Peer-reviewed version available at *Sustainability* **2017**, *9*, 1805; doi:10.3390/su9101805

Article

Determinants of the acceptance of sustainable production strategies in conventional and organic dairying in Europe: an empirical analysis

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Abstract: The goal of the study was to assess the farmers' acceptance of three sustainable production strategies, namely 'Agro-forestry', 'Alternative protein source' and 'Prolonged maternal feeding'. Data on the acceptance of these strategies were collected by a survey of dairy farmers in six EU countries (AT, BE, DK, FI, IT, UK). An extended version of the Technology Acceptance Model (TAM) was applied by means of Structural Equation Modelling to testing various hypotheses on attitudes and intentions of dairy farmers towards these novel production strategies, as well as the influence of organic practices and collaborative behaviours along the supply chain. We found that the most preferred strategy - across all countries - was soy substitution by alternative protein sources. We also found that the intention to adopt a sustainable production strategy may derive from the influence of opinions (and behaviours) of relevant others, showing the role of interactions among farmers and other stakeholders in the adoption of innovations. Finally, the perceived usefulness of all investigated strategies is higher for organic farmers, while collaborative patterns reduce the impact of subjective norm on usefulness and overall acceptance. Our findings should encourage policy makers to consider the important role of supply chain management practices, including collaboration, to enhance the sustainability of dairy farming systems.

Keywords: dairy farming; sustainability; organic farming; technology acceptance model; structural Equation Modeling

1. Introduction

Research into the acceptance of innovations in the last two decades has yielded many competing models. The majority of these models focus on acceptance to consumers rather than farmers. The Theory of Reasoned Action (TRA), proposed by Fishbein and Ajzen [1] and extended by Fishbein [2], informs all the technology acceptance models. This suggests that only a small number of variables can explain the individual's intention to perform a behaviour. A person's attitude towards objects/products and subjective norms determine the person's behavioural intention and will result in actual behaviour. Three very important basic models dealing with the acceptance of innovations exist in literature, from which all the others evolved: the Technology Acceptance Model (TAM), developed by Davis in 1989 [3] and applied to evaluating the determinants of potential consumer acceptance towards computer usage and the information technology; the Theory of Planned Behaviour (TPB), proposed in 1991 by Ajzen [4] applied to information technology use and extended by Taylor and Todd in 1995 [5]; and finally, Venkatesh and colleagues, extending beyond the well-known TAM, built the Unified Theory of Acceptance and Use of Technology (UTAUT) model in 2003 [6]. A full account of the vast theoretical and empirical literature based on the extension of the TAM basic model for the acceptance of innovations is beyond the scope of this paper. We refer the interested reader to the systematic review by Venkatesh et al. [6], as well to Kings and He's [7] and Li and Shu's [8] meta-analyses. In recent years these models have been applied to many innovation research topics, including new food and new food technologies and their acceptance to consumers and other stakeholders.

In this paper we present the results of the assessment of the acceptance of three sustainable production strategies among dairy farmers.

The objective of our study was to assess the acceptance of these strategies and its determinants, in order to inform relevant extension and other policies. Data were collected in six different EU countries: Austria, Belgium, Denmark, Finland, Italy and UK (England and Wales).

This paper is organised in three sections. In the first section the three selected sustainable production strategies are described, together with the model and hypotheses used for the analysis, the survey instrument, the data collection, and the measurements and constructs used. The second section on results reports the main findings of the farmers' survey with respect to the three novel production strategies proposed. The third section draws together the results and attempts some preliminary conclusions on the farmers' acceptance of the sustainable production strategies proposed.

2. Materials and Methods

2.1. Methodology

The three strategies have been selected, after preliminary qualitative research reported elsewhere [9][10], as potential innovative solutions to increase the competitiveness and sustainability of organic and low-input dairy supply chains.

The following three strategies were selected after extensive qualitative preliminary research and stakeholder involvement:

- Agro-forestry – Integration of cows and trees on the same plot of land
- Alternative protein source – Use of home- grown protein crops, such as lupins, beans and peas, as animal feed
- Prolonged maternal feeding – The calves and lambs can suckle directly from their mothers (or a foster mother) for the first 3-5 months after they are born.

All the sustainable strategies were presented to the respondents in a common format, in terms of strengths and weaknesses, threats and opportunities by looking at Social, Technological, Environmental, Animal Welfare, Economics and Policy arguments. The specific statements used in the survey are reported in the Appendix.

Our model is presented in Figure 1.

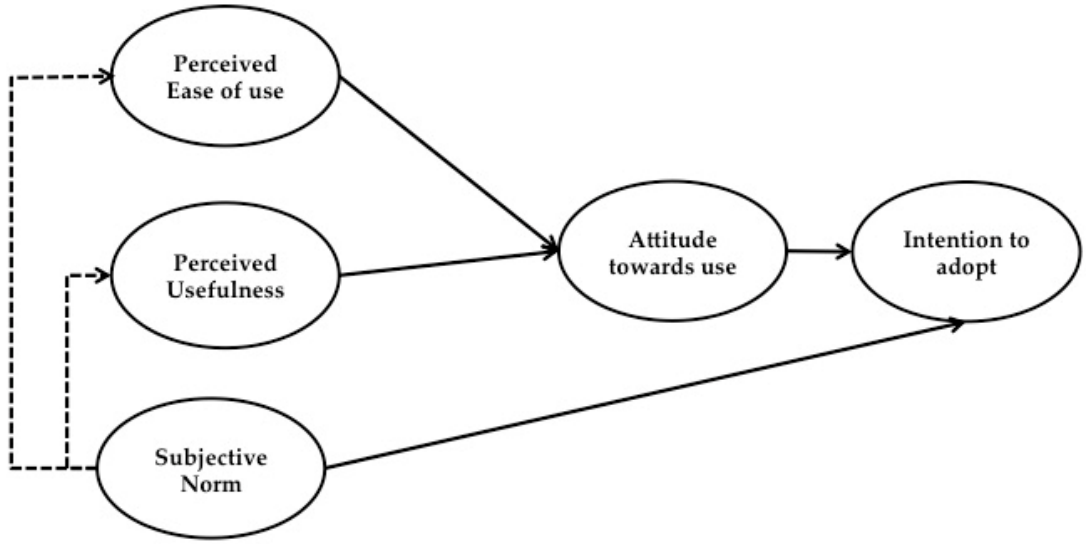

Figure 1 Supply chain innovation acceptance model used in the this survey – Modified TAM model

Five constructs were included in the model and questionnaire (Table 1): attitude towards use (3 items: [11], [12], [13]), perceived ease of use (3 items: [3], [14], [15], [16], [6]), perceived usefulness (4 items: [17], [3], [15]), subjective norm (3 items: [3], [6]), and intention to adopt (2 items: [18], [6]).

Davis' Technology Acceptance Model (TAM) was the starting point, since TAM is the most widely applied model focusing on how a technology affects individual perception and, ultimately, adoption of an innovation [6]. As suggested by Davis in further paper [19], attitude towards use was included as an "affective" antecedent to behaviour. Attitude, as an antecedent of intention and behaviour in the PCB model, was also inserted in other models of innovation acceptance, often in substitution (or as synonym) of intention [20]. Further, Taylor and Todd [5] have provided an integration of TAM with some elements of the Theory of Planned Behaviour. Our model is a slightly modified version of the latter model since only stated (intention) and not actual use (behaviour) was observed. For farmers, attitude towards a sustainable production strategy is considered a critical variable in the adoption decision process, especially in the case of organic farming [21], [22], [23].

All scale items were measured using a 7-point Likert scale (from 1 = ''strongly disagree'' to 7 = ''strongly agree''). Sumatupang and Sridharan's collaboration index on information sharing [24] – as simplified and applied to farmers by Naspetti et al. [25] – was measured on a 3-point scale (from 1=never to 3=often). The collaboration index was composed of three items. Each item was measured both upstream (collaboration with suppliers) and downstream (collaboration with customers).

Table 1 Definition of the multi-item constructs

CONSTRUCT	DEFINITION	ITEM CODE	ITEM WORDING
Attitude towards Use	A farmer's positive or negative feeling associated with the adoption of the production strategy	AA1	I think that the adoption of such a production strategy in the dairy supply chain would be acceptable for my company.
		AA2	All things considered, I think that adopting this production strategy in the dairy supply chain is not a good idea. (*)
		AA3	I think that the adoption of such a production strategy in the dairy supply chain would be wise.
Perceived Ease of Use	The extent to which a farmer believes that using a particular production strategy would be free of effort	PEOU1	I think that the adoption of this production strategy in the dairy supply chain would require a substantial restructuring of supply chain activities and processes. (*)
		PEOU2	I think that the adoption of such a production strategy in the dairy supply chain would not demand much work.
		PEOU3	All things considered, I think that the adoption of such a production strategy in the dairy supply chain would require a large effort in training and advice. (*)
Perceived Usefulness	The extent to which a farmer believes that using a particular production strategy will enhance her farm performance.	PU1	I think that the adoption of this production strategy in the dairy supply chain would improve the profitability of my company.
		PU2	All things considered, I think that the adoption of such a production strategy in the dairy supply chain would not prove useful for my company. (*)
		PU3	I think that the adoption of this production strategy in the dairy supply chain would be advantageous for my company.
	Perceived Financial Cost Tung et al 2008	PU4	I think that the adoption of such a production strategy in the dairy supply chain would be too costly for my company.
Subjective Norm	A person perception of relevant opinions on wether to adopt the production strategy in the SC	SN1	I think that leading companies in the industry would favour the adoption of this production strategy in the dairy supply chain.
		SN2	I think that most people who are important to my company would favour the adoption of such a production strategy in the dairy supply chain.
		SN3	If it were widespread, I think that my company would favour the adoption of such a production strategy in the dairy

			supply chain.
Intention To Adopt	A person intention to adopt the production strategy	IA1	All things considered, my company would be very unlikely to adopt this production strategy. (*)
		IA2	I think that my company would adopt this production strategy.
Collaboration Index	Thinking about your own company, how often do you collaborate with your Customer(1)/ Supplier(2) on the following issues?	CI1.1 CI2.1	Information sharing on innovation policy
		CI1.2 CI2.2	Information sharing on certification issues
		CI1.3 CI2.3	Information sharing on product quality

*Denotes a reverse-scored item.

The list of the hypotheses (H) formulated is reported in Table 2.

Table 2 Hypotheses

	DEFINITION
H1	Dairy farmers' attitude towards a sustainable production strategy is positively associated with their intention to adopt it.
H2	The more that a dairy farmer perceives a novel production strategy as useful, the more favourable is that farmer's attitude towards its adoption.
H3	The more a dairy farmer perceives a novel production strategy as easy to use, the more favourable is that farmer's attitude towards its adoption.
H4	The more that a dairy farmer perceives a novel production strategy as easy to use, the more that farmer will perceive that novel strategy as useful.
H5	The more that a dairy farmer perceives the influence of social and peer pressure to be favourable, the more favourable that farmer is towards the adoption of sustainable production strategies. H5.a Subjective norm is positively associated with perceived usefulness of the sustainable production strategies. H5.b Subjective norm is positively associated with perceived ease of use of the sustainable production strategies.
H6	The higher the information sharing within the supply chain the lower the effect of subjective norm on farmer's acceptance of a sustainable production strategy.
H7	Perceived ease of use associated to the sustainable production strategies is higher for organic farmers.
H8	Perceived usefulness of the sustainable production strategies is higher for organic farmers.

The original TAM model involved two primary predictors – *perceived ease of use* (PEOU) and *perceived usefulness* (PU) – as direct explanatory variables for behavioural intention. In our model – following Rezaei-Moghaddam and Salehi [26] – we preferred to explore the inclusion of *attitude towards use* as mediating between the *perceived ease of use* and *perceived usefulness* latent variables and *intention* (see H1, H2 and H3).

According to Davis [3], an individual adopts a (new) technology primarily because it is useful, rather than because it is easy to use. Indeed, in prior empirical TAM studies, *perceived ease of use* is found to exhibit: (a) a direct effect on behavioural intentions or attitudes lower than *perceived usefulness*; (b) an indirect effect by being one antecedent of *perceived usefulness* itself. In other words, *perceived usefulness* partially mediates the effect of *perceived ease of use* . Users tend to downsize the difficulties in using an innovation if the benefits of its usage are substantial (see H4). In our case, *subjective norm* can be defined as a subjective perception of social pressure to accept or not a sustainable production strategy in dairying. The opinion of other relevant people or institutions (fellow farmers, other supply chain members, advisers, family members, media, etc.) may influence the behaviour or, subordinately, its antecedents (see H5).

The decision to adopt a new technology or a novel production strategy is related to the amount of knowledge one has regarding how to use that technology appropriately [27]. Besides, organic farming systems are 'information intensive' and the availability of information is particularly relevant for 'knowledge-based' innovative production strategies [23]. When information is not available, people tend to rely on other people's opinions and experience, which are broadly referred to as *subjective norms*. Indeed, experience enhances knowledge and information [28][29] and information should moderate the effect of subjective norms on the acceptance of an innovation and in its adoption process (see H6).

Furthermore, organic farmers are often more educated and more open to innovations aiming at enhancing the sustainability of the whole farm [23][30]. We postulate that this could have an effect on any of the 'cognitive variables' of the original Davis' model (usefulness and ease of use), see H7 and H8.

2.2 Description of the Questionnaire

A four-section questionnaire was developed. The first section was aimed to elicit basic information about the respondents' role in dairy farming and eligibility to answer the survey. The second section included the description of the production strategies (1: Agro-forestry, 2: Alternative protein source, 3: Prolonged maternal feeding) and 15 itemized questions relative to the 5 constructs included in our model. During the administration of the questionnaire, the three production strategies were proposed in a randomised order; all the items, except the two measuring behavioural intention, were also randomised. At the end of the question related to each innovation, an open question was added to collect the respondent's opinions about the production strategy previously shown. At the end of this whole section, respondents were asked to rank (1st-2nd-3rd) the three production strategies according to their preferences. The third section dealt with socio-economic information about the respondents: legal status, number of full time employees, organic certification and first year of organic production, heads of cattle, sheep and goats. The last section addressed the assessment of the level of direct upstream and downstream collaboration within the farmers' supply chain. The original questionnaire was written in English and translated in the other languages by relevant partners. Back-translation was used to check that the original sense of each question was not lost in translation. Extensive crosschecking, editing and pre-testing were conducted before sending out the final questionnaire.

2.3 Data Collection

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The survey was administered to a convenience sample of organic and low-input dairy farmers (including those who had on-farm processing) in 6 EU countries (AT, BE, DK, FI, IT, UK). We used an online questionnaire platform (Qualtrics) to administer the survey, which was emailed to lists of dairy farmers and to dairy farmers associations. In UK, in addition to emailing the survey to a list of contacts and industry bodies, responses were collected by personal interviews using the same platform to input data (CAPI). In all countries, various email reminders were sent and computer assisted telephone interviews were conducted in some cases. In total, 193 farmers completed the survey (Table 3). Respondents were offered the opportunity to receive the survey results as a small benefit for their participation.

Table 3 Description of the sample

Country	AT	BE	DK	FI	IT	UK	TOTAL
N° questionnaires	7	40	19	35	47	45	193
Dairy Farmers	4	38	17	35	28	39	161
On-farm Dairy Processors	3	2	2	0	19	6	32

2.4 Measurement and construct validation

All measures for the study constructs were drawn from previous literature on acceptance models for innovations, but were adapted to the specific application of the acceptance of sustainable production strategies in the dairy system. The measures, definition, their reference sources and scale items have been shown in Table 1.

The measurement scales were pre-tested by experts in the dairy sector. Minor modifications were made, based on the comments collected throughout the pre-test. For parsimony in administration of the questionnaire, many constructs were just identified. In any case, a confirmatory factor analysis (CFA) was conducted on multi-item scales (attitude towards use, perceived ease of use, perceived usefulness, and subjective norm). All 13 items were retained. The final measurement model had close fit (χ^2 = 187.31, degrees of freedom [*df*]=80, p <0.001; Root Mean Square Error of Approximation [RMSEA] = 0.042, [C.I. 90%: 0.04-0.058]; Standardized Root Mean Square Residual [SRMSR] = 0.040).

Measurement reliability and validity were evaluated. Cronbach's alpha provided strong evidence of measurement reliability for all variables, except perceived ease of use, which exhibited a value just below 0.70 (see Table 5 for measurement properties). This latter value is just above the average reported in other studies but well above the minimum value of 0.63 [7].

Convergent validity is supported by the high and significant standardized loadings for the measures [31]. The loadings of the perceived ease of use variable were significant and, though not high, all above the 0.50 threshold. Multiple-group measurement invariance was tested for the organic vs. conventional grouping and for each novel production strategy. The model exhibited close fit for configural invariance (RMSEA = 0.49 [C.I. 90%: 0.039-0.059]) and construct-level metric (equal factor loadings: RMSEA = 0.50 [C.I. 90%: 0.041-0.059]) across the organic and conventional groups. Testing invariance across the different novel production strategies yielded good fit for configural invariance (RMSEA = 0.57 [C.I. 90%: 0.047-0.067]), while construct-level metric invariance was rejected.

Table 4 Constructs

CONSTRUCT	Standard Loading	Mean	S.D.	Cronbach's alpha
Attitude towards use (AA)				0.90
AA1	0.93***	4.13	1.89	
AA2 (-)	0.93***	4.08	1.88	
AA3	0.75***	4.12	1.94	
Perceived ease of use (PEOU)				0.67
PEOU1 (-)	0.59***	3.52	1.64	
PEOU2	0.79***	3.04	1.56	
PEOU3(-)	0.50***	3.17	1.52	
Perceived Usefulness (PU)				0.91
PU1	0.95***	3.81	1.82	
PU2 (-)	0.82***	3.89	1.93	
PU3	0.89***	3.56	1.76	
PU4	0.78***	3.48	1.74	
Subjective Norm (SN)				0.84
SN1	0.87***	4.08	1.75	
SN2	0.83***	3.92	1.68	
SN3	0.68***	3.57	1.59	
Intention To Adopt (IA)				0.90
IA1 (-)	0.95***	3.67	1.94	
IA2	0.86***	3.85	2.02	
Collaboration Index (CI)				0.80
CI1.1	0.84***	1.83	0.70	
CI1.2	0.78***	1.96	0.74	
CI1.3	0.75***	2.43	0.68	
CI2.1	0.83***	1.90	0.63	
CI2.2	0.80***	1.93	0.65	
CI2.3	0.76***	2.25	0.70	

*** P<0.001

3. Results

3.1. Acceptance of Innovative Production Strategies

The analysis of the 193 completed survey shows that the production strategy 'Alternative Protein Source' is broadly the most preferred and was ranked first by 147 out of 193 respondents (76%). The other two production strategies were less favoured: 'Agroforestry' was ranked first by only 26 out of 193 (13%) and 'Prolonged Maternal Feeding' was the least preferred innovation (10%: 20 out of 193 ranked it first). Using rank-weighted scores (=rank x respondent choosing that rank), it is clear that 'Agroforestry' and 'Prolonged Maternal Feeding' score are equal and well above the preferred strategy (the lowest the score the most preferred the strategy is: see Table 4).

Table 5. Rank-weighted scores of tested sustainable strategies

	Rank-weighted score			**Sum**
Agroforestry	26	146	282	**454**
Alternative Proteins	147	68	36	**251**
Prolonged Maternal Feeding	20	172	261	**453**

3.2. Attitude Towards the Use of Novel Production Strategies

After having read the information card on the specific production strategy, respondents were asked to rank 15 statements for five different constructs in a 7-point Likert Scale. Among these constructs, respondents were asked to rate 3 statements to assess their attitude towards the use of new production strategies (AA). The average value of the attitude towards use scale was relatively high for the 'Alternative Protein Source' strategy (M=5.22, SD=1.19) and was in each country above the mid-point of 4, meaning that in each country the supply chain members have a positive feeling associated with the adoption of the production strategy in the supply chain. The mean values for the other production strategies were lower: 'Agroforestry' (M=3.62, SD=1.68) and 'Prolonged maternal feeding' (M=3.47, SD=1.75). Values around a mean of 3 (add st. dev.) indicate that the majority has a negative feeling associated with the adoption of the production strategy in the supply chain (e.g. 3 value in the Likert Scale adopted is equal to "Somewhat Disagree"). An Hotelling's T-squared test was performed to determine if the average attitude was different among the strategies. We reject the null hypothesis of equal means, $F(2,192)=98.79$, $p=.000$, Hotelling $T^2=198.61$). However, as expected from the previous results on rankings, we cannot reject the equality of equal mean attitude towards 'Agroforestry' and 'Prolonged maternal feeding', $F(1,192)=1.35$, $p=.25$).

3.3. Intention to adopt novel production strategies

Respondents were also asked to rank in a 7-point Likert Scale two questions on their intention to adopt each of the production strategies. The intention to adopt (IA) scale confirms a relatively high mean value for the 'Alternative Protein Source' strategy (M=4.92, SD=1.54), meaning that in each country the majority would adopt this production strategy. The mean values for 'Prolonged Maternal Feeding' (M=3.14, SD=1.86) and 'Agroforestry' M=3.19, SD=1.69) are significantly lower: $F(2,191)=69.88$, $p=.000$, Hotelling $T^2=140.48$. However, we cannot reject the equality of equal mean intention to adopt of 'Agroforestry' and 'Prolonged maternal feeding', $F(1,192)=0.11$, $p=.739$).

3.4. Information sharing along the supply chain

Figure 2 reports the results of the level of information sharing along the supply chain by country and dimension of collaboration. The scale range from 1='Never' to 2='Sometimes' and 3="Often", indicating how often the respondents declare to collaborate respectively with suppliers and customers on each dimension (Innovation Policy, Certification Issues, Product Quality). The sub-scale Information sharing on Product Quality has the highest value (M=2.34, SD=0.55), meaning that this form of collaboration occurs, on average, more than 'Sometimes'. The information sharing on Certification Issues (M=1.95, SD=0.61) and on Innovation Policy (M=1.87, SD=0.57), on average occurs less often. The difference with Product Quality is significant, F(2,188)=97.77, p=.000, Hotelling T^2=196.57, p=.000, but we cannot reject the equality of the average level of collaboration on Innovation Policy and Certification Issues, F(1,189)=3.14, p=.078.

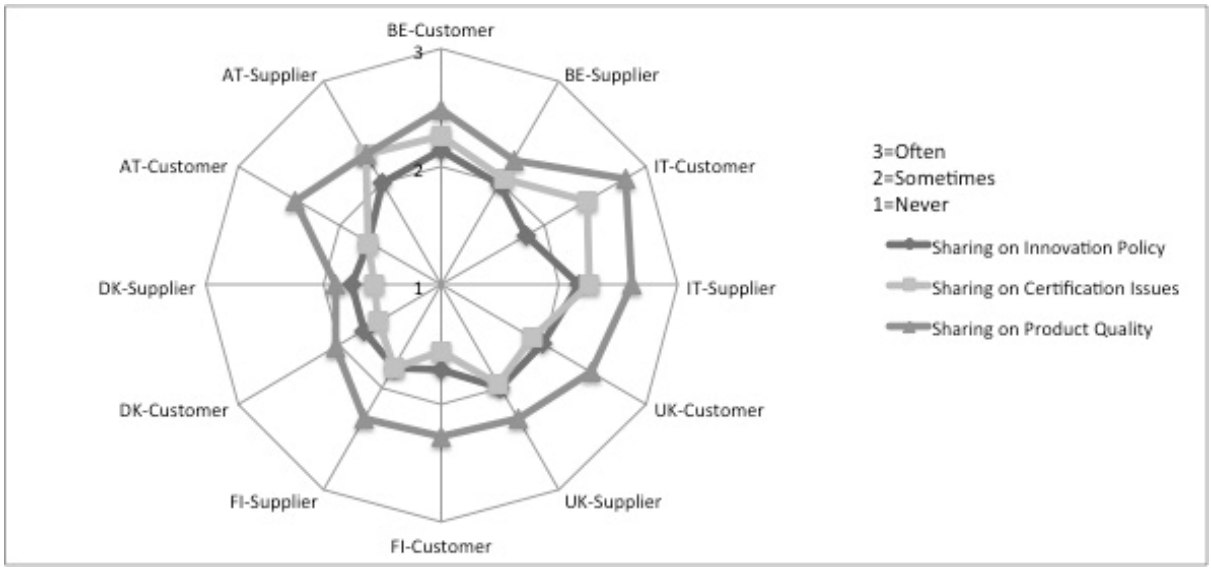

Figure 2 Information sharing with customers and suppliers: item results

3.5. Structural equation modelling (SEM) analysis

For this analysis a sample of 190 complete responses from farmers could be used for which we had no missing data on the measurement variables. Each farmer rated three strategies, so the number of observations available for the model for dairy farmers was 570. Given that the multi-item latent variables were measured by ordered categorical indicators, inspection of the data suggested an estimation method robust to departure to non-normality. Following Finney and Di Stefano [32], we used a Satorra-Bentler scaling of the variables with ML estimation. The original model included only the solid arrow paths: subjective norm impacting only on intention to adopt, as in the Taylor and Todd's [5] model. There was a poor fit between this model and the observed data (χ^2 = 668.80, degrees of freedom [df]=85, p<0.001; Root Mean Square Error of Approximation [RMSEA] = 0.11, [C.I. 90%: 0.102-0.118]; CFI = 0.84; Standardized Root Mean Square Residual [SRMSR] = 0.31).

Modification indices and residuals suggested that the fit could be improved. In modifying the model, the exploratory, post-hoc model-fitting strategy proposed by Byrne [33] was followed: each parameter/path was separately incorporated into or deleted from the model, and subsequently tested. Only significantly different modifications were retained. The choice of each parameter/path to incorporate or delete was based on theoretical and statistical considerations.

This sequential procedure led to incorporating first a path between subjective norm and perceived usefulness. The fit improved substantially (χ^2 = 194.92, degrees of freedom [df]=42, p <0.001; Root Mean Square Error of Approximation [RMSEA] = 0.049, [C.I. 90%: 0.040-0.057]; CFI = 0.97; Standardized Root Mean Square Residual [SRMSR] = 0.40). Unfortunately, in this model the paths

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from Perceived usefulness and Perceived ease of use and Attitude were non-significant as was the path leading from attitude to Intention to adopt. Since we found a model where Intention is simply caused by Subjective Norm not very informative, we explored modification indices for further improvements.

This led to adding another path from Subjective Norm to Perceived ease of use. This model did not fit the data significantly better (χ^2 = 194.46, degrees of freedom [*df*]=83, p <0.001; Root Mean Square Error of Approximation [RMSEA] = 0.049, [C.I. 90%: 0.040-0.057]; CFI = 0.97; Standardized Root Mean Square Residual [SRMSR] = 0.40). There was no further improvement possible from modification indices, so we explored our structure for theoretical simplifications. Since paths from/to Attitude were still not significant, we decided to drop this variable. Indeed, in most TAM-related literature this variable is often either a proxy of Intention or, when Intention is included, left out. Indeed, from a theoretical point of view, we believed there was some merit to having both into the model, Attitude and Intention being separate constructs in the TPB model.

The new model fit the data slightly worse (χ^2 = 120.92, degrees of freedom [*df*]=48, p<0.001; Root Mean Square Error of Approximation [RMSEA] = 0.052, [C.I. 90%: 0.040-0.063]; CFI = 0.97; Standardized Root Mean Square Residual [SRMSR] = 0.41). However, there was a significant path going from Subjective Norm to Perceived Usefulness to Intention to Adopt. Perceived Ease of Use had no outgoing significant paths (neither to perceived usefulness nor to intention), while it was caused by Subjective Norm. The exclusion of this variable led to our next model, which finally exhibited a close fit. For the sake of parsimony, since the path from Subjective Norm to Intention was not significant, it was removed to get our final model, reported in Figure 3.

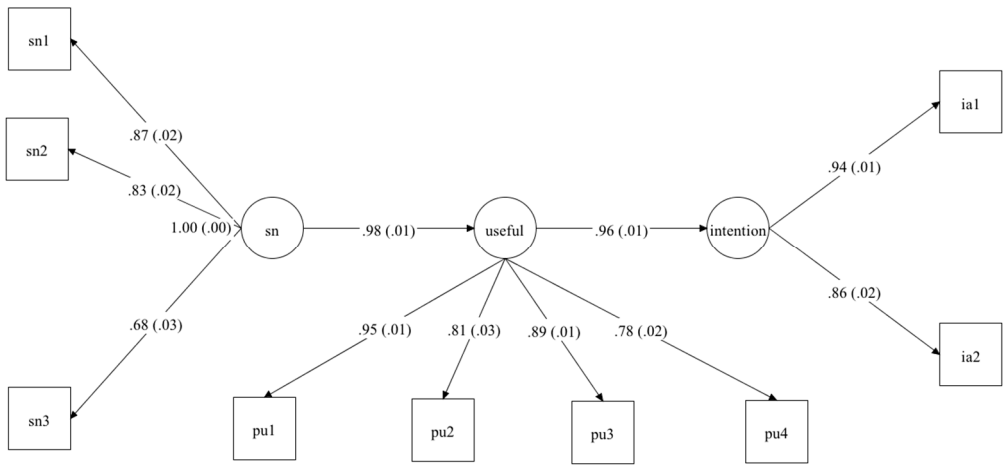

Figure 3. Final estimated model. Standardized parameter estimates are shown with associated standard errors in parentheses. (In circles the following latent variables: Sn=Social Norm; useful=Perceived Usefulness; intention=Intention to adopt; in squares the measured items)

The final results indicate a close fit between the model and the data (χ^2 = 50.64, degrees of freedom [*df*]=25, p <0.001; Root Mean Square Error of Approximation [RMSEA] = 0.042, [C.I. 90%: 0.025-0.059]; CFI = 0.99; Standardized Root Mean Square Residual [SRMSR] = 0.02). The model provides good insights on the adoption of novel production strategies by dairy farmers. Given we dropped attitude towards use in the final model, Hypotheses 1 to 3 were not supported. Hypothesis 2 was partially supported in the sense that perceived usefulness appears as the only driver of adoption, albeit – as we have seen – the model does not support a mediation role for attitude towards use.

The cognitive aspect prevails, confirming the importance of perceived usefulness as a predictive variable of intention. The findings do not contrast with the original findings of Davis [3] or those of Taylor and Todd [5]. They also found all path coefficients in the model significant with the exception of the paths from Ease Of Use to Attitude and Attitude to Behavioural Intention. Similar results are reported in Adrian et al. [34], though their model in general had a quite poor fit. This finding indicates that dairy farmers, when they intend to adopt a new production strategy, do so primarily because they consider it useful and believe that it will provide substantial benefits. In contrast, ease of use in our model is completely mediated and shadowed by Subjective Norm. Dairy farmers tend to consider useful what other relevant people or institutions (e.g. leading companies, other farmers, advisers, etc.) consider useful too. This finding confirms the role of Subjective Norm in influencing intentions – as hypothesised by the TPB model – but qualifies the role of Perceived Usefulness as mediator of this influence. Hypothesis 5, as specified in Hypothesis 5a, is, therefore, supported.

We conducted a post-hoc analysis in order to (a) test model invariance across organic and conventional farmers; (b) test model invariance across the three different production strategies; and (c) explore the existence of interaction between the collaboration patterns of information sharing and the explanatory variables in the model.

Multi-group analyses were conducted to cross-validate the model across different samples. Specifically, we tested for configural and metric invariance across organic and non-organic (conventional) farmers, and across the three different strategies.

The first step was to test the multi-group configural model in which no parameter constraints are specified. The second step consisted of testing for full metric invariance (invariant factor loadings, intercepts and structural regression paths). Configural invariance was found holding for both the organic and conventional samples and for each strategy ($p<0.05$). Therefore, we can conclude that the model is not farmers' group or strategy specific. Full metric invariance could be established for the organic and conventional groups ($p<0.01$), but – quite expectedly - not for the three strategies. These results suggest that while organic and conventional farmers form their intention in identical manners (that is their perceived usefulness is influenced by subjective norms to the same extent, and intentions are equally influenced by 'Perceived Usefulness'), the way constructs are measured and the strength of the path differs in relation to each production strategy.

Tests of latent means differences, besides, showed that organic farmers – on average – perceive all the three strategies as more useful and have a higher intention to adopt any of them in comparison with conventional farmers. Therefore, while Hypothesis 7 could not be tested and therefore is not supported, Hypothesis 8 (i.e. Perceived Usefulness of the sustainable production strategies is higher for organic farmers) could not be rejected. Organic farmers – on average - exhibit a higher Subjective Norm in relation to the three strategies, too. This finding means that their social environment is more favourable to these strategies than the conventional farmers' environments is.

The last analysis was performed on collaboration indexes of information sharing. In particular, we tested if information sharing was moderating the direct effect of subjective norm on Perceived Usefulness (and, indirectly, on Intention to Adopt). Since we have found that the opinion of 'relevant others' is so important in forming the supply chain members' opinions on the usefulness of a certain novel production strategy, we wanted to analyse if there were significant interactions with collaboration patterns (in terms of downstream and upstream information sharing) within the supply chain. We interacted the collaboration index/information sharing variable with Subjective Norm, and we performed the estimation not assuming normality of the interaction term.

The interaction term was statistically significant and exhibited a negative sign. This finding suggests that Hypothesis 6 is also not rejected: as collaborative efforts on information sharing increase along the supply chain, the impact of Subjective Norm on Perceived Usefulness is decreased. Farmers who share more knowledge and information on innovation certification and product quality feel less subject to the opinions of other people in forming their opinions on the usefulness of an innovation strategy.

4. Discussion and Conclusion

'Alternative protein feeding' is the sustainable production strategy that exhibits – in all countries– the highest level of acceptance. It is always ranked at first place by more than 50% of the respondents. The other two strategies are far less accepted, with 'Prolonged maternal feeding' showing the lowest level of acceptance with the notable exception of the Danish supply chain. The modelling results shows that the intention to adopt one of the three innovations is strongly influenced by the understanding of the usefulness of the innovation itself, while this understanding is strongly influenced by the opinion of 'relevant others' (fellow farmers, advisers, other supply chain members). The strong importance of usefulness in influencing the choices is also illustrated by the comments that were made by respondents (e.g. "*It is useful to reduce the costs of feed*" (IT farmer); "*Trees and cattle don't mix well*" (UK farmer). The level of information sharing within the supply chain mitigates this influence, while organic farmers – in general – exhibit a higher perception of usefulness and intention of all the three strategies, but they are even more influenced by others than conventional farmers are.

Our results make some theoretical contributions. First, we have fully tested an extended Technology Acceptance Model (TAM) model in the dairy sector.

Indeed, with respect to their application, we found that the influence of Perceived Ease of Use on Intention to Adopt and Perceived Usefulness superseded by the role of Subjective Norm in influencing the latter variable.

Furthermore, we found that differentiating between Attitude towards Use and Intention to Adopt is probably unnecessary in this context: the 'cognitive response' variable – Perceived Usefulness –seems to influence behavioural intention without needing an affective mediator.

This finding partially contradicts the view of Davis [19], where he included the attitude towards adoption as a mediator between his two original constructs (Perceived Usefulness -PU and Perceived ease of Use - PEOU) and actual adoption behaviour. However, Davis never introduced behavioural intention between attitude and behaviour. The Theory of Planned Behaviour (TPB) considers attitude as one of the influencers of the behavioural intention, which is the latent, unobservable construct that immediately precede behaviour.

However, in the TBP model, subjective norms contribute – side by side with attitudes – to influence intentions. In our empirical findings, in the context of technology decisions in the dairy sector, the role of subjective norm is a very strong antecedent of the salient belief regarding the usefulness of a production strategy.

In summary, our study confirms the validity of general TAM framework in explaining technology adoption intentions (and decisions), but also demonstrates that, in the context of sustainable novel production strategies aimed at the organic and low-input dairy sector, the individual farmer's belief is strongly influenced by those of others, specifically leading peers and other significant influencers. Further research is needed to validate our findings in other contexts, but we believe that the results of our study have theoretical implications that go beyond the specific case under observation.

Our findings also have relevant practical implications for dairy farmers, compound feed producers and retailers, dairy processors, researchers, and advisers. As stated earlier, farmers' perceptions of what other relevant people want them to do, strongly influences what farmers' perceive as useful to adopt. This may have to do with the fact that some of the production strategies tested here have not been widely tested and evaluated through research and by farmers. This is true in particular, for the two strategies that are ranked less favourably (Agroforestry and Prolonged Maternal Feeding). Under such conditions, pioneers are taking the risk for all the followers, and this may turn out very costly in dairy farming, where a large portion of the farm capital is invested in the livestock. The diffusion of innovative practices among dairy farmers – given the risks associated to investments in livestock – is probably best operationalized through 'innovation clubs', where innovation can be tested under conditions of practical farming and pioneer farmers don't feel alone.

The fact that the most preferred strategy - across all countries and roles in the dairy supply chain was soy substitution by 'Alternative proteins', may derive from the large influence of others' opinions

(and behaviours) on each individual. Many farmers stated that they have already adopted this strategy confirming that this has been more widely tested. Individual farmers consider this more useful and are more likely to adopt those novel production strategies that receive broader consensus among their peers, their advisers and the society in general.

Finally, the finding that those farmers who are better at sharing information along the supply chain (with both their customers and suppliers) are those whose opinions are less impacted by others may help understanding the role of increased collaboration. Sharing knowledge and information along the supply chain is important to speed up the adoption of novel technologies and strategies, especially those which appear less 'mainstream' in the eyes of the prospect adopters.

Sustainable production strategies, especially those applied in organic farming, need strong collaboration throughout the whole supply chain: input producers need to recognise the (novel) needs of their farming customers, while processors, distributors and finally consumers need to perceive the higher value produced by means of these more sustainable practices. In the past, organic farming, itself seen as innovation, has been an example on how sharing information and knowledge can become viral, even against strong corporate interests in the chemical input industry and against mainstream knowledge-based supply chains that were not favourable (and in many instances still are) to its diffusion (universities, research centres, advisory and extension agencies) [23].

The importance of a collaborative supply chain management is not new to the organic farming sector and was analysed in previous studies [25].

In the organic and low-input dairy supply chain, lack of home-grown or local feed is among the greatest barriers to real sustainable and safe development. Given an 'Alternative Proteins Source' strategy is prone to have implications on farm productivity, profitability as well as in milk quality, the success of this strategy hinges upon an increased collaboration among the various supply chain actors.

Our previous qualitative results indicate that 'Prolonged maternal feeding' is likely be the most appealing strategy to consumers [10], but cannot be applied with success without an increased level of information from farm to fork. The level of information about the likely impact of this strategy among dairy farmers is very low. Without consumer recognition of higher welfare standards, the payoffs of that strategy appear negative.

Finally, it is likely that agroforestry, as a sustainable alternative feed/increased welfare strategy, needs wider societal support, since the public goods produced (biodiversity, reforestation, etc.) cannot all be paid by the consumer.

Indeed, our findings should encourage policy makers to consider the important role of supply chain management practices, including collaboration, to enhance the sustainability of dairy farming systems. 'Agroforestry' and 'Prolonged maternal feeding' are somewhat more innovative strategies since have been less tested and diffused, so further research and development could bring higher benefits if they are found to allow the achievement of higher level of sustainability.

Furthermore, information needs to be freely accessible by all interested parties in order to be shared within a supply chain. Since providing information and knowledge is costly, increased public efforts in the direction of increased free access to information resources as well as increased provision of information, advisory and extension services are paramount to the adoption of sustainable production strategies in the dairy supply chain. Farmer-led research could be an effective way for researchers and the farmer together to develop sustainability of agriculture [35].

In the future, the role of information sharing practices is likely to become increasingly crucial to achieve higher levels of sustainability – in all domains: environmental, economic and social – of supply chains, even outside the agro-food sector.

Acknowledgments

The authors gratefully acknowledge the financial support of the EU Commission for the research project "Sustainable Organic and Low-Input Dairying" (EUFP7 SOLID). The views expressed here are not in any way attributable to the EU Commission but are solely the responsibility of the authors.

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APPENDIX

Information presented on the sustainable production strategies

1 Agroforestry

Agroforestry innovation in dairy production is the integration of animals (cows, sheep) and trees on the same plot of land.

Innovation strengths/opportunities:

- Enables the production of wood, forage, livestock and fruits or nuts (depending on trees chosen), on the same plot of land, which improves farm revenue.
- Increases soil and plant biodiversity and carbon sequestration and reduces soil erosion.
- Trees offer shelter to grazing animals that benefit animal welfare.

Innovation weaknesses/threats:

- High initial financial investment for the purchase of trees and ongoing management input.
- The forage value of the leaves for animal nutrition is largely unknown.
- Trees may be damaged by livestock that eat, step on or rub against them.

2 Alternative protein source

Use of home- grown protein crops, such as lupins, beans and peas, as animal feed.

Innovation strength/opportunities:

- Reduces the amount of imported soya from outside the EU, and therefore reduces the risk of GMO contamination in the European food chain.
- Cultivation of protein crops, such as field beans and peas, play a fundamental role in organic/low-input agriculture by improving soil fertility.
- Farmers can produce animal feed on farm and therefore avoid extra costs associated with third party supply, logistics, delivery and handling.

Innovation weaknesses/threats:

- Limited research available to determine the effects of alternative proteins on dairy animals' production and long-term impact on health and fertility.
- Protein content and biological value of local alternative protein crops are often lower than for soya.
- Locally home-grown alternative proteins may be insufficient to fulfil year round demand of dairy farms, therefore feed from external sources may still be required.

3 Prolonged maternal feeding

The calves and lambs can suckle directly from their mothers (or a foster mother) for the first 3-5 months after they are born.

Innovation strength/opportunities:

- Maternal feeding provides natural immunity for the animals.
- Improvement in animal welfare, as animals are allowed to exhibit natural behavior.
- Additional costs of buying milk replacer to feed the calves/lambs can be avoided.

Innovation weaknesses/threats:

- Provision is needed for changes in the housing/handling of both mother and offspring.
- Separation causes mother and offspring stress as they have had time to develop a strong social bond.

- Reduction in the amount of milk available to sell commercially during the calf/lamb suckling period.