones to spray his crops? Honestly, I cannot find the reason.
> Interviewer: Do you mean that you wouldn't want to buy from somebody who uses drones on his farm?
> Thomas: Yes, exactly.
> Interviewer: Why? Could you explain it to me?
> Thomas: Well, how to say it, I'm trying to imagine a drone in Ilias's (a farmer selling in farmers' market) farm and I believe that something is wrong with this picture. I cannot clearly explain it, but it doesn't fit well.
> Interviewer: Have you ever visited Ilias's farm?
> Thomas: No, but I still believe that there is something wrong with this picture.

Some interviewees noted that SFSCs are based on an "old-fashioned" way of producing food, which has an inherited value since it (re) connects food producers, food and consumers. Food products are viewed as the outcome of the seamless interaction between farmers and farms and are perceived by consumers as purer (even farm products produced through conventional practices) than the products sold through mainstream distribution channels. The use of more sophisticated technology in food production is considered as a threat to this "pureness." Although buyers seem to acknowledge the need to use technology in farm practice, smart appliances (sensors, farmbots or drones) are conceived as exogenous invasions that can disturb the harmony of farmer-food-consumer relations.

Interestingly, we discovered that not only consumers but also farmers endorse this perception. According to our analysis, for farmers, the engagement in SFSCs is associated with a shift in their understanding of farming, and with the cultivation of a different mindset that emphasizes value creation through the establishment of a stronger connection with consumers. For most of the interviewed producers, their involvement in SFSCs signified a change in their understanding of their role as farmers. As a farmer who engaged in SFSCs seven years ago stated in her interview:

> When we (the family) decided to start selling vegetables and fruits in farmers' market we believed that the only difference between selling to the wholesaler and selling directly to consumers is that you have to undertake the transportation of products to market. Then, we realized that we had to change our philosophy. We started cultivating a little bit of this and a little bit of that. That's the way it works in the farmers' markets. It was not easy at the beginning, but it really was a reinvention of farming. We almost abandoned technology; most of the works are done by hand now. […] I asked some people about these (smart) technologies. Some of them tried to advertise them to me. But I realized that using such technologies would be a huge change for us. I'm not sure we can change but I'm rather sure that we don't want to change. To use such technologies, now, is for me like changing my religion. (Anna, 43 years old).

In addition, data uncovered that farmers' and consumers' attitude towards smart farming technologies has some ideological foundations.

For some farmers, the adoption of such technologies is considered as a practice incompatible with their basic beliefs about farming. The fact that some new entrants in farming – who, according to interviewees, face agriculture as an opportunity to gain an extra income – use sensors and other smart systems further enhances this perception. The issue of “real farming” came to the fore many times during the qualitative interviews, as the following comment indicates.

> Technology is good, we all use it, but farming is much more than using technology. We feed people here. You have to use your senses, your mind, your body. You can’t just sit in a chair and reading graphs. This is not real farming. After all, most of the guys that bought such technologies are not real farmers. In my village, we have two “smart” farmers. Well, I don’t know whether they are really smart, but I can reassure you that they are not farmers. One of them is a lawyer, and the other one has a betting shop. (Dimitris, 47 years old)

Interestingly, both consumers and producers see smart farming technologies as a menace to the unconventional character of SFSCs. Short supply schemes are conceived of as an alternative to what some consumers term “industrialized agriculture,” or as relatively isolated islands within the broader, commercially oriented agrifood systems. Since smart technologies are considered as belonging to this industrialized universe, farmers and consumers seem to be afraid that their introduction to SFSCs can transgress this unconventional character. Again, as the following part of an interview with a consumer indicates, the farmer-land relationship – which mediates the consumer-farm connection – is central to this belief.

> Maria (53 years old, consumer): I’m afraid that smart systems change agriculture. I don’t know what farmers say, but I cannot figure out why somebody to want losing touch with the earth. When technologies decide, humans are just supporting actors. I’m not sure, but when technology produces instead of farmers then they became just sellers of food, they are not any more food producers. This is not the case in the farmers’ markets. You know that these people are in connection with their land.
> Interviewer: So, what would you think in case some of the farmers you are buying from decided to install smart technologies?
> Maria: It would be like losing my connection with their farms. It would be like buying from the megastore in my neighborhood. Not exactly the same, but quite close to buying industrialized food.

6. Discussion and conclusions

In this study, we aimed to uncover farmers’ and consumers’ perceptions of the compatibility between smart farming technologies and SFSCs and to depict how these perceptions affect their willingness to participate in “smart SFSCs.” As it is well known, in the innovation process, actors’ perceptions form a parallel reality, which paves the way for or hampers adoption (Russell and Hoag, 2004). Hence, understanding and analyzing how farmers and consumers who engage in SFSCs conceive short food supply schemes and give meaning to smart technologies are pivotal for forecasting a potential combination of smart farming and SFSCs.

Our qualitative results showed that the compatibility between smart farming technologies and SFSCs can be divided into two types. Actual compatibility refers to the fit between smart technologies and farming characteristics. According to the analysis, farmers believe that smart technologies cannot solve the actual problems they face in their everyday farm practice, whereas the multicultivation and the low level of farms’ technological advancement make the transition to smart production systems difficult if not impossible. Interestingly, consumers were also found to agree that the adoption of smart technologies by farmers who sell their products through SFSCs is not practically feasible.

However, for both consumers and farmers, SFSCs are viewed as alternative, relatively isolated sub-systems within the wider “industrialized” agrifood system. These sub-systems are characterized by a superior distinctiveness and symbolize a stronger connection between farmers, farms, and consumers. Hence, to their view, the introduction of smart technologies in SFSCs can interrupt this connection, thus altering the alternativeness of short supply schemes. This “symbolic compatibility” negatively affects farmers’ and consumers’ perceptions of smart technologies.

Even though, as the quantitative strand of this study revealed, SFSCs participants have positive attitudes towards smart technologies, smart farming is considered as a threat to both the quality of the farmer-consumer relationship and the optimally distinct character of SFSCs. This can lead us to question – as Carolan (2020) notes – what these technologies “do,” rather than what these technologies “are” or how can they be used in the practice of farming. In the case of SFSCs, it seems that these technologies are artifacts that transgress consumers’ imagery of SFSCs, alter the relationship between farmers and their farms, increase the distance between consumers and farm production, and lead to a conventionalization of food production and distribution. This can explain why perceptions of compatibility predict willingness to engage in smart SFSCs for both consumers and farmers, or – in other words, why perceived incompatibility reduces this willingness.

Of course, the fact that consumers and farmers see smart technologies as incompatible with SFSCs does not mean that such technologies have nothing to offer to alternative food networks. The potential of smart farming technologies is more than well documented in the literature (e.g., Rutter, 2014; Garg and Aggarwal, 2016). However, their tailoring to the features of highly-intensive agriculture makes their contribution to alternative food production and distribution schemes questionable. Hence, although the standardization of technology can facilitate innovation processes in technologically advanced industries as the classic work of Farrell and Saloner (1985) shows, it seems to be a barrier to the diffusion of smart technologies in the farming sector, where many different “agricultures” simultaneously exist.

This finding indicates the need for policies that move beyond the promotion of smart technologies to industrialized, technologically advanced farms – which is the case so far (Bronson, 2019) – to the investment in the development of lower-scale smart technological solutions for farmers who follow alternative production and/or distribution routes. To this end, the establishment of innovation brokering services could be a solution (Turner et al., 2017), since brokers could ensure the connection between different types of farming and technology providers, thus permitting AgTech companies to know the real needs of farmers.

On the other hand, to date, both research and policy place an intense emphasis on the ways smart farming technologies can lead to a technological makeover of agriculture. However, these technologies also transform farming systems, generating a new status quo referring not only to the practice (Rotz et al., 2019) but also to the meaning of farming (Carolan, 2017). As our findings indicate, such a change is not always welcome by farmers and consumers – at least in the case of SFSCs, where smart technologies are viewed as factors that can weaken the relational fabric between them. Given that farmers and consumers actively and reciprocally co-transform smart technologies into value (Lioutas et al., 2019; Jayashankar et al., 2020), a more concise focus on the ways these two groups – and other actors involved in the agrifood systems – conceive these technologies is necessary.

Before closing, it is important to note a couple of limitations of this study. First, the term “smart technologies” refers to a bundle of technological advancements and not to a single set of technologies. Future researchers could focus on specific smart technologies in order to examine the compatibility between them and alternative food distribution networks. Second, our study was limited to a specific area. Comparisons with other regions are needed to enhance our conclusions.

However, despite these limitations, the work presented herein responds to recent calls for research on the degree to which smart technologies can meet the needs and peculiarities of different agrifood production and distribution approaches (Lioutas and Charatsari, 2020; Klerkx et al., 2019). Although our study focused exclusively on SFSCs, it offers some preliminary insights into this issue. However, much more research is needed to identify how smart technologies can alter the meaning and the nature of different "agricultures."

CRediT authorship contribution statement

Evagelos D. Lioutas: Conceptualization, Methodology, Formal analysis, Writing - original draft, Writing - review & editing, Investigation. **Chrysanthi Charatsari:** Conceptualization, Methodology, Formal analysis, Writing - original draft, Writing - review & editing.

Declaration of Competing Interest

None.

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