An analysis of farmers' perceptions of the impact of technology on farm

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Abstract: *The study analyses Scottish livestock farmers' perceptions of the impact of using smart technologies on their farms. The data used in this study were collected through a large scale survey of 441 Scottish agricultural holdings in 2016, which investigated farmers' uptake of novel technologies. The analysis focusses on the factors influencing farmers' perceptions of how useful to their businesses some of the technologies applied on farm are, in this case, electronic identification (EID) reading equipment for sheep or cattle management (e.g. handheld EID tag reader or EID enabled crates and pens) and precision agriculture (management tools aimed at continuous automatic monitoring of each animal in real time recording).*

We use structural equation modelling (SEM), a statistical method used to test hypotheses and assess the strength of the causal relationships between variables, i.e., how much these variables influence one another. In our case, we use SEM to test the effect of various factors on perceptions of the impact of using technologies on the farm business. We perform model estimation with the Diagonally Weighted Least Squares method using the statistical package Lisrel 8.80.

The model has a good fit according to the measures of absolute, incremental and parsimonious fit. The model explains 62 per cent of the variance in perceptions of the impact of using technologies on the farm business. Results indicate that significant influences on the perceived impact of using technologies on the farm business include age, gender, education, profit orientation, farm labour, perceived usefulness of information on technologies, attitudes towards technological uptake, and perceived difficulty to uptake technologies.

Keywords: *technological uptake, livestock farms, electronic identification, precision agriculture, structural equation modelling*

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Introduction

During recent decades technology has progressed to support the changing requirements placed upon agriculture to intensify production to meet increasing food demand at least cost to the environment. The study of technological adoption has evolved to include the analysis of adoption determinants to understand what may influence adoption rates and the potential constraints to the adoption of innovation.

While early adoption studies focused primarily on technological innovations that increased farm productivity, more recently the focus has moved towards studies on the adoption of environmentally friendly and animal welfare technologies. There is an ever growing literature analysing technology adoption behaviour in agriculture, part of which focussing on the factors that influence it (Fairweather and Keating, 1994; Beedell and Rehman, 2000; Nuthall, 2001; Adrian et al., 2005; Toma et al., 2016).

Farmers' uptake of innovative technologies (followed by the impact the uptake has on their business) has occurred at a different pace and magnitude depending on a number of factors. These factors include socio-demographic characteristics such as age, gender, educational level, farm economic characteristics such as income and size, farmers' access to information on technological uptake, and attitudinal variables related to various aspects of technology, such as risk and suitability of the specific technologies to farm circumstances (Beedell and Rehman, 2000; Nuthall, 2001; Toma et al., 2016).

This study analyses Scottish livestock farmers' perceptions of the impact of using smart technologies on their farms. The analysis focusses on the factors influencing farmers' perceptions of how useful to their businesses some of the technologies applied on farm are, i.e. whether applying them has led to changes to their business. The technologies considered are electronic identification (EID) reading equipment for sheep or cattle management (e.g. handheld EID tag reader or EID enabled crates and pens) and precision agriculture (management tools aimed at continuous automatic monitoring of each animal in real time recording). The study contributes to the literature on the analysis of determinants of technological uptake and tests the impact of age, gender, education, information access, attitudes and perceptions about technological uptake in general and more specifically regarding the suitability to/difficulty to uptake, on not just uptake but its perceived impact on business.

We use data collected through a large scale survey of 441 Scottish agricultural holdings in 2016, which investigated farmers' uptake of novel technologies, and structural equation modelling (SEM), a statistical method used to test hypotheses and assess the strength of the causal relationships between variables, i.e. how much these variables influence one another. In our case, we use SEM to test the effect of various factors on perceptions of the impact of using technologies on the farm business.

Method and data

Conceptual model

Based on a review of the literature and expert opinion, we built and tested a conceptual model (Figure 1). The model consists of causal relationships between the main variable, perceptions of the impact of using smart technologies on-farm, and potential determinants previously identified in the literature, namely socio-demographic variables (age, gender, educational level), profit orientation, farm labour, perceived usefulness of information on technologies, attitudes towards technological uptake, and perceived difficulty to uptake technologies.

As in most behavioural analyses, the conceptual model includes direct and indirect relationships between the influencing variables and the variable of interest. Socio-demographic, economic and information related variables will influence perceptions of the impact of using smart technologies on-farm either directly or indirectly through attitudes towards technological uptake or perceptions about the difficulty to uptake technologies on farm. This is consistent with the type of relationships identified in the literature (Toma et al., 2016).

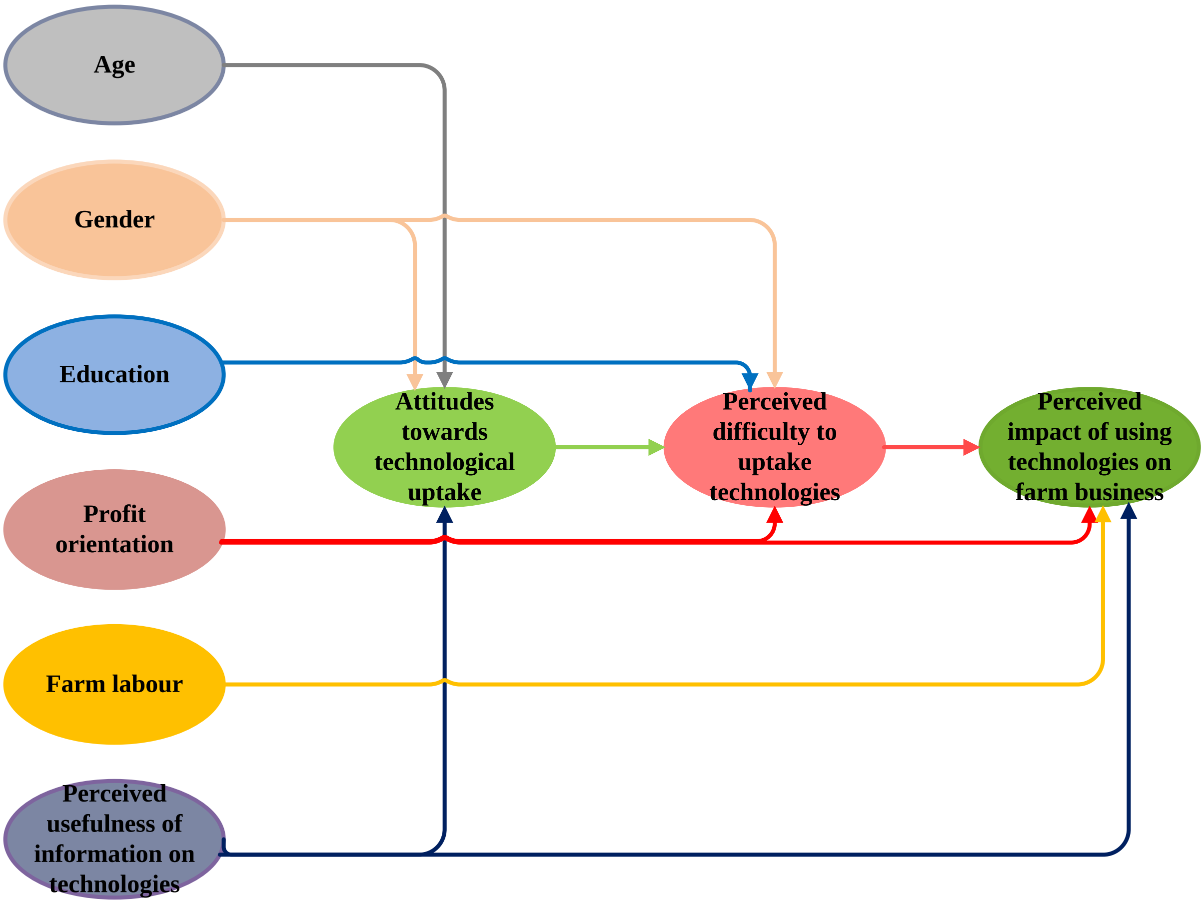

Figure 1. Conceptual model

Data

The data used in this study were collected through a large scale survey of 441 Scottish agricultural holdings in 2016, which investigated livestock farmers' uptake of novel technologies.

The part of the questionnaire used in this analysis and consistent with the aim of testing the relationships outlined in the conceptual model include close-ended questions on the following: socio-economic characteristics (gender, age, education, profit orientation, number of employees); perceived usefulness of technology information sources (open days, monitor/ demonstration activities, meetings with other farmers, trade press, internet, agricultural consultants, government information sources, representatives of research/educational organisations, representatives of industry organisations); attitudes towards uptake of technology on-farm; perceptions of the difficulty of applying technologies on-farm (EID reading equipment for sheep management e.g., handheld EID tag reader or EID enabled crates and pens; EID reading equipment for cattle management e.g., handheld EID tag reader or EID enabled crates and pens; and precision livestock farming such as GPS on tractors; soil sampling/mapping); perceptions of the impact on business of the technologies applied on-farm (EID reading equipment for sheep management e.g., handheld EID tag reader or EID enabled crates and pens; EID reading equipment for cattle management e.g., handheld EID tag reader or EID enabled crates and pens; and precision livestock farming such as GPS on tractors; soil sampling/mapping).

Table 1 presents a description of the latent variables and their corresponding indicators included in the SEM model.

Table 1. Description of latent variables and their corresponding indicators

Latent variables	Indicators (statements)	Values and labels
Gender	Gender	1 (male), 2 (female)
Age	Age	1(35 and under), 2 (36-44), 3 (45-54), 4 (55-64), 5 (over 65)
Education	Education	1 (school), 2 (college), 3 (university or higher)
Profit	Profit orientation	1 (yes), 2 (no, but it is important that it breaks even), 3 (no, we expect to make a loss)
Labour	Farm labour (How many people are employed on this land?)	1 (none), 2 (1-3), 3 (4-10), 4 (more than 10)
Information	How useful do you/would you find the following in terms of getting ideas and/or help with application of technology for livestock management:	1 (Not at all useful), 2 (2), 3 (3), 4 (4), 5 (extremely useful)
	Info1 (Attending open days, monitor/demonstration activities, organised study tours/visits)	
	Info2 (Meeting with other farmers)	
	Info3 (Consulting the Press (Farmers Weekly etc.))	
	Info4 (Consulting the Press (TV))	
	Info5 (Consulting the internet)	
	Info6 (Asking for advice from agricultural consultants)	
	Info7 (Consulting Government information sources)	
	Info8 (Consulting representatives of research/educational organisations)	
	Info9 (Consulting industry organisations (e.g. QMS, NFU))	
Attitudes	Attitud1 (My farm needs new technologies to stay competitive)	1 (strongly disagree), 2 (disagree), 3 (unsure), 4 (agree), 5 (strongly agree)
	Attitud2 (Other farmers come to me for advice when considering adopting a new technology)	
	Attitud3 (Sharing knowledge about new technologies with others is important to me)	
	Attitud4 (Time and money spent in adopting new technologies usually pay off)	
Difficulty	how difficult do you/would you find applying the following on your business/holding:	1 (difficult), 2 (2), 3 (3), 4 (4), 5 (easy)
	Difficulty1 (EID reading equipment for sheep management (e.g. handheld EID tag reader or EID enabled crates and pens))	
	Difficulty2 (EID reading equipment for cattle management (e.g. handheld EID tag reader or EID enabled crates and pens))	
	Difficulty3 (Precision livestock farming (such as GPS on tractors; soil sampling/mapping))	
Impact	How has applying the following technologies affected your business/holding:	1 (least beneficial), 2 (2), 3 (3), 4 (4), 5 (most beneficial)
	Impact1 (EID reading equipment for sheep management (e.g. handheld EID tag reader or EID enabled crates and pens))	
	Impact2 (EID reading equipment for cattle management (e.g. handheld EID tag reader or EID enabled crates and pens))	

	Impact3 (Precision livestock farming (such as GPS on tractors; soil sampling/mapping))

Table 2 presents some descriptive statistics for the variables included in the model.

Table 2. Descriptive statistics

Latent variables	Indicators	Cronbach Alpha	Mean Statistic	Std. Deviation Statistic	Skewness Statistic	Skewness Std. Error	Kurtosis Statistic	Kurtosis Std. Error
Gender	Gender		1.21	.410	1.409	.116	-.014	.232
Age	Age		3.67	1.039	-.488	.116	-.237	.232
Education	Education		1.84	.749	.272	.116	-1.179	.232
Profit	Profit		1.10	.368	1.393	.116	1.537	.232
Labour	Labour		1.43	.606	1.291	.116	1.502	.232
Information	Info1	0.855	3.57	1.234	-.554	.119	-.619	.238
	Info2		3.71	1.160	-.674	.119	-.264	.238
	Info3		3.31	1.226	-.410	.119	-.664	.238
	Info4		2.75	1.257	.143	.119	-1.008	.238
	Info5		3.46	1.260	-.565	.121	-.643	.241
	Info6		3.44	1.270	-.533	.120	-.698	.238
	Info7		2.95	1.221	-.072	.119	-.917	.238
	Info8		2.90	1.147	-.080	.120	-.723	.239
	Info9		3.04	1.202	-.267	.120	-.775	.238
Attitudes	Attitud1	0.607	3.15	1.134	-.260	.117	-.997	.233
	Attitud2		2.68	1.193	.075	.116	-1.334	.232
	Attitud3		3.68	.974	-.990	.116	.546	.232
	Attitud4		3.38	.898	-.400	.117	-.347	.233
Difficulty	Difficulty1	0.729	3.69	1.276	-.719	.134	-.486	.267
	Difficulty2		3.58	1.289	-.606	.131	-.678	.261
	Difficulty3		2.88	1.333	.001	.120	-1.073	.240
Impact	Impact1	0.777	3.46	1.277	-.545	.173	-.720	.344
	Impact2		3.39	1.285	-.465	.190	-.775	.377
	Impact3		3.27	1.287	-.401	.163	-.796	.325

Method

We used a structural equation model (SEM) with observed and latent variables to test the conceptual model and assess the strength of the research hypotheses, namely the effects the determinants have on the perceptions of the impact of using technologies on the farm business. As each variable might influence perceptions both directly and indirectly (through their effect on other variables in the model, which subsequently directly influence behaviour), the variance explained by the model is higher than when other methods, e.g., regression analysis, are used.

The model consists of two parts: the measurement model (which stipulates the relationships between the latent variables and their component indicators), and the structural model (which describes the causal relationships between the latent variables). The model is defined by the following system of three equations in matrix terms (Jöreskog and Sörbom 2007):

The structural equation model: $\eta = B\eta + \Gamma\xi + \zeta$

The measurement model for y: $y = \Lambda_y \eta + \varepsilon$

The measurement model for x: $x = \Lambda_x \xi + \delta$

Where: η is an m*1 random vector of endogenous latent variables; ξ is an n*1 random vector of exogenous latent variables; B is an m*m matrix of coefficients of the η variables in the structural model; Γ is an m*n matrix of coefficients of the ξ variables in the structural model; ζ is an m*1 vector of equation errors (random disturbances) in the structural model; y is a p*1 vector of endogenous variables; x is a q*1 vector of predictors or exogenous variables; Λ_y is a p*m matrix of coefficients of the regression of y on η; Λ_x is a q*n matrix of coefficients of the regression of x on ξ ; ε is a p*1 vector of measurement errors in y; δ is a q*1 vector of measurement errors in x.

We estimate the model using the Diagonally Weighted Least Squares (DWLS) method and the statistical package Lisrel 8.80 (Jöreskog and Sörbom 2007). We combine Prelis to compute the asymptotic covariance matrix (Muthén 1984; Bollen 1989) and Lisrel for test statistics to estimate the significance of causal relationships (Jöreskog and Sörbom 2007). DWLS estimation method is in accordance with the types of variables included in the model (ordinal and categorical) and the deviation from normality in these variables (Finney and DiStefano 2006). The model is validated based on absolute (root mean square error of approximation and goodness of fit index), incremental (adjusted goodness of fit index, non-normed fit index, comparative fit index and incremental fit index) and parsimonious (normed chi-square) goodness of fit (GoF) indicators (Hair et al. 2006). A satisfactory level of overall goodness-of-fit does not certify that all constructs meet the requirements for the measurement and structural models. The validity of the model is assessed in a two-step procedure, measurement and structural models. Model selection is executed through a nested model approach, in which the number of constructs and indicators remains constant, but the number of estimated relationships is changed iteratively (Toma et al., 2016).

Results and discussion

The model explains 62 per cent of the variance in perceptions of the impact of using technologies on the farm business. All variables have a statistically significant effect on the perceived impact of using technologies on the farm business.

The model has very good fit according to the measures of absolute, incremental and parsimonious fit (Hair et al. 2006). The main goodness of fit (GoF) indicators (estimated and recommended values) for the estimated model are presented in Table 3.

Table 3. Goodness of fit indicators

GoF indicators	Estimated value	Recommended value
Degrees of Freedom (df)	231	-
Satorra-Bentler Scaled Chi-Square	384.26	-
Normed chi-square (Chi-Square / df)	1.66	[1-3]
Root Mean Square Error of Approximation (RMSEA)	0.039	0.00-0.10
Goodness of Fit Index (GFI)	0.93	0.90-1.00
Non-Normed Fit Index (NNFI)	0.92	0.90-1.00

Comparative Fit Index (CFI)	0.93	0.90-1.00
Adjusted Goodness of Fit Index (AGFI)	0.91	0.90-1.00
Incremental Fit Index (IFI)	0.93	0.90-1.00

Further testing of the suitability of the model was accomplished by comparing it with two alternative models using a nested model approach. The results across all goodness-of-fit measures favoured the estimated model in most cases.

After assessing the goodness-of-fit of the model and accuracy of the measurement model, the standardised structural coefficients were observed for empirical and theoretical implications. Table 4 presents the standardised total effects between the latent variables included in the model.

Table 4. Standardised total (direct and indirect) effects (t-values in parentheses)*

Observed/ latent variables	Total effects on 'attitudes'	Total effects on 'difficulty'	Total effects on 'impact'
Gender	-0.28	-0.32	-0.19
Age	-0.28	-0.14	-0.08
Education	-	0.18	0.11
Profit	-	-0.17	-0.05
Labour	-	-	0.16
Information	0.37	0.19	0.48
Attitudes	-	0.50	0.30
Difficulty	-		0.59
R-square	30%	36%	62%

* The latent variable scores and observational residuals depend on the unit of measurement in the observed variables. As some of these units are the result of subjective scaling of the observed variables the observational residuals were standardised (rescaled such that they have zero means and unit standard deviations in the sample) (Jöreskog and Sörbom 2007). Total effects represent how much a one unit change in an independent variable will change the expected value of a dependent variable.

Perceptions of the difficulty to uptake technologies on farm have the strongest effect (59 per cent ceteris paribus) on perceptions of the impact of technological uptake on the farm business. This is as expected as the more difficult the uptake, the less beneficial it may be to the farm business at least in the short term.

Perceived usefulness of information sources has a significant impact (48 per cent ceteris paribus) on the perceived impact of technological uptake on business. The information requirements of the specific technologies, especially precision agriculture technologies, are considerable and therefore better access to technology information are likely to influence uptake of these technological innovations (Larson et al., 2008).

The next strongest influence is attitudes towards technological uptake, with a significant effect (30 per cent ceteris paribus) on the perceived impact of technological uptake on business. The effect is mediated by perceptions of the difficulty to uptake technologies on farm. This suggests that positive attitudes towards technologies in general will influence farmers in taking things further and envisage the suitability of the technologies for their farms and ease of uptake.

The ranking above confirmed a number of hypotheses, namely that farmers will uptake new technologies if these match well the circumstances of their business, and that uptake is facilitated by better access to information especially so for those technologies which demand stronger technological knowledge. Attitudes towards technological uptake in general may be important but less so than the more specific aspects of it, namely farmers may be interested or largely in favour of technologies however they are more likely to be steered towards uptake if the specific technologies considered are not difficult to implement and farmers have the knowledge required for implementation (Walton et al., 2008; Larson et al., 2008).

Of lower but still significant impact, other influences include socio-economic characteristics, gender (19 per cent ceteris paribus), farm labour (16 per cent ceteris paribus), education (11 per cent ceteris paribus), age (8 per cent ceteris paribus) and profit orientation (5 per cent ceteris paribus). The literature agrees upon the fact that younger more educated male farmers are more likely to uptake technological innovations on farm. Availability of farm labour influences the impact technological uptake will have on farm business and this is consistent with findings from the literature where both higher availability of labour and the focus on profit depict larger farms, which are more likely to be associated with technology adoption. Profit orientation effect on perceived impact of technological uptake on farm confirms findings from the literature that technological adoption behaviour is inherently associated to the economic and financial behaviour of the farm (Adrian et al., 2005).

Conclusions

Our study analysed the factors influencing the perceived impact of technological uptake on the farm business. The results confirm findings from the literature that, in addition to socio-economic and attitudinal factors, access to information influences technological uptake and the impact it has on business. The findings are policy relevant as they give indication on what factors may influence how to target information transfer to potential technology adopters and thus lead to behavioural change.

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