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The Effects of Individual Variables, Farming System Characteristics and Perceived Barriers on Actual Use of Smart Farming Technologies: Evidence from the Piedmont Region, Northwestern Italy

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Abstract: Smart Farming Technologies (SFTs) have a real potential to deliver more productive and sustainable agricultural production. However, limited empirical research is available on the role played by objective and subjective factors in the adoption of such disruptive innovations, especially in the Italian context. This study investigated the role of education, farm size, being a sole farmer, and perceived barriers in affecting the use of SFTs in a sample of Italian farmers from the Piedmont region (North-West Italy). Three hundred and ten farming operators were questioned via a paper-and-pencil questionnaire. The analyses showed that low levels of education and working on-farm alone were positively associated with perceived economic barriers, which in turn were negatively associated with the adoption of SFTs. Farm size had a positive direct effect on SFT adoption. The results pointed out the need for targeted policies and training interventions to encourage the use of SFTs.

Keywords: barrier to innovation; farmers' perception; innovation adoption; Smart Farming; Italy

1. Introduction

Agriculture is the oldest sector of the economy and after a period of consolidation of technologies since 1990–2000, it has experienced a spectacular evolution under the so-called Precision Agriculture (PA). Geo-positioning systems, geomapping, sensors and actuators, assisted and automatic guidance steering systems, and electronic communications are examples of technologies that working together makes it possible to adopt the variable rate technology, the most advanced example of integration of PA [1,2]. Smart Farming goes beyond the response of PA technologies to the field variability through the rapid advancement in the last decade of a combination of internet technologies and future-oriented technologies such as the internet of things (IoT), cloud computing and data analytics techniques, ability to store and process data, and to return information for decision making in real-time [1–3]: thus, smart farming has a strong relation, but it is not limited, to the concepts of PA.

These technologies, together with synthetic biology, neurotechnologies, nanomaterials, advance energy and storage technologies are expected to disrupt and greatly affect economies and societies over the next future (10–15 years) unfolding their effects on the entire agricultural value chain [2,4,5]. Smart Farming Technologies (SFTs) are recognized to have a real potential to deliver several advantages to agriculture: a more productive, profitable and sustainable agricultural production, based on a more precise and resource-efficient approach able to reduce the ecological footprint of this sector, safer and better quality products and enhanced consumers' products acceptance through traceability and new direct forms of interaction among farmers, traders, processors, retailers

and consumers [6], and safer and healthier working conditions for the agricultural workforce [7]. This is a fundamental issue if we consider that it is expected that the world population will further expand from the current 6 billion to 9–11 billion people in 2050 and this population will need to be fed within the limits of planet Earth's carrying capacity [8].

As noticed by Long and colleagues [9], a still limited amount of empirical research is available about farmers' views on the adoption of such disruptive technologies and innovations in developed and developing countries. These studies covered different practices within Australian agriculture [10], vineyards in New Zealand [11], Australian wool farmers [12], wine and sheep industries in the USA and Australia [13], seed-potato growing in the Netherlands [14], and citrus farming in Brazil [15]. Additional initiatives in such domain are reported in O'Grady and O'Hare [16]. Overall, the previous research pointed out a low level of SFT adoption, often highlighting the seemingly irrational and inefficient outcomes of technological innovation adoption. For instance, successfully adopted technologies and innovations may be nevertheless rejected by the users who go back to the original practice or technology even where benefits were being enjoyed [10–12,16].

To interpret these results, different factors have been singled out [17,18]. Farmers' education affected the use of SFTs, with less educated persons being usually less confident and less inclined towards the use of technologies [19,20] and not having the knowledge to understand the benefits or to manage them [3,16]. The adoption of SFTs was reported to be lower also among sole farmers and in small farms: indeed, as noticed by Giannakis and colleagues [21] for sensor network irrigation technology in southern Europe countries, the presence of small and split-up holdings does not create the adequate economies of scale for the uptake of the technology. As pointed out by Long and colleagues [9], the heterogeneity of farms and operator's characteristics can explain SFTs uptake through "the primacy of perception, in terms of the perceived (rather than actual) benefits of adoption" (p. 13). Perceptual and attitudinal aspects of human behavior are indeed important drivers for decisions, which can affect the behavior toward new technologies [19]. The core subjective factor which has been investigated in previous studies is farmers' perception of the financial cost of technological innovation, its economic benefits, and its appropriateness in fitting the "day-to-day" reality on a farm [19,20]. Perceived high investments and poor returns have been pointed out as significantly lowering SFTs adoption [13]. A survey performed by Kernecker and colleagues [22] in 7 European countries indicated that some of the key improvements of SFTs are related to costs, in terms of reduction and increased cost-benefit clarity. Statistics Denmark reported that in 2018 only one out of four farmers used precision technology in some form, and half of the farmers not using precision technology mentioned that costs relative to expected benefits were too high [23]. Based on a multi-temporal survey investigation, Reichardt and Jurgens [24] showed that most of the farmers in Germany neither used any smart farming technology nor considered introducing it to their farms; the high costs for the technology, especially in combination with a small farm size were the main reasons why most of the farmers hesitated to introduce any of the technologies. Besides this economic concern, another relevant variable affecting the use of technology which has been underinvestigated in agriculture (for exceptions see [10] and [25]) is represented by the commercial aspects: the use of overly scientific language or jargon in presenting the technology to the consumers and the difficulties in being trained and supported in the case of malfunction were shown to be relevant factors in hindering the use of technology in many sectors [26], since without these facilitating factors the potential users may not have the necessary skills and capabilities to integrate and use the innovation.

Context and Aims of the Present Study

As regards technological innovation in agriculture, statistics show that while in the USA possibly up to 80% of farmers use some kind of SFTs, on farms in European Union Countries, the rate is no more than 25% [27]. Adoption of SFTs represents a strategic priority of the EU policies, and a Horizon 2020 thematic network has been developed, the Smart-AKIS (Agricultural Knowledge and Innovation System) Network [28], to bridge the gap between the field and research on the identification and

delivery of new Smart Farming solutions to fit farmers' needs [28,29]. Italy is the second agricultural power in the EU-28, with a turnover of more than EUR 55 billion in 2015 [30]. With 1,620,884 active farms operating on an agricultural area of almost 13 million hectares, in 2010, one out of four of the EU-28's holdings was in Italy [31]. According to the data from the 2010 Sixth General Agricultural Census, the average Utilized Agricultural Area (UAA) of the Italian agricultural holdings is 7.9 hectares [32], while the average size of farms in the 28 European Union countries, in the same year, was about 16.1 hectares [30]. In Italy, farms smaller than 5 hectares account for 73% of the total, while holdings with a standard value production of less than € 8000 represent 62% of the total Italian farms [31]. Italian agriculture employs around 3,900,000 people, with 15.2% distributed in the North-West, 22% in the North-East, 13.6% in the Centre, and the remaining, nearly 50%, in the South. According to the last agricultural census, most of the farm owners (58%) are in the age range 35–64, while nearly 5% is in the age 20–34 years. About 32% of the farm owners have a middle school diploma, while 22% have a level of education equal to high school and 6% have a university degree [32]. Employment of foreigners in the Italian agriculture continues to increase, attaining 147,000 units in 2016 (16.9% of the total agricultural workforce) [33]. As regards the use of SFTs, the last agricultural census reported that only 61,000 out of 1.6 million farms recorded in the census were using Information and Communication Technologies (ICT) [34], pushing the Italian policy makers to adopt strategic national guidelines to support the development and adoption of SFTs [35].

The Piedmont region is in the North West part of Italy. The Piedmont represents about 4% and 8% of the total national agricultural holdings and Utilized Agricultural Area (UAA), respectively. In the Piedmont, there are approximately 1 million hectares of UAA and 67,000 agricultural holdings with an average surface of 15 ha, very similar to those of the neighbouring regions of the Po valley (Lombardia 18 ha, Emilia Romagna 14.5 ha), while larger when compared to the national average (7.9 ha). The Piedmont covers 35% of the Po River catchment; 41% of the UAA is on the plane, mainly with maize-based systems, while 31% is on the hills, mainly with vineyards and winter cereals [36]. The average standard output of farms from the Piedmont is approximately 60,000 €: it can be considered representative of the Italian national average (35,000 €) when compared to the outperforming (Lombardia, 135,000 €; Emilia Romagna, 90,000 €) or underperforming (Liguria and Puglia, 12,000 €; Calabria 10,000 €) regions [24]. The composition of the average Piedmont farm standard output is very similar to those from other Northern Italian regions (Veneto, Emilia Romagna, Friuli-Venezia Giulia) and to the Italian average: 50% from plant/vegetable, 40% from livestock and 10% from mixed systems [36]. The average gross saleable production for hectare of the farms in the Piedmont is about 4800 €, slightly higher than the national average (3600 €) but lower than that from outperforming Italian North-East regions (5500 €) [36]. The Piedmont agricultural workforce represents about 4% of the national workforce in this sector, and foreign workers account for about 7% of the employees [37]. Most of the farm owners are in the age range 35–64 (63%) and have a level of education equal to that of middle school (about 37%), whereas 25% have a high school diploma and fewer than 5% have a university degree [32]. Even in the Piedmontese context, as reported also at the national level, Smart Farming is struggling to spread among end users [38,39]. This phenomenon is observed despite the fact that there are numerous initiatives at the regional level to promote the creation of innovative firms in the agricultural sector. Only in 2017, the Piedmont region financed 14 research and development projects for over 4.5 million euros within the Agrifood Innovation Pole, in order to support innovation and competitiveness of the agri-food sector, by networking the knowledge of small and medium enterprises, innovative start-ups, large companies and research institutions [40].

Despite these figures, there is a lack of research about SFTs and factors affecting their adoption in Italy and in the Piedmont in particular. Previous studies by Cavallo and colleagues [38] investigated Italian farmers' attitudes toward technological innovations in agriculture, pointing out different user profiles with various degrees of openness to technological solutions. However, the innovations considered in those studies dealt mainly with the technological features equipping the tractors, and the promoting/hindering factors for their adoption were not investigated. Long and colleagues [9] pointed

out the existence of different perceived barriers in the adoption of technological innovation among farmers of different European countries (including Italy). Nonetheless, the barriers were investigated only as regards one type of technology (i.e., climate-smart agriculture) and they were explored by means of a literature review and qualitative semi-structured interviews, thus without considering the quantitative relationships between these variables and the adoption of technological solutions.

Based on the analysis of the available literature about SFTs adoption and the characteristics of the Italian context and the Piedmont in particular, this study aimed at investigating the role played by sociodemographic variables (education), farming system characteristics (farm size and being a sole farmer), and subjective factors (farmers' perceived barriers) in affecting the use of SFTs in a sample of Piedmontese farmers. The following four hypotheses were tested. Based on Long and colleagues [9], we hypothesized that working alone will show a positive association with perceived economic (H1a) and commercial (H1b) barriers, and that working on a large farm will show a negative association with both perceived economic (H2a) and commercial (H2b) barriers. Based on Pierpaoli and colleagues [19], being a highly educated farmer is expected to have a negative association with perceived economic (H3a) and commercial (H3b) barriers. In their turn, and based on Long and colleagues [9], Adrian and colleagues [20], and Daberkow and McBride [17], perceived economic (H4a) and commercial (H4b) barriers will be negatively related to the actual use of SFTs. The tested hypotheses are summarized in Figure 1. As suggested by the methodological literature [41], in the model, we tested the direct effects linking the independent and the dependent variables without the intervention of the mediators, even though we did not draw any hypothesis on such links.

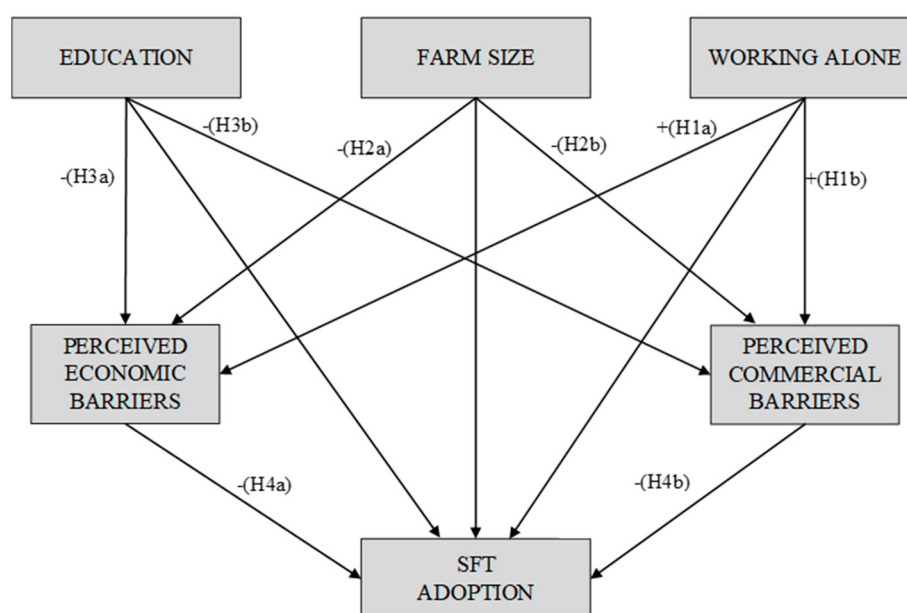


Figure 1. Expected relations among the model's variables.

Based on the range of technology fields encompassed by the definition of Smart Farming [19], and considering previous evidence from Kernecker and colleagues [22] on the most and least important SFTs for farm operation according to European farmers, the model was tested across farming technologies divided into two groups, to determine whether the same patterns of variables and associations can be identified: management information systems (e.g. technologies for collecting, storing, processing, and disseminating data for decision making) vs in-field advanced working tools (such as robots and autonomous machines and traditional machines, such as tractors, with embedded PA devices/systems). Understanding the role played by different variables related to both the farming system and to the operators, in promoting or hindering the adoption of SFTs, could highlight possible solutions in terms of policies, work re-organization and/or operators' training, to support and promote

the use of SFTs. This is particularly relevant for the European, and in particular the Italian, context, since the adoption of SFTs is still in its early stages in these areas, and the characteristics of the farming system may discourage the adoption of technological solutions [31].

2. Materials and Methods

2.1. Participants and Setting

The participants were recruited among the visitors of the 36th National Exhibition of Agricultural Mechanization in Savigliano, the largest agricultural machinery exhibition in the Piedmont region (Northwestern Italy). The Savigliano Exhibition is a public event that mostly features equipment but also attracts people and families because of its recreational and entertaining activities. Agricultural exhibitions play an important role in the life of Italian small country towns, where they often combine amusement elements, breeding stock exhibitions and sports happenings, with lectures, seminars and conferences. Since the agricultural population is spread across the country and has varying operating schedules, agricultural machinery exhibitions are one of the best occasions where a large and wide-ranging group of farmers, agricultural workers and other agricultural business operators come together. Therefore, such events provide a suitable place to conduct surveys and other data collection activities [24,38,42,43].

2.2. Instrument

The participants were administered a paper-and-pencil questionnaire. The sections and items of the questionnaire were developed considering previous instruments [38,42] and the main critical issues raised in previous studies about the adoption of SFTs [9]. The questionnaire was pilot-tested with 9 operators before being submitted to the sample of the present investigation.

The questionnaire started with the presentation of two groups of images. In group 1, there were represented drones, sensors for data acquisition and automatic download, and agricultural apps (SFT Type 1). In group 2, there were pictures of agricultural robots and autonomous machines, and tractors equipped with CAN-bus (the controller area network (CAN) bus is an electronic system connecting components of the tractor (engine, transmission, hydraulic system), implements (seeder, fertilizer spreader, etc), and sensors (typically GPS positioning system) to effectively control the various systems and to increase the productivity [44,45]). (SFT Type 2). Images have been selected to represent the two groups of technologies investigated, the management information systems (SFT Type 1) and the in-field advanced working tools technologies (SFT Type 2), being attractive and as much as possible explicative of their possible use. After the participants were explained what technology the pictures represented, they were asked to choose one of them based on the fact that they either have had a direct experience of any of the depicted SFTs, or they have been using them or they have heard about them from someone else. After this choice, the participants were asked whether they actually used some of the technologies belonging to the SFT type they have chosen (0 = do not use, 1 = use it at least some times a year).

Then, participants had to indicate on a 2-category format (0 = no, 1 = yes) whether they considered (in case of actual users)/would consider (in case of non-users) any of the following aspects as regards the adoption of the selected group of SFTs: low cost-benefit ratio, insufficient external subsidy to get SFT, uncertain results, lack of other farmers to share the costs with, scarce matching with farmers' needs, low after-sale technical support, hard to be trained, and inaccessible language. The items were developed based on the barriers identified in previous studies [9,26] and those reported in the questionnaire by Kernecker and colleagues [22]. A standard socio demographic form, assessing also participants' relation with work (profession, years of experience in the agricultural sector, farm size and being a sole farmer) and their technological background (use of ICT in everyday life) closed the questionnaire.

2.3. Procedure

The questionnaire was handed out to people walking through the exhibition by trained research assistants. The assistants explained the aims of the study and informed the participants that the questionnaire was anonymous. No incentive was offered to participate in the survey. The questionnaire was in Italian and it took approximately 7–8 min to be filled in. The response rate was approximately 79%.

2.4. Statistical Analyses

In previous studies, the role played by sociodemographic variables, farming system characteristics and perceptual factors has been usually analyzed through discrete choice (logit or probit) models [13]. These models consider all the variables at the same hierarchical level, not taking into account that farmers' perceptions may be outcomes of some, and predictors of other, variables at the same time, as it was shown to be the case in other processes like those leading to a farm accident [42]. To overcome this issue, in the present study we decided to test our hypotheses by means of a mediation analysis [41]. A mediation model seeks to identify and explain the mechanism that underlies an observed relationship between an independent variable and a dependent variable via the inclusion of a third variable, known as a mediator. Rather than a direct causal relationship between the independent variable and the dependent variable, a mediation model proposes that the independent variable influences the mediator variable, which in turn influences the dependent variable, allowing the researcher to detect the reason of the association between the independent and dependent variables.

Descriptive statistics were calculated for the variables of interest and then a structural equations model (Maximum Likelihood extraction) was estimated using Amos 22.0 [46]. The fit of the model was evaluated through the combination of different indexes: the Incremental Fit Index (*IFI* [47]), the Comparative Fit Index (*CFI* [48]), and the Root Mean Square Error of Approximation (*RMSEA* [49]). To investigate whether the variables and their relationships vary between the two types of SFTs, the structural invariance of the model across the two types of SFTs (Type 1: sensors for data acquisition and automatic download, and agricultural apps ($n = 115$) vs Type 2: agricultural robots and autonomous machines ($n = 195$)) was tested.

3. Results

The study involved a sample of 310 farming operators (97.1% men, $M_{age} = 39.85$ years, $SD = 17.44$). On average, the participants have been working in agriculture for 19.96 years ($SD = 16.80$). As regards the use of ICT in everyday life, 65.6% of the sample declared to use some technological devices (PCs, smartphone or tablet) almost every day, 18.0% sometimes and 16.4% never used them. As regards the investigated SFTs, 37.1% of the participants focused on SFT Type 1, whereas 62.9% chose SFT Type 2. Overall, 74.8% of the interviewed people reported not to use the type of SFTs they have chosen (in particular, 75.7% for Type 1 and 74.4% for Type 2). Table 1 reports the additional descriptive statistics for the variables investigated in the study.

Table 1. Descriptive statistics for the variables of interest.

Variable	Level	%
Education	None	0.6
	Primary school	2.9
	Secondary school	29.7
	High school	59.0
	Degree and over	7.8
Farm size (ha)	Up to 2	15.8
	2 to 9	37.4
	10 to 29	22.6
	30 to 49	11.9
	50 and over	12.3

Table 1. Cont.

Variable	Level	%
Working alone	Yes	27.1
	No	72.9
Variable	Mean	SD
Perceived economic barriers	0.61	0.27
Perceived commercial barriers	0.43	0.34

Participants' scores on the questionnaire scales (first 5 items representing economic barriers, Cronbach's $\alpha = 0.530$; the other three the commercial barriers, Cronbach's $\alpha = 0.478$) were computed as a sum of the score given for each item. The alphas of the scales were below the usual 0.7 threshold. However, this was due to the low number of their items more than to their low correlation. Indeed, two confirmatory factor analyses showed that the scale on the economic barriers was unidimensional, $\chi^2(5) = 2.065$, $p = 0.840$, $IFI = 1.000$, $CFI = 1.000$, $RMSEA = 0.000$ (Confidence Interval (CI) = 0.000, 0.045). The same held true as concerns the battery on commercial barriers, $\chi^2(6) = 0.000$, $p = 1.000$, $IFI = 1.000$, $CFI = 1.000$, $RMSEA = 0.225$ (CI = 0.172, 0.282).

The structural equations model showed that H2a, H2b, and H4b were falsified. Indeed, the farm size did not show any significant association with either perceived economic or commercial barriers ($b = -0.01$, $SE = 0.01$, $p = 0.85$ and $b = -0.06$, $SE = 0.02$, $p = 0.28$). Moreover, commercial barriers did not show any significant association with the actual use of SFTs ($b = -0.08$, $SE = 0.16$, $p = 0.15$). All the other paths of the model were statistically significant (see Figure 2). Consistent with H1a and H1b, working alone was positively associated with both economic and commercial barriers. Consistent with H3a and H3b, education showed a negative association with perceived economic and commercial barriers. Consistent with H4a, perceived economic barriers were negatively associated with actual use of SFTs. Finally, farm size showed a direct (i.e., without any mediation) significant positive association with the actual use of SFTs. The fit of the model was satisfactory, $\chi^2(8) = 12.148$, $p = 0.145$, $IFI = 0.967$, $CFI = 0.965$, $RMSEA = 0.041$ (CI = 0.000, 0.085). Table 2 shows that the two indirect effects we modelled reached statistical significance.

Table 2. Indirect associations of education and working alone with SFT adoption.

	Education	Farm Size	Working Alone	Perceived Economic Barriers
Perceived economic barriers				
SFT adoption	0.026		−0.079	
Perceived commercial barriers				

Note. $p < 0.05$.

Supplementary analyses tested the structural invariance of the model across the two groups of technologies. Based on Reise and colleagues [50], we compared the fit of a baseline model, in which we tested our model simultaneously on both groups of technologies, with that of an invariant model, in which we constrained the parameters to be equal across SFT Type 1 vs SFT Type 2. The hypothesis of invariance can be accepted if the difference in the χ^2 value of the invariant model compared to that of the baseline model is not significant for a number of degrees of freedom equal to the difference in degrees of freedom of the two models, i.e., if constraining the parameters to invariance does not determine a significant worsening in the model fit. For our model, the hypothesis of invariance could be accepted. Indeed, the fit of the baseline model, $\chi^2(16) = 19.128$, $p = 0.262$, $IFI = 0.976$, $CFI = 0.973$, $RMSEA = 0.025$ (90% CI = 0.000, 0.061) was statistically equal to that of the invariant model $\chi^2(22) = 26.682$, $p = 0.224$, $IFI = 0.962$, $CFI = 0.960$, $RMSEA = 0.026$ (90% CI = 0.000, 0.057), $\chi^2(6) = 7.554$, $p = 0.272$.

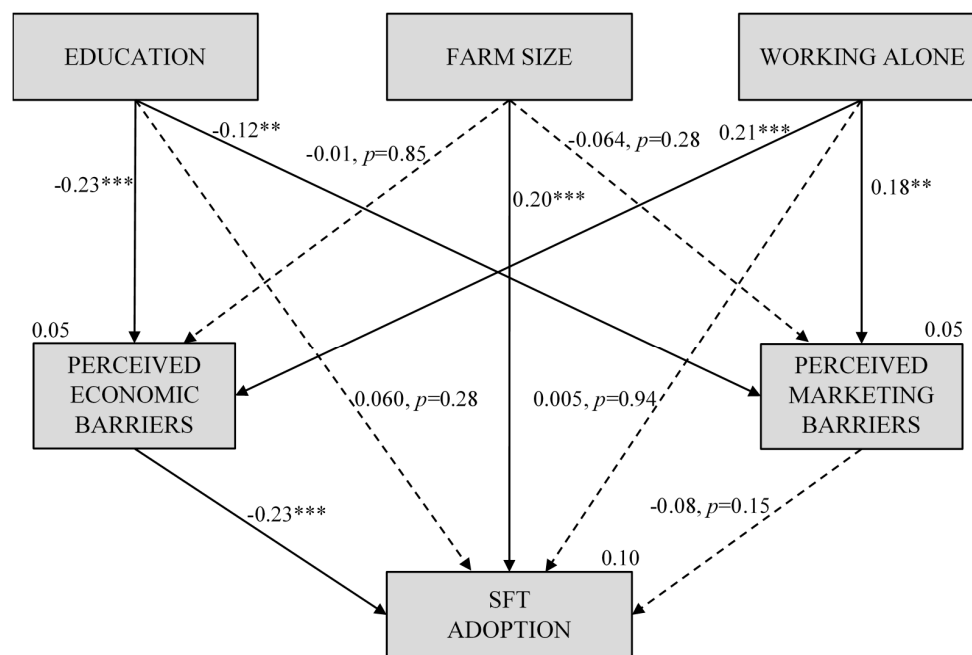


Figure 2. The final mediated model: the actual use of SFTs is predicted by working alone, farm size, education, via perceived economic barriers (significant paths in bold solid lines). Errors are omitted; standardized parameters (i.e., regression β coefficients) are displayed. Note. ** $p < 0.01$, *** $p < 0.001$.

4. Discussion

The present study investigated how individual- and farming- related factors affect the adoption of different SFTs via the mediation of perceived economic and commercial barriers in a sample of Italian farmers. The study added a novel contribution to previous knowledge on technological innovation uptake in farming, by pointing out that different variables intervene at different levels in the process leading to SFTs adoption. Furthermore, the study investigated this issue in Italy, an often neglected context even though it is a good representation of a large percentage of the European agricultural system and its characteristics.

Overall, consistent with previous studies performed in different countries [11,12], the results showed a low uptake of both types of the investigated technologies, even though participants reported to be familiar with ICT in their daily life. This discrepancy between a quite common use of ICT in everyday life and its low adoption in agricultural business in the studied sample stresses the importance of identifying which critical factors would benefit from targeted interventions to promote SFTs diffusion among farmers.

The analyses showed that working alone on a farm and low education were positively associated with the perception of economic and commercial barriers, and they predict the adoption of SFTs via the mediation of perceived economic barriers. As with any business, farmers have an interest in maximizing production and making a profit [51]; thus, governmental policies and financial support can reduce the actual economic barriers, but they may not be sufficient to capture the full complexity of farmers' attitudes and beliefs [52]. Other factors related to the cultural accessibility of SFTs should be taken into account and addressed, with both a restyling of the way in which SFTs are presented on the market, and the promotion of targeted information campaigns to maximise the perceived economic benefit of SFTs. Previous studies pointed out the relevance of formal communication channels in promoting the adoption of sustainable innovations in agriculture [53,54]. In particular, Genius and Koundouri [55] in their study about irrigation technology adoption pointed out the importance of providing extension services to effectively assist farmers in building knowledge about the benefits of new technologies and promoting their adoption.

Being a sole farmer puts high time and economic pressures on the individual, and requires creative ways to complete a job, with an increased exposure to occupational accidents and injuries [56]. More and more automated tasks may make farm operations easier, especially when it comes to using heavy equipment or performing physical tasks [57], and reduce farmers' occupational safety risk exposure [27]. Given the high rate of sole farmers in Italy [34] and in the rest of the European Union [58], the relationship between working alone and adopting some technological solutions on farm should be further investigated.

As regards education, the present results are consistent with previous evidence [20] and they raise some considerations about the need to equip farmers with the right mix of both job-specific and cross-cutting core skills to make them able to see the economic benefits and access SFTs. To deal with this issue, new forms of presentation and learning of SFTs may be encouraged, addressing especially low-educated farmers, by using virtual classes, e-learning, and blended training programmes (virtual and on-site learning) [27].

With regard to farm size, the present study showed that working on a small farm lowered the adoption of SFTs. This result is consistent with previous evidence [20] and the same pattern has been observed in different countries whose agricultural systems are characterized by small farms rather than big plots of land [21,27]. Smaller farmers are typically not able to keep up with new technologies because of the lack of investment capital or knowledge, thus creating a large digital divide between big and small farmers [27], increasing the likelihood that educated workforce available in small farms exit to other sectors [59]. New education forms such as those focusing on the role of experienced farmers as mentors [60] may be particularly useful, since smaller farmers often find it challenging to participate in costly and time-intensive traditional training forms. Furthermore, stimulating international exchange of knowledge and ideas and new forms of cooperation between farmers and farms, and encouraging global collaboration may all be effective ways to reach out to smaller farms.

In Northern Italian regions, a total of 322 startups are defined as “agrifood cores”, and they grew by + 74% in one year, from 2016 to 2017 [61]. Despite the innovative thrust promoted by the ever-increasing number of startups and the potential benefits of Smart Farming in terms of cost reduction, quality and crop yield, the present study and other research conducted in the Piedmont area confirmed the poor acceptance and poor adoption of new technologies to support agricultural activity [39]. Strong public intervention will be needed to create the suitable conditions for new business models and new economic opportunities along the agricultural value chain, so that new technologies might not be developed, marketed and adopted by large-scale operations only [2]. It is recognized that the SFTs can provide great environmental benefits, for example, through a more efficient use of water, chemicals and other inputs based on site-specific needs, helping farmers to cope with labor shortage and aging of the rural population, and can lead to new forms of diversification on farms, being a lever to boost growing trends such as farming of high quality or peculiar varieties, organic farming, or growing crops for fair and equitable trade, supported by the increasing consumer, society and market consciousness [6,22,62]. Thus, the access to SFTs should also be encouraged by targeted incentives and support programmes both in developed and developing countries aimed at removing, or at least reducing, the barriers to adoption of the SFTs the study pointed out. For example, in the European Union, the policy makers should consider supporting the introduction and adoption of SFTs among the measures of the next Common Agricultural Policy (CAP) for the years 2021–2027 to cope with the aims the European Commission has so far proposed: to react to challenges such as climate change and generational renewal while ensuring high-quality and safe food and a competitive European agricultural sector [63].

Limitations of the Present Study and Possible Research Developments

Some limitations of the present study should be acknowledged. The survey was carried out in the Piedmont region, Northwestern Italy, and it involved a non-random sample of farm operators, selected among the visitors of an agricultural exhibition. Previous studies have shown that farmers from the Piedmont can be usefully surveyed to analyze the dynamics of the Italian farming population [42,43].

With regard to the participants' selection procedure, since the participants were recruited during an exhibition, one could argue that our sample was probably composed of farmers who were more open to innovation compared to nonparticipants. If this were true, our sampling process could lead to a selection bias. However, due to the very peculiar characteristics of the Savigliano exhibition (which combines amusement elements with seminars and conferences), we are confident that the participants involved in the study nicely represented both the "innovative" and "unwilling" adopters, following the categorization of technology users provided by Cavallo and colleagues [39]. In addition, since we were interested in studying the relations between variables in at least bivariate analyses and not their absolute state as resulting from univariate analyses, the bias arising from the lack of complete representativeness of the sample is significantly less impactful [64]. Thus, as a whole, we are confident about the validity of our results. However, more generalizable results will be available by extending further studies to additional areas of the country. For instance, a previous study investigating the innovation capacity of small olive and wine firms in southern Italy (Campania region, [65]) through cluster analysis pointed out that non-innovators represented the largest cluster of the analyzed sample, and they faced obstacles to innovation similar to those considered in this study. Replicating the same analysis performed in this study in this and other Italian Mediterranean regions characterized by different types of farming operations would provide a wider view on the critical variables for innovation adoption.

The findings of this study need to be interpreted with caution due to the heavy reliance on self-report measures, whose potential biasing effects must be acknowledged [66]. In a future development of the research, it would be useful to gather some objective indicators such as the farm turnover and the actual participation in specific training programs and activities. Finally, agriculture is characterized by a dynamic environment where situational variables are likely to have a considerable influence on farmer decision-making processes regarding technological adoption. Future research should incorporate longitudinal designs to investigate the pathways of this decision-making process over time and across situations. This would also allow to investigate the effects of ageing of the farming population on farmers' aptitude to innovate [21].

5. Conclusions

Smart Farming applications do not target only large, conventional farming exploitations, but could also be new levers to boost other common or growing trends in agricultural exploitations, such as family farming and organic farming. Moreover, SFTs contribute to provide great benefits in terms of environmental issues, for example, through a more efficient use of natural resources such as water, or reducing input in pesticides and nutrients. Previous studies reported low levels of SFTs adoption, but factors affecting SFTs adoption have been underinvestigated in Italy and in the Piedmont region in particular. The present study focused on the Piedmontese context to point out some critical variables, related to both the farming system and individual characteristics which should be addressed to increase SFTs adoption among farmers. Perceived economic barriers play a relevant role in mediating the effects of education and being a sole farmer on SFTs uptake, pointing out the relevance of institutional interventions and policies to encourage the use of SFTs. Much effort should also be employed to train operators to make them aware about the useful and effective returns of SFT adoption, regardless of the specific type of technology considered.

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References

1. Wolfert, S.; Ge, L.; Verdouw, C.; Bogaardt, M.-J. Big Data in Smart Farming—A Review. *Agric. Syst.* **2017**, *153*, 69–80. [\[CrossRef\]](#)
2. Pham, X.; Stack, M. How data analytics is transforming agriculture. *Bus. Horiz.* **2017**, *61*, 125–133. [\[CrossRef\]](#)
3. Pivoto, D.; Waquil, P.D.; Talamini, E.; Pauletto Spanhol Finocchio, C.; Dalla Corte, V.F.; de Vargas Mores, G. Scientific development of smart farming technologies and their application in Brazil. *Inf. Process. Agric.* **2018**, *5*, 21–32. [\[CrossRef\]](#)
4. Manyika, J.; Chui, M.; Bughin, J.; Dobbs, R.; Bisson, P.; Marrs, A. *Disruptive Technologies: Advances That Will Transform Life, Business, and the Global Economy*; McKinsey Global Institute: New York, NY, USA, 2013; Available online: www.mckinsey.com/mgi/publications/multimedia/ (accessed on 15 April 2019).
5. OECD. *OECD Science, Technology and Innovation Outlook*; OECD Publishing: Paris, France, 2018. [\[CrossRef\]](#)
6. Walter, A.; Finger, R.; Huber, R.; Buchmann, N. Smart farming is key to developing sustainable agriculture. *Proc. Natl. Acad. Sci. USA* **2017**, *114*, 6148–6150. [\[CrossRef\]](#) [\[PubMed\]](#)
7. Colantoni, A.; Monarca, D.; Laurendi, V.; Villarini, M.; Gambella, F.; Cecchini, M. Smart Machines, Remote Sensing, Precision Farming, Processes, Mechatronic, Materials and Policies for Safety and Health Aspects. *Agriculture* **2018**, *8*, 47. [\[CrossRef\]](#)
8. Bukchin, S.; Kerret, D. Food for Hope: The Role of Personal Resources in Farmers' Adoption of Green Technology. *Sustainability* **2018**, *10*, 1615. [\[CrossRef\]](#)
9. Long, T.B.; Blok, V.; Coninx, I. Barriers to the Adoption and Diffusion of Technological Innovations for Climate-Smart Agriculture in Europe: Evidence from the Netherlands, France, Switzerland and Italy. *J. Clean. Prod.* **2016**, *112*, 9–21. [\[CrossRef\]](#)
10. Wheeler, S.A. What Influences Agricultural Professionals' Views towards Organic agriculture? *Ecol. Econ.* **2008**, *65*, 145–154. [\[CrossRef\]](#)
11. Cullen, R.; Forbes, S.L.; Grout, R. Non-Adoption of Environmental Innovations in Wine Growing. *New Zeal. J. Crop Hortic. Sci.* **2013**, *41*, 41–48. [\[CrossRef\]](#)
12. Sneddon, J.; Soutar, G.; Mazzarol, T. Modelling the Faddish, Fashionable and Efficient Diffusion of Agricultural Technologies: A Case Study of the Diffusion of Wool Testing Technology in Australia. *Technol. Soc. Chang.* **2011**, *78*, 468–480. [\[CrossRef\]](#)
13. Tey, Y.S.; Brindal, M. Factors Influencing the Adoption of Precision Agricultural Technologies: A Review for Policy Implications. *Precis. Agric.* **2012**, *13*, 713–730. [\[CrossRef\]](#)
14. Van de Kerkhof, B.; van Persie, V.; Noorbergen, H.; Schouten, L.; Ghauharali, R. Spatio-temporal analysis of remote sensing and field measurements for smart farming. *Procedia Environ. Sci.* **2015**, *27*, 21–25. [\[CrossRef\]](#)
15. Carrer, M.J.; de Souza Filho, H.M.; Batalha, M.O. Factors Influencing the Adoption of Farm Management Information Systems (FMIS) by Brazilian Citrus Farmers. *Comput. Electron. Agric.* **2017**, *138*, 11–19. [\[CrossRef\]](#)
16. O'Grady, M.J.; O'Hare, G.M.P. Modelling the smart farm. *Inf. Process. Agric.* **2017**, *4*, 179–187. [\[CrossRef\]](#)
17. Daberkow, S.G.; McBride, W.D. Socioeconomic profiles of early adopters of precision agriculture technologies. *J. Agribus.* **1998**, *16*, 151–158.
18. Daberkow, S.G.; McBride, W.D. Farm and operator characteristics affecting the awareness and adoption of precision agriculture technologies in the US. *Precis. Agric.* **2003**, *4*, 163–177. [\[CrossRef\]](#)
19. Pierpaoli, E.; Carli, G.; Pignatti, E.; Canavari, M. Drivers of Precision Agriculture Technologies Adoption: A Literature Review. *Procedia Technol.* **2013**, *8*, 61–69. [\[CrossRef\]](#)
20. Adrian, A.M.; Norwood, S.H.; Mask, P.L. Producers' Perceptions and Attitudes toward Precision Agriculture Technologies. *Comput. Electron. Agric.* **2005**, *48*, 256–271. [\[CrossRef\]](#)
21. Giannakis, E.; Bruggeman, A.; Djuma, H.; Kozyra, J.; Hammer, J. Water pricing and irrigation across Europe: Opportunities and constraints for adopting irrigation scheduling decision support systems. *Water Sci. Technol. Water Supply* **2016**, *16*, 245–252. [\[CrossRef\]](#)
22. Kernecker, M.; Knierim, A.; Wurbs, A.; Kraus, T.; Borges, F. Experience versus expectation: Farmers' perceptions of smart farming technologies for cropping systems across Europe. *Precis. Agric.* **2019**, 1–17. [\[CrossRef\]](#)
23. Statistics Denmark. *Precision Agriculture. Business Sector*; Newsletter; Statistics Denmark: København, Denmark, 2018.
24. Reichardt, M.; Jürgens, C. Adoption and future perspective of precision farming in Germany: Results of several surveys among different agricultural target groups. *Precis. Agric.* **2009**, *10*, 73–94. [\[CrossRef\]](#)

25. Eidt, C.M.; Hickey, G.M.; Curtis, M.A. Knowledge Integration and the Adoption of New Agricultural Technologies: Kenyan Perspectives. *Food Secur.* **2012**, *4*, 355–367. [CrossRef]
26. Wielicki, T.; Arendt, L. A Knowledge-Driven Shift in Perception of ICT Implementation Barriers: Comparative Study of US and European SMEs. *J. Inf. Sci.* **2010**, *36*, 162–174. [CrossRef]
27. European Parliament. *Precision Agriculture and the Future of Farming in Europe. Scientific Foresight Study*; STOA IP/G/STOA/FWC-2013-1/Lot 7/SC5; Scientific Foresight Unit (STOA): Brussels, Belgium, 2016; Available online: http://www.europarl.europa.eu/RegData/etudes/STUD/2016/581892/EPRS_STU581892_EN.pdf (accessed on 11 April 2019).
28. Eip-Agri. *Smart Farming Thematic Network*; European Commission: Brussels, Belgium, 2017; Available online: <https://ec.europa.eu/eip/agriculture/en/news/smart-farming-thematic-network> (accessed on 2 April 2019).
29. Gava, O.; Favilli, E.; Bartolini, F.; Brunori, G. Knowledge networks and their role in shaping the relations within the Agricultural Knowledge and Innovation System in the agroenergy sector. The case of biogas in Tuscany (Italy). *J. Rural Stud.* **2017**, *56*, 100–113. [CrossRef]
30. Eurostat. *Agriculture, Forestry and Fishery Statistics*; Publications Office of the European Union: Luxembourg, 2016; Available online: <https://ec.europa.eu/eurostat/web/products-statistical-books/-/KS-FK-16-001> (accessed on 25 March 2019).
31. INEA. *Italian Agriculture in Figures 2012*; Istituto Nazionale di Economia Agraria: Rome, Italy, 2012. Available online: <http://dspace.crea.gov.it/bitstream/inea/292/1/2101.pdf> (accessed on 3 April 2019).
32. ISTAT. *6° Censimento Generale Dell'agricoltura 2010 Caratteristiche Strutturali Delle Aziende Agricole 24 Ottobre*; ISTAT: Rome, Italy, 2010; Available online: https://www.istat.it/it/files/2011/03/1425-12_Vol_VI_Cens_Agricoltura_INT_CD_1_Trimboxes_ipp.pdf (accessed on 10 May 2019).
33. INEA. *Italian Agriculture in Figures 2018*; Istituto Nazionale di Economia Agraria: Rome, Italy, 2019.
34. ISTAT. *Censimento Agricoltura*; Data Warehouse; ISTAT: Rome, Italy, 2010; Available online: <http://dati-censimentoagricoltura.istat.it/Index.aspx> (accessed on 13 March 2019).
35. Ministero delle Politiche Agricole Alimentari e Forestali. *Linee Guida per lo Sviluppo Dell'agricoltura di Precisione in Italia. 2017*. Available online: file:///C:/Users/e.cavallo/Downloads/Linee_Guida_Agricoltura_di_precisione.pdf (accessed on 6 May 2019).
36. INEA. *Italian Agriculture in Figures 2013*; Istituto Nazionale di Economia Agraria: Rome, Italy, 2014. Available online: http://dspace.crea.gov.it/bitstream/inea/843/1/Italian_agriculture_figures_2013.pdf (accessed on 21 March 2019).
37. FAI CISL. *Lavoratori Immigrati in Agricoltura*; Fondazione FAI CISL: Rome, Italy, 2017; Available online: <https://www.faicisl.it/attachments/article/2458/Lavoratori%20immigrati%20in%20agricoltura%20-%20Fondazione%20Fai%20Cisl%20Studi%20e%20Ricerche.pdf> (accessed on 7 May 2019).
38. Cavallo, E.; Ferrari, E.; Coccia, M. Likely Technological Trajectories in Agricultural Tractors by Analysing Innovative Attitudes of Farmers. *Int. J. Technol. Policy Manag.* **2015**, *15*, 158–177. [CrossRef]
39. Cavallo, E.; Ferrari, E.; Bollani, L.; Coccia, M. Attitudes and behaviour of adopters of technological innovations in agricultural tractors: A case study in Italian agricultural system. *Agric. Syst.* **2014**, *130*, 44–54. [CrossRef]
40. Regione Piemonte. *Il Sistema dei Poli di Innovazione Regionali*; Regione Piemonte: Piemonte, Italy; Available online: <https://www.regione.piemonte.it/web/temi/fondi-progetti-europei/fondo-europeo-sviluppo-regionale-fesr/sistema-dei-poli-innovazione-regionali> (accessed on 14 May 2019).
41. Hayes, A.F. Beyond Baron and Kenny: Statistical Mediation Analysis in the New Millennium. *Commun. Monogr.* **2009**, *76*, 408–420. [CrossRef]
42. Caffaro, F.; Micheletti Cremasco, M.; Roccato, M.; Cavallo, E. It does not Occur by Chance: A Mediation Model of the Influence of Workers' Characteristics, Work Environment Factors, and Near Misses on Agricultural Machinery-Related Accidents. *Int. J. Occup. Environ. Health* **2017**, *23*. [CrossRef] [PubMed]
43. Caffaro, F.; Roccato, M.; Micheletti Cremasco, M.; Cavallo, E. Falls from agricultural machinery: Risk factors related to work experience, worked hours, and operators' behavior. *Hum. Factors* **2018**, *60*, 20–30. [CrossRef] [PubMed]
44. Tarighi, J.; Ghasemzade, H.; Bahrami, M.; Abdollahpour, S.; Mahmoudi, A.; Cultrera, A.; Cavallo, E. Evaluation heavy duty tractor performance using CAN/bus technology. *Biol. Forum* **2015**, *7*, 734–738.
45. ISO. *ISO 11783-1:2017—Tractors and Machinery for Agriculture and Forestry—Serial Control and Communications Data Network—Part 1: General Standard for Mobile Data Communication*; International Organization for Standardization: Geneva, Switzerland, 2017.

46. Arbuckle, J.L. *Amos TM 23 User's Guide*; IBM: Chicago, IL, USA, 2014.
47. Bollen, K.A. *Structural Equations with Latent Variables*; Wiley: New York, NY, USA, 1989.
48. Bentler, P.M. Comparative Fit Indexes in Structural Models. *Psychol. Bull.* **1990**, *107*, 238–246. [[CrossRef](#)]
49. Steiger, J.H. Structural Model Evaluation and Modification: An Interval Estimation Approach. *Multivar. Behav. Res.* **1990**, *25*, 173–180. [[CrossRef](#)]
50. Reise, S.P.; Widaman, K.F.; Pugh, R.H. Confirmatory Factor Analysis and Item Response Theory: Two Approaches for Exploring Measurement Invariance. *Psychol. Bull.* **1993**, *114*, 552–566. [[CrossRef](#)]
51. Gasson, R.; Crow, G.; Errington, A.; Hutson, J.; Marsden, T.; Winter, D.M. The Farm as a Family Business: A Review. *J. Agric. Econ.* **1988**, *39*, 1–41. [[CrossRef](#)]
52. Flett, R.; Alpass, F.; Humphries, S.; Massey, C.; Morris, S.; Long, N. The Technology Acceptance Model and Use of Technology in New Zealand Dairy Farming. *Agric. Syst.* **2004**, *80*, 199–211. [[CrossRef](#)]
53. Caffaro, F.; Roccato, M.; Micheletti Cremasco, M.; Cavallo, E. An Ergonomic Approach to Sustainable Development: The Role of Information Environment and Social-Psychological Variables in the Adoption of Agri-Environmental Innovations. *Sust. Develop.* (in press). [[CrossRef](#)]
54. Unay Gailhard, I.; Bavorová, M.; Pirscher, F. Adoption of agri-environmental measures by organic farmers: The role of interpersonal communication. *J. Agric. Educ. Ext.* **2015**, *21*, 127–148. [[CrossRef](#)]
55. Genius, M.; Koundouri, P.; Nauges, C.; Tzouvelekas, V. Information transmission in irrigation technology adoption and diffusion: Social learning, extension services, and spatial effects. *Am. J. Agric. Econ.* **2013**, *96*, 328–344. [[CrossRef](#)]
56. McLaughlin, A.C.; Sprufera, J.F. Aging Farmers Are at High Risk for Injuries and Fatalities: How Human-Factors Research and Application Can Help. *North Carol. Med. J.* **2011**, *72*, 481–483.
57. Caffaro, F.; Lundqvist, P.; Micheletti Cremasco, M.; Nilsson, K.; Pinzke, S.; Cavallo, E. Machinery-Related Perceived Risks and Safety Attitudes in Senior Swedish Farmers. *J. Agromedicine* **2018**, *23*, 78–91. [[CrossRef](#)] [[PubMed](#)]
58. European Commission. How Many People Work in Agriculture in the European Union? An Answer Based on Eurostat Data Sources Contents. *EU Agric. Econ. Briefs* **2013**, *8*, 1–17. Available online: http://ec.europa.eu/agriculture/rural-area-economics/briefs/pdf/08_en.pdf (accessed on 5 March 2019).
59. Giannakis, E.; Efstratoglou, S.; Antoniadou, A. Off-Farm Employment and Economic Crisis: Evidence from Cyprus. *Agriculture* **2018**, *8*, 41. [[CrossRef](#)]
60. Lundqvist, P.; Svennefelt, C.A. Health and Safety Strategy in Swedish Agriculture. *Work* **2012**, *41* (Suppl. S1), 5304–5307. [[CrossRef](#)] [[PubMed](#)]
61. Cosimi, S. A Milano Parte Seeds&Chips, una Startup su Dieci Lavora Nell'agritech. Available online: <https://thefoodmakers.startupitalia.eu/62109-20180507-milano-parte-seedschips-startup-dieci-lavora-nellagritech> (accessed on 11 May 2019).
62. Alliance for Internet of Things Innovation. Smart Farming and Food Safety Internet of Things Applications—Challenges for Large Scale Implementations. 2015. Available online: <https://aioti.eu/wp-content/uploads/2017/03/AIOTIWG06Report2015-Farming-and-Food-Safety.pdf> (accessed on 6 May 2019).
63. European Commission. *Future of the Common Agricultural Policy*; European Commission: Brussels, Belgium, 2019; Available online: https://ec.europa.eu/info/food-farming-fisheries/key-policies/common-agricultural-policy/future-cap_en (accessed on 11 May 2019).
64. Roccato, M. L'uso della statistica nella ricerca in psicologia sociale [Using statistics in social-psychological research]. In *Metodi, Modelli e Tecnologie Dell'informazione a Supporto Delle Decisioni [Methods, Models, and Information Technologies as a Support for the Decision-Making]*; Maio, A.D., Gallo, M., Simonetti, B., Eds.; Franco Angeli: Milan, Italy, 2008; Volume 2, pp. 183–191.
65. De Martino, M.; Magnotti, F. The innovation capacity of small food firms in Italy. *Eur. J. Innov. Manag.* **2018**, *21*, 362–383. [[CrossRef](#)]
66. Schuman, H.; Presser, S. *Questions and Answers in Attitude Surveys: Experiments on Question Form., Wording, and Context*; Academic Press: New York, NY, USA, 1981.

