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Adoption of computer based information systems The case of dairy farmers in Canterbury, NZ, and Florida, Uruguay

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Abstract

While the penetration of computer technology into farm offices and homes is quite extensive in some countries, use of the technology as a key component in farm management is not as extensive as might be expected. This study of two farming communities (dairying in Canterbury, NZ, and in Florida, Uruguay) was used to develop models explaining computer uptake and use with the objective of gaining an improved understanding of the process. This can lead to systems more appropriate to farmer requirements. The resulting model stresses that farmer attributes (objectives, personality, education, skills, current information management processes, learning style) are associated with the use of computerised information systems. The size of the business is also important through its impact on potential benefits. The model was developed using information from both non-users and computer owners, as clearly, the non-user's views and data are critical to improving effective adoption. The conclusions, once more, stress that software developers must work with farmers; both in design, and training and support, and the system must be configurable to suit a range of farmer characteristics. Perhaps the packages should also be priced on the potential benefits, not one price for all.

Keywords: Computer adoption; Information systems; Information management; Adoption variables; Structural equation model

1. Introduction

An adequate information supply together with land, labour, capital, and management is required for a successful agricultural business. Information management may become easier, timelier, and generally provide greater value through computerised information system use (Mac Rae, 1984/1985; Lazarus and Smith, 1988; Putler and Zilberman, 1988; Batte et al., 1990; Iddings and Apps, 1990; Jarvis, 1990; Gibbon and Warren, 1992; Nuthall and Bishop-Hurley, 1994; Ortmann et al., 1994; Schmidt et al., 1994; Woodburn et al., 1994; Amponsah, 1995; Warren et al., 1996, 2000; Stubbs et al., 1998; Bryant, 1999; Hoag et al., 1999; Nuthall and Benbow, 1999; Walburger and Davidson, 1999; Lacroix et al., 2001). However, encouraging farmers to change their information management has not been as straightforward and as easy as expected. For instance, farmers have shown a low rate of management software adoption and its effective use relative to farmers' adoption behaviour of technical innovations (Morris et al., 1995; Preve, 1999).

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Table 1
List of main farm information system adoption barriers reported in the literature

Factor operating as a barrier of FMIS[a] innovation adoption	King et al. (1990)	van der Putten et al. (1992)	Eleveld et al. (1992)	Huirne et al. (1996)	Cox (1996)	Beers (1996)	Parker and Campion (1997)
Failure in addressing the real problem	×		×	×	×	×	×
Failure in fitting with farmer patterns of work		×	×	×		×	×
Requirement of inputs (data) that are not familiar, or available		×	×		×		×
Complexity	×				×		×
Unclear cost–benefit relationship	×				×		×
Lack of integration	×		×				
Lack of computer literacy					×		

[a] FMIS means farm management information system.

This study is about better understanding farmers' information management behaviour, particularly in relation to the software adoption process, and consequently how farm information systems might be improved through greater use of more useful software.

Since the farmer is usually an essential component of the farm information system, the choice of information technology is an individualistic process that is usually governed by the farmer's characteristics, such as personality, experience, age, education, and goals. These features are highly personal features, so there may be a considerable variation in the choice of the information technology and system configuration among farmers.

Past research has identified factors believed to operate as software adoption barriers. Table 1 summarises the findings. In these studies, some refer to management information systems in a broad sense (King et al., 1990; Beers, 1996; Huirne et al., 1996), while other papers focus on decision support systems (DSS) (Cox, 1996; van der Putten et al., 1992; Parker and Campion, 1997).

The main barrier is the failure of developers to address the real problem. This issue was summarised by the saying "technology looking for a solution" (Parker, 1999).

Closely related to this issue, the next two barriers reported refer to the usability of the new technology, and that the systems seem to be unsuitable for farmer's standard patterns of work (furthermore, farmers often prefer physical work relative to office time). Similarly, developers have often produced applications that require inputs that are either unfamiliar or unavailable to the farmers.

Other problems include the complexity in design and presentation of DSS, and the difficulty in assessing the largely intangible benefits of information system improvements. If a clear perception of the economic benefit derived from software were available, this would be a major contributor to encouraging farmers' adoption (Gelb et al., 2001).

The lack of integration among the different components of many information systems is another problem. Pre-computer information systems were usually automatically integrated within the farmer's mind.

Finally, it is obvious that for the use of computerised information systems, a certain level of computer literacy is required (Taylor et al., 1991). While this restriction appeared to be significant at the beginning of the 1990s, it is now less relevant given the current trend in computer uptake. However, especially for developing agricultures, this barrier still exists.

Parker (1999) commented that the threat to advisers, the time commitment, and the lack of software updating could also have been factors in the slow uptake.

However, on the more positive side, the factors identified as being associated with on-farm computer adoption have been business size, education, and age. A positive correlation between farm size and computer uptake was found in almost all reviewed studies. Similarly, a positive correlation between the farmer's education level and computer adoption was also found in the majority of reviewed studies. Farmer age was the third factor reported to be correlated with computer uptake. The younger the farmer, the more likely was computer adoption. That is, young, better educated farmers operating larger farms are likely to represent the future expansion of the industry, and these are the farmers most likely to adopt computers.

It has also been found that farmers who owned an off-farm business were more likely to adopt a computer (Putler and Zilberman, 1988). Other studies have found a positive relationship if farmers have off-farm employment (Woodburn et al., 1994; Warren et al., 1996). Off-farm employment is thought to expose farmers to new technologies, to broaden their perspective on management, and to increase their willingness to adopt computers.

In addition, those farmers who previously applied formal approaches to record keeping and who used off-farm services were more likely to adopt a computer (Batte et al., 1990; Ortmann et al., 1994; Woodburn et al., 1994). Ohlmer (1992) noted that farmers using on-farm computers carried out the same management tasks as they previously hired from service organisations. Also, off-farm employment may expose farmers to new technologies and broaden their management perspectives resulting in greater adoption and use.

While computer uptake is a pre-condition, an important issue is whether farmers using a computer believe that they have improved their information management. Several of the reviewed studies addressed this issue (Batte et al., 1990; Ortmann et al., 1994; Woodburn et al., 1994; Amponsah, 1995; Nuthall and Benbow, 1999). Previous research concluded that managers' perceptions of system performance (system usefulness) were significantly correlated with actual information system use, and presumably, with system value (Alter, 1976). These studies have tested associations between farmers' opinions of system usefulness and similar factors used to explain computer uptake, such as farm and farmers' characteristics (Batte et al., 1990; Amponsah, 1995; Nuthall and Benbow, 1999). However, other factors that may be related to system development were not included. Such factors may explain why Nuthall (2004) found mixed economic benefits to computer use.

Undoubtedly, the studies reviewed have helped in understanding farmers' computer behaviour. However, many questions remain unsolved. Firstly, most studies have focussed on explanatory variables in isolation, i.e., studying their individual effects on the dependent variable. These relationships may well be obvious correlations, but may fail to provide basic causal factors that would be useful in enabling systems to help farmers' improve their information management. A study of the interrelationships among explanatory variables will improve the understanding of both computer uptake and the effects of individual variables. Secondly, since the farmer is usually an essential component of the farm information system, the choice of information technology is an individualistic process that is usually governed by the farmer's features, such as personality, experience, age, education, and goals. Former studies have only included part of these personal features. The inclusion of new variables, such as personality traits, learning styles, and farmers' goals may provide a more comprehensive explanation and a better understanding of information management behaviour.

It is expected that farmers seek information and develop their information systems until they feel confident that more information activity will cost more than the marginal return of the information. The farmer's current knowledge base and experience influences the degree of information analysis—new, younger farmers tend to develop and seek more information until their skills and knowledge base are developed to their satisfaction for the particular farm (Nuthall, 1997). Consequently, it is envisaged that farmers' belief in the adequacy of their current information system influences whether they change (i.e., invest in a computer system).

2. Materials and methods

2.1. Model specification

Two farming communities were used to develop models to better explain farmer computer use behaviour. These studies were in Canterbury (New Zealand) and Florida (Uruguay), focussing on dairy farmers. While New Zealand and Uruguay share some similarities such as an economy based on pastoral industries without subsidies, and similar country and population sizes, these two countries also have enough different cultural, economic, and sociological backgrounds to enrich and create the development of contrasting models for different levels of agricultural sophistication.

Initially, it was hypothesised that farmer software adoption behaviour could be explained through the model presented in Fig. 1. This model uses behavioural modelling concepts (Kline, 1998) using mediating variables to assess the relationships. The model accepts that behaviour is not a simple linear cause-and-effect relationship, and relies on three types of variables. The first group includes antecedent variables (circles), such as the farmers' permanent characteristics (farmer's personality and formal education), farm characteristics and community culture. The second group includes

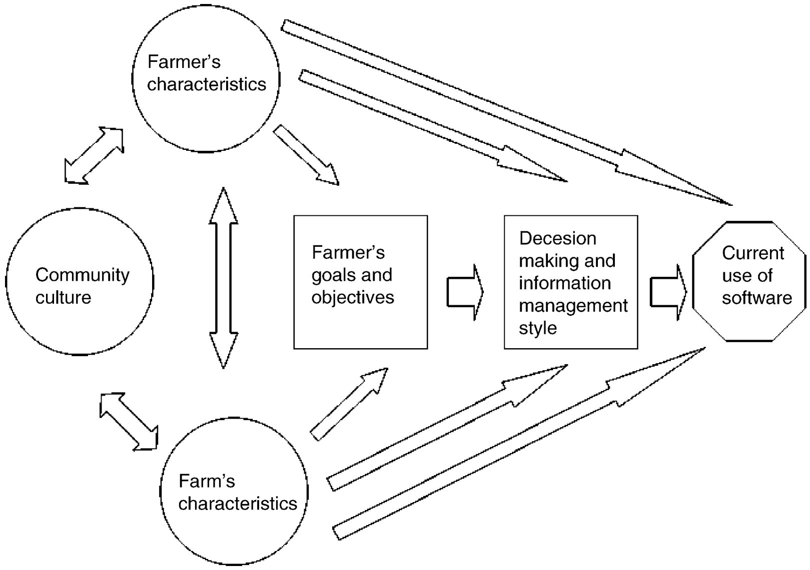

Fig. 1. Information innovation adoption model.

mediating variables (rectangles), such as coping styles, appraisals, objectives, and goals. The last group are the behaviour outcome variables (octagon), which in this case, is the single variable reflecting the use of an on-farm computerised information system.

The proposed model (Fig. 2) allows both direct and indirect relationships between antecedent and outcome variables. For example, education may affect a farmer's objective, management style and whether a computer is used. Thus, the use of software comes as a consequence of the variable itself (education), as a consequence of how education may affect the farmer's goals, and also as a consequence of how education may affect the farmer's decision-making and information management style. Another advantage of the new representation is the consideration of the simultaneous effects. Education, as an explanatory variable, may not be acting alone, but interacting with farm characteristics and/or with elements of community culture.

An explorative qualitative model containing three reasons for adoption/rejection was developed to give the model more detail. The first reason involved what was defined as the 'knowledge gap'. This criterion identified the differences

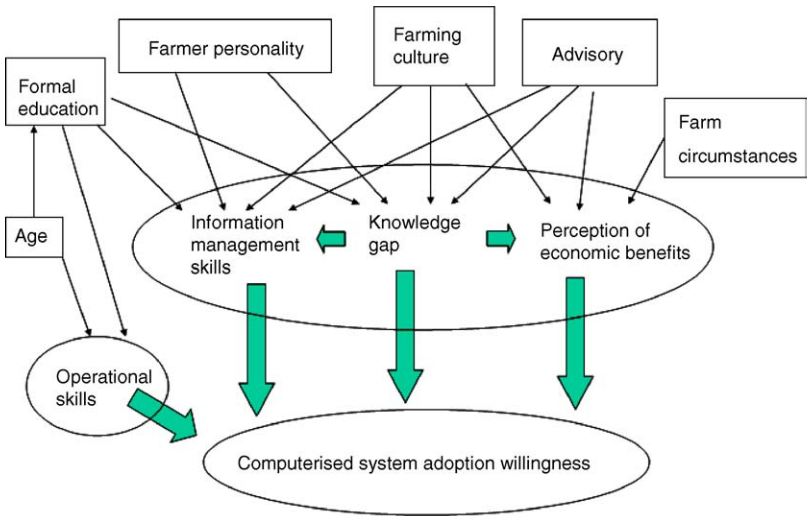

Fig. 2. An enhanced model of computerised system adoption.

in knowledge that each farmer possesses relative to the software developers' knowledge of what the software should do and look like. Farmers with a large 'knowledge gap' are unlikely to use the software. The 'gap' was subjectively assessed in an interview.

Since each farmer already has an information system, some formal–some not, the introduction of software and computer technology may be potentially useful for some farmers, but not necessarily for all. Some farmers may mainly use their minds to record and process relevant farm data, and make decisions mostly by intuition, and being content with their systems, have no desire to change. Thus, the second reason involved the 'benefit perception' and identified the farmers' perception of the economic benefits and ease of management derived from adoption. Finally, the third reason involves the skills needed to manage the information innovation. In this case, the most obvious skill required is computer operation ability.

Farmer interviews provided strong evidence to support the set of reasons proposed. Non-user farmers who were not considering computerised systems invariably saw computers as useless for their particular situations (as you would expect). These farmers saw themselves far away from computer technology (a major knowledge gap), expressed their scepticism of potential economic benefits, and they had neither the operational skills to operate a computer system, nor the information management skills compatible with this kind of technology. In contrast, non-user farmers who were thinking of using this technology (they did not feel alienated by computer technology) had a positive perception of potential economic benefits, and showed information management skills more compatible with computerised system use.

Both groups of farmers (those considering software use and those who were not) shared a lack of operational skills. This lack of operational skills may delay computerised system adoption, but it could be more easily removed than the other barriers. Conversely, the other barriers ('knowledge gap', perception of economic benefit, and information management skills) seem to be more permanent factors that may interact with each other. An important question is whether an appropriate extension programme might positively influence these barriers?

This qualitative information enabled putting more structure to the proposed model (Fig. 2). This model also specifically introduces the farmer's age, formal education, personality, farming culture, advisory, and farm circumstances (area, herd) as variables reflecting both the farmer's and the farm's characteristics. The possible interactions between these factors and those included in the hypotheses are briefly discussed.

Formal education is one of the main developers of knowledge so it is a direct contributor in reducing the farmers' 'knowledge gap'. At the same time, formal education also builds information management skills by providing problem solving frameworks and information searching strategies as well as opportunities for obtaining computer skills. In addition, age is related to (computer) operational skills. A negative relationship was found between age and education, i.e., the younger the farmer, the more educated. Also relevant in some cases, as noted before, are the farmer's off-farm employment experiences.

Given a small 'knowledge gap', some farmers may think about a problem and its solution somewhat differently relative to other farmers. This has been described as "an attitude toward change", a factor which may be used to distinguish early adopters from laggards (Rogers, 1983). Similarly, personality features may be related to information management skills. For instance, the learning styles defined by Kolb (1984) in a classification scheme specifying a person's predominant style could well be relevant.

Similar to formal education, farming culture is another main developer of farmer knowledge. Farming culture involves the values, ideas, and principles that were shared by the farming community when farmers were children and developed their thinking. Farmers usually belong to complex networks that involve family members, friends, neighbours, and colleagues. Part of this knowledge involves the usual procedures to deal with and solve problems. In this context, information management skills usually exist as validated "rules of thumb". In this way, farmer opinions and experiences may become key components in a particular farmer's perception of economic benefits of using computer technology. Clearly, the farming culture difference between Canterbury and Florida is significant, as are differences in education and off-farm experience. These latter factors may mediate and change the influence of culture.

While not being as important as formal education and farming culture, the farmer–advisor relationship may also contribute to information management skills, and provides ideas for formulating the economic perception of technological changes.

The model also suggests three of the factors interact with each other. Information management skills can be considered part of a farmer's knowledge. On the other hand, when an economic benefit perception is developed, key "knowledge" is required to estimate the expected values of possible costs and benefits. According to the farmer interview data (see Section 3), these factors do not seem to act sequentially, as originally supposed. In contrast, they seem to be highly integrated, perhaps because they are different aspects of a unique major factor. Clearly, operational skill represents a different factor, which is related sequentially with the first one, preventing adoption.

It was clear from the interviews that farmers not considering using software stated their lack of time, information knowledge, and training opportunities as reasons. While some Canterbury farmers also felt a lack of confidence and a fear of computers, some Florida farmers stated that they had other investment priorities rather than computerising their information management.

2.2. Data collection

To obtain the data necessary to explore the proposed models, all dairy farmers (537) in the Canterbury region were sent a mail survey, and as part of this process they were asked if they would be prepared to be interviewed to obtain detailed qualitative and scored data. Of the 191 agreeing 39 were randomly selected with strata for farm size, age, and education. In Florida, where obtaining a formal postal list was impossible, 408 dairy farmers were identified through advisers and companies. This was thought to be approximately 90% of the total. A stratified (size, age, education) random selection of 41 were successfully interviewed, and another 20, who were known to have computers, were purposively selected and interviewed. The combination of the mail and interview surveys enabled obtaining the following information: age (years), experience (years), education (1–5 scale), tenancy (0/1 freehold), personality traits (based on openness, conscientousness, extraversion, agreeableness, and neuroticism (Matthews and Deary, 1998) using a locally developed 25 question set), goals (1–5 scale using a 29 question set adapted from the goals used by Willock et al., 1999), learning styles (Kolb, 1984), management team structure (0/1 for team), time at management work (% of total), office time (h/week), adviser use (0–3 scale), information system (0–1 scale based on computer use), information sources (1–3 scale for ranges of sources), information skills (rated for problem definition and recognition, information processing), and software usefulness (1–5 scale), software 'fit to work environment' (1–5 scale), software matching current decision approach (1–5 scale), and software friendliness (1–5 scale). In addition, the 'knowledge gap' was subjectively assessed from the farmer's education and computer system knowledge, as was the similarly obtained 'benefit perception'. To ensure consistency, all farmers were interviewed by the same person.

While it would have been desirable to include a greater number of respondents in the interview phase, the time and resources precluded this, particularly in Florida with the greater distances and less well-developed records. It will not be clear whether a larger sample would have altered the conclusions until further work is conducted.

Relationships between individual explanatory variables and the dependent variable (use or non-use of software) were investigated for statistically significant differences using the t-test for numeric explanatory variables, the Mann–Whitney U-test for non-numeric ordinal explanatory variables, and the Chi-square test for non-numeric non-ordinal explanatory variables. Statistical tests were performed in the SPSS 10.0 package. From these tests, it was clear some of the variables, thought to be related, were statistically non-significant. Consequently, for example, some of the personality and learning style variables were dropped from further consideration (e.g., agreeableness did not seem to be relevant). The remaining variables were used to create a logistic regression equation explaining software use. While for Canterbury 89% and Florida 78%, of the variance was explained, only the age, education, herd size, and abstract conceptualisation learning style variables had reasonably significant coefficients (of course, given many variables, the variance explained increases). Thus, it was concluded that the structural equation concept was likely to provide a more logical and robust explanation of software use. Furthermore, rather than use a simple use/non-use dependent variable, it was felt a cardinal variable would likely enrich the analysis. Thus, the dependant variable was defined as the degree of computer use (−1 for farmers not considering computer use, 0 for those considering purchase, 1 for farmers using software for one information area, and 2 and 3 for those using software in two, or three or more, information areas). Note that the main information area was 'financial'.

2.3. Data simplification and model estimation

Firstly, to avoid multicollinearity among related variables, and secondly, to improve the observation/variable ratio in order to obtain a better statistical estimation, data reduction was carried out. Given the size of the detailed interview samples (39 and 61 for Canterbury and Florida, respectively), it was desirable to reduce the number of variables. Hair et

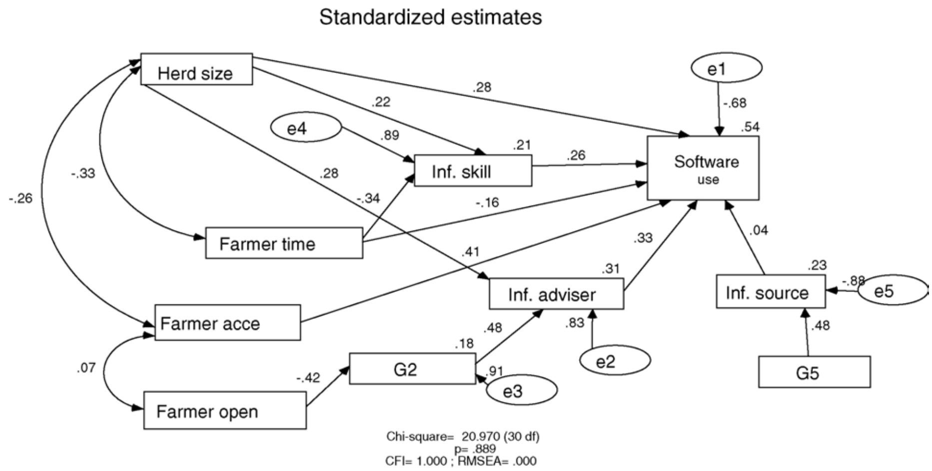

Fig. 3. Canterbury: farmer software adoption SEM model. *Notes:* e1–e5 are error variables. G2 and G5 are both 'quality of life and production' (I and II) factor goals. Farmer acce is the 'conceptualisation-experience' factor. Values on the left of double-head arrows are Pearson-correlation coefficients; values over single-head arrows are standardised regression weights (if these are squared, they quantified the variable influence); values on the right superior corner of dependent variables show R^2 coefficients indicating the part of the total variable variation explained. All parameters were estimated simultaneously. All parameters were significant at the 5% level except time/inf (0.067), herd/inf (0.21), herd/adviser (0.077), inf/software (0.077), time/software (0.252), and inf/software (0.743).

al. (1998) recommend there should be at least five observations per explanatory variable to make the statistical analysis feasible.

Data reduction principal component analysis was applied to identify the underlying factors for the farmer characteristics, farmer goals, and information management practices. The criteria to determine the number of factors in each model area was an eigenvalue greater than one. Loading values were obtained using a varimax rotation.

For estimating underlying farmer characteristics, 10 variables were included, those measuring the four Kolb (1984) learning modes (concrete experience, ce; reflective observation, ro; abstract conceptualisation, ac; and active experimentation, ae), dairy farming experience, age, education, and three personality traits (openness, conscientiousness, and neuroticism).

For farmer goals, variables related to innovation, production orientation, profit orientation, and quality of personal and family life were included.

For information management practices, data reduction was carried out in two steps. Firstly, underlying factors were estimated using the information source scores. Secondly, a new factor analysis was carried out using the management work percentage and office time, the three information management skills (problem definition, information processing, and problem recognition), adviser involvement, and the information source factors.

3. Results and discussion

The structural equation models were estimated using the AMOS 4.0 package (Arbuckle and Worthke, 1999). Both models (Figs. 3 and 4) showed statistically significant discrepancy tests that provide overall model validation (Arbuckle and Worthke, 1999). Other measurements of model fitness, the comparative fit index (CFI) and the root mean square error of approximation (RMSEA) indicated a good overall model adequacy. Suggested values are closer to 1 for the CFI and lower than 0.05 for the RMSEA (Arbuckle and Worthke, 1999).

In the Canterbury case, the estimated model was able to explain 54% of the variation in software use, and in the Florida case, the estimated model explained 60%. In both cases, the estimated models showed the direct and indirect effects of hypothesised variables.

Antecedent variables showed statistically significant associations in the Canterbury case, but no significant associations were found in the Florida case. Farm size had a negative relationship with both farmer 'time' (a principal component based on experience (years), age (years), and education (score)—experience and age had negative effects, while education a positive impact) and 'conceptualisation-experience' factors. The association between farm size and

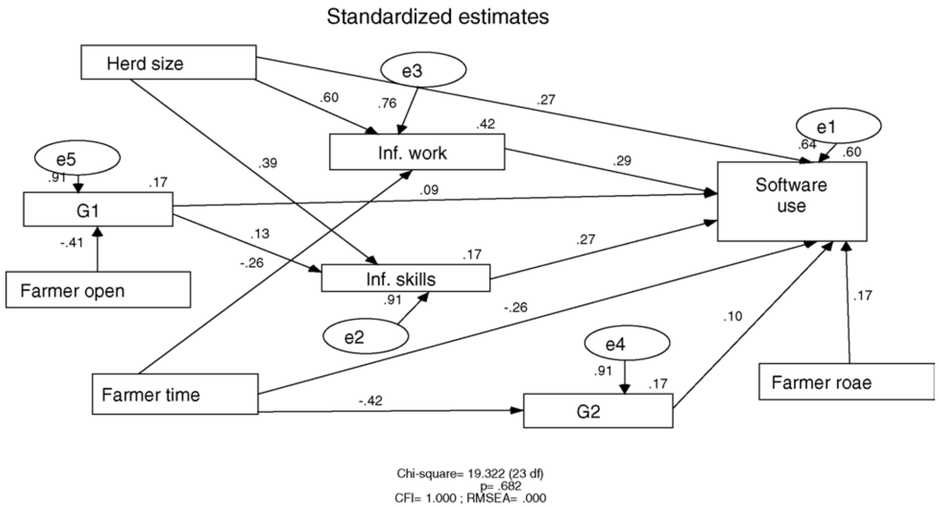

Fig. 4. Florida: farmer software adoption SEM model. *Notes:* e1–e4 are error variables. G1 and G2 are 'quality of life and production' and 'production and profit' factor goals. Farmer roae is 'observation-experimentation' factor. Values on the left of double-head arrows are Pearson-correlation coefficients; values over single-head arrows are standardised regression weights (if these are squared, they quantified the variable influence); values on the right superior corner of dependent variables show R^2 coefficients indicating the part of the total variable variation explained. All parameters were estimated simultaneously. All parameters were significant at the 5%, or better, except G1/inf (0.341), G1/software (0.34), Roae/software (0.068), G2/software (0.342).

the farmer 'time' factor may be related to recent expansion in the Canterbury dairy industry. New dairy conversions in the region were usually carried out as larger farms, and those responsible were commonly younger, and more educated, than the typical Canterbury farmers.

As expected, farm size had a positive effect on software use and a similar standardised regression weight in both models (0.28 and 0.27 for Canterbury and Florida, respectively). This direct relationship can be seen as the effect that farm size has on farmers' perception of economics benefits of software use found in previous studies, and in the qualitative analysis.

Besides farm size, both cases also showed the negative effect of the farm 'time' factor on software use, with a higher standardised regression weight in Florida (−0.26) than in Canterbury (−0.16). As noted, this variable involves negative effects of age and experience, and a positive effect of education on software use. This direct relationship can be seen as the combined effect of those variables on software use, mainly through the relative cost of developing the required skills to operate a computerised system and the relative recovery time of this investment. The higher weight for the Florida case reflects the stronger influence that these variables have on software adoption for the region, and this is probably related to the stronger differences in education attainments, and to the early stage of the overall adoption process.

Apart from the farm size and farmer 'time' factor, a third antecedent variable exhibited a direct effect on software use in both cases. In the Canterbury case, the farmer 'conceptualisation-experience' learning style factor showed a positive effect, weighted by 0.41, while in the Florida case, the farmer 'observation-experimentation' factor showed a similar positive effect, weighted in this case by 0.17. For both cases, farmers emphasising an abstract learning approach (analytical and observation) rather than a 'hands on' approach, were more likely to use software. It is interesting to note that farmer learning style factors only showed direct effects on the dependent variable. The higher weight for the Canterbury case may be associated with the more advanced stage of the software adoption process in this location. While education may be more important in explaining early adoption, other variables, such as learning style, may increase their importance as the adoption proceeds over the years.

In both cases, antecedent variables impacted on mediating variables. Farm size did not directly impact on the use of software, but affected the 'information skills' factors in both cases, and is also related to the 'adviser' and 'management work' factors for Canterbury and Florida, respectively. Similarly, the farmer 'time' factor, besides affecting software use, also relates to the 'information skills' and 'management work' factors for Canterbury and Florida, respectively. The trend of these effects was as expected with the bigger the farm, the more information skills required, the more adviser time involved, and the more time spent on management work. In addition, the younger and more educated the farmer, the more information skills used, and the more time spent on management work.

These antecedent variables not only explain software use through farmers' perception of the economics benefit of software use (farm size), the relative cost of developing the required skills to operate a computerised system, and the relative recovery time of this investment (education and age), but their effects also occur through mediating variables. The relative advantage of using software not only depends on the farm size, farmer's age, experience, and education, but also on the current information system itself, and the related practices. Thus, the variables moderate the effects of the structural variables. A large farm with a young and educated farmer, but with a poorly developed information system, may not constitute a situation where software use is likely to occur. On the other hand, farms with a well-developed information system may take advantage of the benefits offered by computerisation, without regard to farm size, age, experience, or farmer education attainments.

Software adoption was also partially explained by the mediating goal variables in both models. In the Canterbury case, both goal factors, 'quality of life and production I' (g2) and 'quality of life and production II' (g5), are indirectly related to the dependent variable through the 'adviser' and the 'information source' factor, respectively. Conversely, in the Florida case, goal factors exhibited both direct and indirect effects, although their direct effects were relatively small (the standardised weights were 0.09 and 0.1 for the 'quality of life and production' (g1) and the 'production and profit' (g2) factors, respectively). However, the relationships were sometimes the inverse to those expected.

In both the Canterbury and Florida cases, the goals were influenced by the antecedent 'openness' variable. In both cases, the meanings of these relationships were not clear. In the Florida model, the 'time' factor also affected the 'production and profit' (goal 2) factor. This relationship means that older farmers were more production and profit oriented. Thus, cultural values (farmers' goals) moderate the effects of structural variables and have direct effects on software use, though the relationships were different to those expected. In the Florida case, agreement with family, production, and profit values seem to be related to older and less educated farmers who exhibited less information skills, and probably pay less attention to the management side of the farming business.

Finally, software use was also explained by information management practice factors in both cases. The 'information skills' factor explained farmer software use, weighted by 0.26 and 0.27 for Canterbury and Florida, respectively. In the Canterbury model, the 'adviser' and the 'information source' factors also showed an effect (weighted by 0.33 and 0.04), whereas in the Florida model, 'management work' was involved (weighted by 0.29).

The good fit between the data and the proposed model reinforces the theory that farmers' software adoption behaviour results from a complex pattern of interrelationships involving structural factors, such as farm and farmer characteristics as well as 'soft' variables, such as goals and practices, which 'mediate' the effects of the first ones. This overall result is highly compatible with the theoretical frameworks used to explain farmer innovation adoption behaviour, particularly Rogers' (1983) innovation-decision process and Vanclay and Lawrence's (1995) barriers to adoption approach. Because of the methodological approach involving the use of logistic regression analysis, previous studies had focussed only on the direct effects on software use.

It is interesting to note that while in Canterbury the learning style dimension involved experience-conceptualisation; in Florida it involved observation-experimentation. This may reflect a deep learning style difference between Canterbury and Florida farmers which could be related to different educational backgrounds, or a different cultural (and maybe language related) interpretation of the learning style test.

The results showed that farm software adoption behaviour in both Canterbury and Florida does have similarities despite the differences in the stage of development and cultural background. In both cases, goal factor effects were different, as expected, showing that relationships between cultural values and behaviour were not straightforward. To test the idea that one model could explain both situations, the data were pooled using a regional variable. However, the results were not helpful with poor explanatory power. In a situation such as the Florida case, where software adoption is 17%, factors related to age, experience, and education seem to have a strong influence in explaining software use. On the other hand, in a situation where software use involves a large number of farmers (64%), such as the Canterbury case, it appears that factors related to farmer personality, such as the learning style, have more influence in explaining software uptake. In this second situation, factors such as age, experience, and education become less important as the diffusion process proceeds.

In both cases, farm size had a strong influence on the software use decision. Similarly, the current development stage of the information system also proved to play a significant role in explaining software use through the influence of the information skill factor in both locations, and the training and support available in both Canterbury and Florida.

4. Factors affecting software usefulness

A further issue is whether farmers using a computer believe that they have improved their information management. Several studies have addressed this issue (Batte et al., 1990; Ortmann et al., 1994; Woodburn et al., 1994; Amponsah, 1995; Nuthall and Benbow, 1999) and tested associations between farmers' opinions of system usefulness and factors similar to those used to explain computer uptake, such as farm and farmers' characteristics (Batte et al., 1990; Amponsah, 1995; Nuthall and Benbow, 1999). Further, Nuthall (2004) looked at historical profit figures relative to computer ownership. Explanatory variables used included age, tenancy, farm type and size, formal education level, and years of computer ownership. Most of these variables had significant effects, and generally, the overall impact of computerisation was positive. However, Nuthall (2004) found mixed benefits suggesting it is also likely that more directly management related factors are important. For example, the extent to which the new information operation fits with the farmer's existing work environment. The better this fit (i.e., no unusual system requirements such as data inputs or time), the greater the use. This "fit" might well depend on the extent of farmer involvement in system development. Similarly, the matching of the information innovation capability with the farmer's decision context could be important. The more flexible the system to accommodate the farmer's requirements, the more successful the system will be. It might also be expected that the more suitable the system facilities (such as an appropriate introduction of inputs, interface, output type, and integration with other applications—effectively, the level of application friendliness), the more likely will the application be successful.

To explore these ideas, the usefulness of the computerised systems was assessed using data collected from both Canterbury and Florida users on a 1–5 scale. In the Canterbury case, from a total of 21 interviews, there were 19 complete observations. In the Florida case, from a total of 20 interviews, there were 14 complete observations.[1]

On average, Canterbury farmers ranked software usefulness at 4.14 and Florida farmers 3.57. This difference is statistically significant (Mann–Whitney test: −2.23, $p = 0.026$). Overall, the farmers believe the systems have been reasonably 'useful'.

A simple linear regression was estimated to explore the successfulness relationship. The results were:

Canterbury

$$\begin{aligned} \text{successfulness score} = {} & 3.84\,(p < 0.001) + 0.097\,\text{WE}\,(p = 0.601) - 0.245\,\text{DS}\,(p = 0.115) \\ & + 0.22\,\text{SF}\,(p = 0.11) \end{aligned}$$

$$R^2 = 0.43,\ F = 3.99\,(p = 0.027)$$

Florida

$$\begin{aligned} \text{successfulness score} = {} & 2.673\,(p = 0.055) + 0.163\,\text{WE}\,(p = 0.208) + 0.111\,\text{DS}\,(p = 0.473) \\ & - 0.033\,\text{SF}\,(p = 0.886) \end{aligned}$$

$$R^2 = 0.26\ F = 1.19\,(p = 0.363)$$

where WE is score on 'fitting with the farmer's work environment', DS the score on 'matching with the farmer's decision system', and SF is the score on software friendliness.

In neither case is the explanatory power strong, and other than the constants, the significance of the variables is poor. Either the models need expanding, and/or the scoring systems were not accurate, but certainly the sample sizes need increasing. Thus, further work in this area is required, though it is interesting to note that in the Canterbury case,

[1] A complete observation included a score on the overall software usefulness, and additional scores on the three dimensions associated with software usefulness. While some computer using farmers were able to assign an overall useful score, they were not able to answer the other related questions.

the Spearman correlation coefficient between successfulness and the concrete experience learning mode was 0.333 ($p = 0.143$), and with extroversion −0.347 ($p = 0.133$), whereas for the Florida case, the two variables of note were the learning modes 'reflective observation' (−0.527 with $p = 0.053$) and concrete experience (−0.642 with $p = 0.013$). It would seem learning styles and personality impact on success.

5. Conclusions

5.1. Implications for farmers wanting to improve their information systems

Farmers with small farms, being 50 years or older, with less formal education, and with learning styles that emphasise either concrete experience or active experimentation, in contrast to reflective observation or abstract conceptualisation, are less likely to use software than colleagues exhibiting different characteristics.

The key question is whether the farmers described above, if they are wondering whether to improve their information systems, should be discouraged from adopting software. The research results, based on the analysis of farmer behaviour, suggest that the key element for these farmers is their current information systems. A large farm, with a young and educated farmer, but with a poorly developed information system, may not constitute a situation where software use is likely to occur successfully without further development of the existing systems. On the other hand, farms with a well-developed information system may be able to take advantage of the benefits offered by computerisation, without regard to farm size, age, experience, or farmer education attainments.

The other farmers, those farming medium and large farms, and exhibiting personal characteristics compatible with software use, should be advised to go ahead and adopt a computerised system.

5.2. Implications for software developers

This study of farmers' software use was not focussed on any particular piece of software. However, the study of software usefulness has shown that both software features, such as the software fitting and matching with the farmer's working environment and decision context, and software friendliness, as well as farmer characteristics, are all likely to influence successful use.

Another strategy to take into account is software pricing. It is clear benefit depends on the size of the business as is uptake. Thus, the software should be priced per cow or hectare, as often occurs with some information services (e.g., cow yield testing) instead of a fixed price. However, the software cost is only a small part of the total costs relative to the time input, though it can act as an initial barrier.

Similarly, the 'time' principal component factor was shown to affect software use. This relates to the farmer's age, experience, and formal education. While software developers can do little to overcome this factor, it may be useful to make commercial software available in educational and extension institutions to increase farmers', and future farmers', exposure to computerised technology. Lazarus and Smith (1988) found that recent college graduates who were exposed to computer technologies in their coursework applied the skills once they became farm operators. Hence, these authors recommended to agricultural software and hardware vendors to increase efforts to introduce their products to college students as well as farmers.

It is interesting to note, however, that as the adoption process occurs, and the computer uptake increases, the association with the educational level becomes progressively less important. This may happen because, as the innovation is adopted and used, its economic advantages become clearer.

To utilise the farmer 'learning style' factor relationships more research is needed. While farmers with a strong learning conceptualisation (Canterbury) and observation (Florida) preference are more likely to use available software, probably future research may be able to find if it is possible to develop a different type of software which better matches other learning styles (experience and experimentation). However, it is interesting to note that after some experience of the analytical approach required using software, software usefulness seems to increase with a more balanced learning style.

5.3. Implications for extension organisations

The real challenge for extension organisations are the non-using farmers, particularly those who exhibit characteristics not related to current software users. However, for these farmers, it is not clear that the software alternative is the most appropriate for their situation and characteristics.

Extension agencies committed to improving farmer's information systems may proactively attempt to perform a 'turning' policy (Beers, 1996) between farm information improvement demand and supply. As part of this 'turning' policy, alternative extension actions may involve:

(a) The identification of relevant groups of farmers who may demand different solutions according to their different information needs and management abilities. This identification activity may require the development of specific methodologies, such as methods of information need identification, information management skill tests, and learning style tests. Cross et al. (1994) has designed a workshop to facilitate farm information management improvement. This has been successfully used for identifying farmer information needs and strategies for improving information management.
(b) The development of non-computerised alternatives for those farmers unlikely to use software. This recommendation may be pertinent where the segment of farmers unlikely to become software users is significant. This may be the most important difference between the two case studies. In the Florida case, as a representative region of the Uruguayan dairy industry, more than one-third of the farmers were not considering software use in the near future, but they may still want to introduce improvements in their information management.
(c) The organisation of farmer software user groups. It seems that having access to other farmers using software may help more effectively than traditional formal classes (Iddings and Apps, 1990). Watching other farmers has proved to be an effective way of spreading observable innovations. Since software use occurs in the farm office and information management is mostly unobservable, the promotion of software users' groups may provide an effective tool in promoting software use, and helping farmers to visualise the returns associated with computer use. If some farmers achieve increased returns from using computers in their management activities, other farmers may be more willing to adopt computers themselves (Jarvis, 1990; Nuthall, 2004).

Another area of improvement would be the development of research tools for measuring farmers' attributes in information management preferences. Research results showed that farmer learning styles were well identified and measured using the Kolb's (1984) learning styles. A test should be developed to test for a farmer's problem solving and learning style with more direct links to information management and the decision-making process.

Overall, this research has proved that the farmer is a very important part of the successful computer use equation, and that each farmer will be different, though training is likely to help overcome some of these differences.

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