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Society's View on Autonomous Agriculture: Does Digitalization Lead to Alienation? †

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Abstract: Digital and autonomous technologies enter the agricultural market at an increasing rate, yet little is known about society's view on this development, although the public is an important stakeholder. By means of a discrete choice experiment (n = 675), societal preferences for different weed control technologies and tractor types of different degrees of autonomy are investigated. The model applied focuses on emotion-related covariates. The results indicate preferences for conventional or autonomous tractors and for methods of weed control that reduce the need for herbicides. Additionally, positive associations with images of robots correlate with the rejection of conventional tractors in the discrete choice experiment.

Keywords: autonomous weed management; digital farming technologies; discrete choice experiment; field crop robot; public acceptance

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1. Introduction

Increasingly autonomous machines represent a groundbreaking development in agricultural technology, yet their success depends as much on economics and farmer acceptance as on the approval of society. To prevent negative societal reactions to the on-going fourth agricultural revolution, some researchers [1] advocate for transferring the concept of Responsible Research and Innovation to agricultural technology development. Additionally, expert interviews point to the importance of public acceptance, or rather the lack thereof, as a barrier to sustainable innovations in the German agricultural sector [2]. More recent research shows that the German population is still largely undecided on the use of digital technologies in agriculture, including autonomous equipment for weed management [3]. A farmer survey in Bavaria, Germany, however, has indicated that fear of creating an image of alienated agriculture significantly reduces the intent of farmers to invest in field crop robots [4], pointing to the importance of societal approval for the adoption of autonomous farming equipment. Therefore, knowledge is needed on society's perspective on autonomous cropping equipment under specific consideration of underlying emotional factors to better understand the perception of autonomous weed management.

2. Materials and Methods

A discrete choice experiment (n = 675) with three attributes, each subdivided into three levels, covering methods of weed management (conventional spraying, spot-spraying, and hoeing), tractor type (conventional tractor, autonomous tractor, and small swarm robots), and changes in consumer price of the end product (none, moderate and strong), respectively, is analyzed using a Hierarchical-Bayes estimation in Lighthouse Studio 9.5.3

(Sawtooth Software, Provo (UT), USA). This experiment was part of a larger online survey (n = 2012) conducted among the German adult population in June 2018 (see [3] for more details). In nine repetitions of the experiment, participants were presented three choice cards, i.e., combinations of one level per attribute, and asked to select the choice card they considered most attractive or alternatively the "none"-option. Four mean-centered covariates were included in the model: Likert-type items "Digital farming technologies alienate the farmer from his/her soil and animals" and "Family farming structures seem valuable and should be preserved" as well as scores of spontaneous associations with images of a large autonomous tractor and a swarm of small robots, respectively, during field work. These covariates are expected to provide an emotional dimension to the experiment, adding to its socioeconomic and technology-focused evaluation [5]. The Likert-type items are each measured on 5-point Likert-type scales (from 1 = "fully disagree" to 5 = "fully agree") and correspond to the concern identified in the farmer survey [4] and the disagreement between society's romanticized view of agriculture and the actual level of technology use on farms in Germany [6], respectively. The image association scores are measured on a scale from −3 to +3, with scores given depending on the entered associations being rated negative (−1), neutral or empty (0), or positive (+1) (cf. [3]). Three associations per image were possible. These two covariates permit a comparison of spontaneously formed image associations with stated choice preferences, which allows a comparison of implicit and explicit associations with different methods of crop protection (cf. [7]). The results of the model are presented as theta-weights, which indicate by how much the part-worth utility of an attribute level changes if a participant evaluates a given covariate better or worse than the sample average.

3. Results

Participants in the experiment considered the method of weed management more important (46%) than changes in the end product price (32%). The tractor type is considered least important (22%). The evaluation of a given product combination is thus predominantly guided by the method of weed management. The sample-average part-worth utilities for each attribute level may be found in Table 1 (column "Constant"). The further columns provide the respective theta-weights for each covariate and attribute level. The overall fit of the model is good (RLH = 0.63).

Table 1. Theta-coefficients of covariates in HB-estimation.

Attribute/Level		Constant	Family Farms Worth Preserving	Farmer Alienation from Soil/Animals	Image of Large Tractor	Image of Swarm Robots
Weed Mngmt	Conventional [H]	−1.530 *	−0.314 *	0.053	0.145 *	−0.173 *
	Spot-Spraying [H]	−0.018	−0.163 *	−0.138 *	0.125 *	0.038
	Hoeing	1.548 *	0.477 *	0.085	−0.270 *	0.136
Tractor Type	Conventional	0.138 *	−0.014	0.150 *	−0.139 *	−0.243 *
	Autonomous	0.088 *	0.002	−0.046	0.052	0.013
	Small Swarm Robots	−0.226 *	0.012	−0.103 *	0.086 *	0.230
Price Increase	None	0.734 *	−0.265 *	−0.196 *	−0.014	−0.014
	Moderate	0.325 *	0.097	−0.027	0.062	0.029
	Strong	−1.058 *	0.167 *	0.223 *	−0.048	−0.015
NONE		−1.169 *	−0.613 *	0.081	−0.395 *	−0.242

Mean root likelihood (RLH): 0.63; [H] herbicide-based method; * significant at 90% confidence level, 2-sided test.

The importance of the weed management attribute breaks down into significant rejection of conventional spraying and preference for hoeing at the sample-level. Spot-spraying, a method using reduced amounts of herbicides, ranks between the two in terms of utility provided, presenting a possible compromise. The rejection of conventional spraying increases among those considering family farming structures important or positively evaluating the image of swarm robots. Those viewing images of large autonomous tractors positively, on the other hand, draw greater utility from conventional spraying than the

sample average. For hoeing, these trends reverse for proponents of family farms and large autonomous tractors. The compromised solution of spot-spraying is rejected significantly by family-farm proponents and those agreeing that digitalization alienates farmers from their soils and animals. Conversely, supporters of large-scale tractors based on image associations also draw above-average utility from spot-spraying.

Regarding the tractor type, the sample draws most utility from conventional tractors, while in comparison finding large autonomous tractors acceptable and favoring swarm robots the least. This evaluation is even more pronounced in those participants who see digitalization as a reason for farmer alienation. Conversely, those evaluating images of large autonomous tractors and swarm robots positively reject conventional tractors at an above-average rate. Those scoring positive on image associations with the large autonomous tractor also rate swarm robots significantly more positively, but not autonomous tractors. A similar trend cannot be observed for positive associations with the image of swarm robots.

The price increase attribute indicates that the sample draws the most utility from no price change but also finds moderate price changes acceptable compared to strong price changes. Strong price changes are rejected. Those individuals agreeing that family farms are worth preserving or that digitalization leads to alienation, however, indicate clearly lower utility from no price change and higher utility from strong price change than the sample average. The image evaluations have no significant impact on the part-worth utilities for this attribute. The "none"-option's negative part-worth utility indicates that participants saw more value in choosing a choice card than the "none"-option. This effect is even more pronounced for those valuing family farms highly or having positive associations with the image of a large autonomous tractor.

4. Discussion and Conclusions

The results of this discrete choice experiment indicate that not all emotion-related items in the model equally impact the evaluation of digital farming technologies. Preferences for family farming structures are associated with the rejection of herbicide-based weed management methods and a greater willingness to accept higher prices. Agreement that digitalization leads to farmer alienation is consequently associated with the rejection of technologies, such as spot-spraying and swarm robots, as well as an above-average preference for conventional tractors. This group also indicates a greater willingness to accept higher prices. The spontaneous image associations match the stated preferences only to a certain degree: Participants with positive image associations tend to reject conventional tractors. However, only those with positive views on large autonomous tractors draw greater utility from swarm robots, which is inconsistent. Positive associations with large autonomous tractors are further linked to increased utility from herbicide-based methods of weed control and reduced utility from hoeing. Those indicating positive associations with swarm robots only indicate decreased utility from conventional spraying.

The inconsistency between image associations and part-worth utilities in the tractor type corresponds to previously found discrepancies between implicit and explicit evaluations [7] and may indicate that participants are driven more by a rejection of the conventional tractor rather than a clear preference for an alternative. Conversely, the type of alternative viewed positively does seem to correlate with participants' opinions on weed management. Those rating the image of swarm robots positively strongly reject conventional spraying, sharing the average sample's preference for precision agriculture methods, such as spot-spraying and automatic hoeing. Yet, participants rating the image of large autonomous tractors positively support herbicide use, as they draw decreased utility, relative to the whole sample, only from hoeing. More thorough investigation of underlying motives behind such relationships may provide a better understanding of these groups in society. The relationship between Likert-type items and part-worth utilities indicates that hesitancy towards certain aspects of digital farming tools may be due to misconceptions. For example, proponents of family farm structures reject herbicide-based measures. It is possible that they are also proponents of organic farming, a variable not included in the

present model. Organic farming and family farming, however, are not synonymous, so this insight may be used to address clearly the differences between the two and explain the utility of different methods of weed management when informing the public. Similarly, those fearing alienation through digitalization project this specifically on spot-spraying and swarm robots. However, precision tools, such as spot-spraying, may provide the farmer with data of his/her soils. Similarly, swarm robots, while physically removing the farmer from the field, can also collect valuable information otherwise inaccessible to the farmer, thus leading to better knowledge about rather than alienation from his/her fields. These aspects should also be communicated to the public to avoid rejection of helpful technologies due to misunderstandings and to reduce the already existing gap between agricultural reality and society's image thereof (cf. [6]).

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