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ORCID:
RS: 0000-0003-1207-8844
RZ: 0000-0002-7315-3126
CZ: 0000-0001-9739-7400
BP: 0000-0002-7621-1598
GP: 0000-0002-8312-0862

Simultaneous evaluation of dairy farmers' behaviour and intention to adopt technological devices

Roberta Selvaggi[1,*], Raffaele Zanchini[2], Carla Zarbà[1], Biagio Pecorino[1], Gioacchino Pappalardo[1]

[1] *Department of Agriculture, Food and Environment, University of Catania, Italy*
[2] *Department of Agricultural, Forest and Food Sciences, University of Turin, Italy*
E-mail: roberta.selvaggi@unict.it; raffaele.zanchini@unito.it; carla.zarba@unict.it; pecorino@unict.it; gioacchino.pappalardo@unict.it
*Corresponding author.

Abstract. Society's awareness of livestock production conditions has increased interest in animal welfare (AW), prompting farmers to consider it in their strategies. However, the adoption of digital devices and sensors to ensure AW is still relatively low. The aim of this study was to assess simultaneously the stated behaviour and intention of dairy farmers towards adopting technological tools for AW. The extended Theory of Planned Behaviour (e-TPB) was selected as theoretical base. It is "extended" since new predictors are integrated in the standard framework of the TPB. The research questions were addressed using a partial least squares structural equation modelling. The findings suggest the existence of a gap between farmers' intentions and behaviour. Perceived Behavioural Control plays a significant role in behaviour, indicating the predominant influence of self-confidence in farmers' choices. Operating margin and technological specialization of the farms are significant predictors of farmers' behavior.

Keywords: Animal welfare, Precision Livestock Farming, Dairy cattle, PLS-SEM, Theory of Planned Behaviour.
JEL codes: D22, D80, D91.

1. INTRODUCTION

Nowadays, dairy farmers face several economic, ecological, and social challenges, including increasing public awareness of animal welfare issues (Borges et al., 2019; Guyomard et al., 2021; Meuwissen et al., 2019; Sekyere et al., 2021; Temple and Manteca, 2020). Farmers' choices are influenced by the new demands of consumers who pay increasing attention to animal welfare conditions, to the point that they are pushing farmers to consider them in their business strategies (Alonso et al., 2020; Blanc et al., 2020; Tullo et al., 2019). As a result, it has proven crucial for livestock farmers to take measures that can improve the quality of life of farm animals (Silva et al., 2021) in order to ensure high production standards.

Exacerbating these ethical concerns is the context of a growing population, estimated to reach 9.8 billion by 2050 (Zarbà et al., 2022), which will imply a significant increase in the demand for food products of animal origin. To meet the growing demand, the related production would have to expand and so would the number of animals, with negative effects on livestock management (Tekin et al., 2021) as well as environmental consequences from increased greenhouse gas emissions causing depletion of the atmosphere.

The scientific literature suggests that technological innovations can help farmers improve their income and farm efficiency (Chavas and Nauges, 2020; Jukan et al., 2017). However, farmers face a complex production reality that significantly affects their business choices.

Tools that can be used to improve the efficiency of livestock farms including in terms of animal welfare include pedometers and collars (Gòmez et al., 2021; Poulopoulou et al., 2019). However, other tools when adopted may improve animal welfare and satisfy the five freedoms of animals[1], making it difficult to choose the most appropriate one (Chapa et al., 2020).

Detecting the physical status of individual animals can prevent disease outbreaks, and consequently save veterinary costs and ensure healthy livestock with better production performance, as well as ensure high welfare standards (Stevenson, 2023; Tekin et al., 2021).

Moreover, the adoption of specific animal welfare devices implies beneficial environmental outputs (Fraser, 2008). In fact, the management of livestock management may help in reducing greenhouse emission (Stygar et al., 2021; Niloofar 2021), for instance, by monitoring the use of water (Morrone et al., 2022; Neethirajan and Kemp, 2021), by ameliorating manure management, by reducing the generation of enteric gas, feeding the animal with better quality products (Bianchi et al., 2022) and consequently changing the habit of feeding livestock with merely locally available grown forages or less valuable agricultural by-products (Gonzali, 2020; Nadal-Roig et al., 2019). Next, livestock wastewater contains large amounts of mineral and organic compounds and in absence of a specific management system they can accumulate in soil and water can provoke serious environmental pollution (Licata et al., 2021).

Overall, animal welfare tools are important for the so-called Precision livestock farming (PLF) technologies which according to Berckmans (2017) is the continuous management of individual animals in real-time monitoring relevant events such as health, welfare, production/reproduction, and environmental impact using information and communication technologies (ICT). PLF constitutes a great support for farmers to accomplish three aspects: welfare (Krampe et al., 2021, Tobin et al., 2022) economic efficiency and health (Stachowicz et al., 2021; Veissier et al., 2019) and environment (Guarino et al., 2017).

Therefore, PLFs are animal-centered tools that can support farmers in herd management decision making (Lovarelli et al., 2020; Simitzis, 2022). PLF tools indicate precise useful information about livestock, and in the event that these indications reveal anomalies, the farmer can take action by choosing new strategies to adopt (Norton and Berckmans, 2017) to maintain the level of animal welfare (Rowe et al., 2019).

In addition, animal welfare devices are part of that category of technology called the Internet of Things (IoT) (Akbar et al., 2020; Akhigbe et al., 2021; Zhang et al., 2021) whose potential is very useful for monitoring animal health (Banhazi et al., 2012). When put in communication with other technological devices, IoT systems act completely autonomously, such as sending a message to the veterinarian in real time (Aquilani et al., 2022), responding to a request for information, automatically activating air conditioning or fans if the animals' body temperature rises. All sensed data are also transmitted and stored in farmers' computers. Each farmer can interpret each piece of information, identify any critical issues and take timely action (Lovarelli et al., 2022; Schillings et al., 2021).

Focusing on dairy animals, there are many PLFs useful for monitoring animal welfare (da Borso et al. 2022; Henchion, 2022). Some of the available technologies can be placed on or in the cow (Stone, 2020) and might be wearable or remote equipment for recording physiological or behavioral parameters (Herlin et al., 2021). Among these devices, there are pedometers, i.e., sensors that, when placed on dairy cows, allow them to monitor the behavior of individual animals. In fact, pedometers function as accelerometers (Mattachini et al., 2013; Stygar, 2021), or measure temperature, movements, digestive activities and panting from heat stress (Ramón-Moragues et al., 2021). In detail, pedometers predict lameness earlier than the appearance of the clinical signs (Mazrier, 2006); detect oestrus periods (Roelof et al., 2005); record locomotion behaviors, the lying and standing time (Mensching et al., 2021; Santo et al., 2020; Shepley et al., 2017; Vasseur, 2017), the frequency of lying (Shepley et al., 2020), the number of lying bouts

[1] Their formulation dates back in the early 1990s and they synthetize society's expectations for the conditions animals should experience when under human control: 1) Freedom from thirst, hunger and malnutrition; 2) Freedom from discomfort and exposure; 3) Freedom from pain, injury, and disease; 4) Freedom from fear and distress; 5) Freedom to express normal behaviour.

and steps, the motion index at a resolution of 1 min (Stachowicz et al., 2022), etc.

With regard to the determinants influencing the use of modern technologies, numerous aspects have emerged in the scientific literature. One aspect is that the breeder's decision to invest in technological devices depends on their propensity to use the technology, their level of awareness of technologies and their capabilities (Makinde et al., 2022), especially if its use opens up new opportunities to improve the livestock' living conditions and a sustainable production (Hartung et al., 2017). Another reason to invest in digital systems turns out to be an improvement in profitability (Rutten et al., 2013; Steeneveld and Hogeveen, 2014) through the use of technology.

Moreover, among the variables that condition the adoption of digital tools in the agribusiness sector there are the operating revenues (Vázquez et al., 2019) and costs of the devices (Makinde et al., 2022).

The type of farm management also seems to have an impact on the intention to install the technology, with some farmers believing that PLF can better support pasture-based systems (Groher et al., 2020; Lomax et al., 2019), while others value their use in the barn as well (Umega and Raja, 2017).

Device's adoption also appears to be influenced by socio demographic aspects, including age, geographic location, education level (Groher et al., 2020; Pierpaoli et al., 2013) as well as attitudes towards animal welfare (Kellert, 1980; Richards et al., 2013).

Given the above, although the use of technology in agriculture and specifically in livestock management results are well recognized, existing technologies for PLF are underutilized. Hence, the present research aims at investigating the perception of dairy farmers about the importance of technology in livestock management and PLF in particular, on the one hand, to update the important research carried out by previous studies (Abeni et al., 2019; Rutten et al., 2013) and, on the other hand, to enrich the scientific literature by proposing a survey based on an hoc questionnaire and carried-out in the province of Ragusa, in Sicily.

It's worth noting that there are numerous regions worldwide known for their milk production, and the choice of a representative study area may depend on the specific focus or research interest within the field of milk production. The Hyblean region, located in the South-Eastern province of Ragusa is known for its agricultural activities, including livestock farming and it is the major milk-producing region in Sicily (Italy) (Ferguson et al., 2007; Pugliese et al., 2021). In 2022, milk deliveries in Sicily amounted to 191.675 tons of which 80.51% (154.314 tons) came from the province of Ragusa (CLAL, 2022).

According to the data reported in the "Statistics" section of the National Veterinary Information System, there were 633 dairy cattle farms in the Sicily region with 44,202 head raised at the end of 2022. Among them, 51 percent (323 farms) are in the province of Ragusa and concern the breeding of more than 30,200 heads (68.32%).

Despite all the barriers already emerged from previous studies in the literature about the adoption of animal welfare devices, to the best of our knowledge, the analysis of dairy farmers' intentions to use such devices is lacking. This is a preparatory aspect to understand the stated behaviour and the motivation associated with the adoption of a certain behaviour.

Considering that intentions and stated behaviours are distinct phases determined by different factors, the present work aims to fill the gap regarding the analysis of their respective determinants. Specifically, we aim to investigate the adoption intentions of dairy farmers by taking into consideration both their individual opinions linked to the decisions, social environment influences and self-perceptions of personal capabilities and limitations. Subsequently, the analysis also regards farmers' behaviour, also using variables already known in literature but evaluated in a broader research context consisting in a simultaneous analysis of intentions and behaviour.

For this purpose, the Theory of Planned Behaviour (TPB) was used as a tool equipped with scientifically recognized constructs for measuring intentions and stated behaviours, in order to check for any correlation between them.

1.1. Objective and research questions

The general objective of the paper is to evaluate what drives dairy farmers toward the adoption of technological devices that can be used to improve firms' performances and animal welfare, by assessing both, stated behaviour and farmers' intention. To reach this goal several drivers of choices were selected. In particular, to properly assess stated behaviour and intention, the Theory of Planned Behaviour was selected as theoretical base by including the related psychological constructs: Intention, Subjective Norms, Perceived behavioural control and Attitude. Moreover, other variables were integrated in the model, related to socio-demographic characteristics of dairy farmers and firms' characteristics. For this motivation, the model adopted lies on the extended Theory of Planned Behaviour since new predictors are integrated in the standard framework of the TPB. Based on these considerations, the general objective can be deeply explored trough the following research questions:

1) Can the Attitude, Social Norms and Perceived Behavioural Control affect dairy farmers intention to adopt technological tools?
2) Can the Perceived Behavioural Control and intention affect dairy farmers' behaviour?
3) Can the socio-demographic characteristics of dairy farmers and firms' characteristics influence the stated behaviour?

The research questions were addressed using a multivariate statistical tool such as partial least squares structural equation modelling (PLS-SEM).

The paper is divided in different sections as follow: theoretical framework where the Theory of Planned Behaviour is deeply explained; methodology that includes information related to data collection and statistical modelling; results; discussion; conclusion where a brief sum of the outcome, implication, limitation and future research are included.

2. THEORETICAL FRAMEWORK

In this complex system, considering dairy farmers only as profit maximisers can be reductive and decrease the capacity to detect factors influencing behavioural changes (Despotović et al., 2019). Literature has provided several tools to improve the Attitudes (ATT), Social Norms (SN) and Perceived Behavioural Control (PBC) ability to describe producer behaviour using validated multi-items scales, such as the Theory of Planned Behaviour (TPB) (Despotović et al., 2019; Pienak et al., 2010; Rezaei et al., 2019). TPB was firstly formalized by Ajzen, (1991) that indicated that human behaviour can be conditioned by intention (INT). Intention can also be affected by three other constructs, as illustrated in Figure 1.

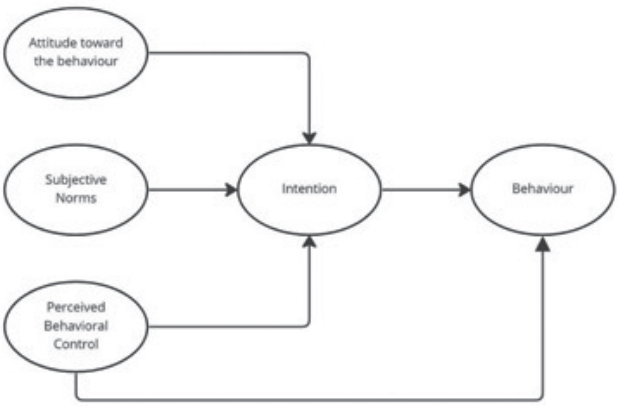

Figure 1. Theory of planned behavior by Aizen (1991).

The constructs individuated by Aizen have different meanings and are built using different items that are processed to find latent variables that describe their underlying information, which can be used as either dependent or independent variables through multivariate models (Raimondo et al., 2022). In particular, intention can be considered as the motivation associated with the adoption of a certain behaviour, a concept also related to the probability of performing it (Dorce, 2021; Raimondo et al., 2022). Attitudes group personal judgments and opinions that can be positive or negative toward a specific behavior, and can lead to the consequences of decisions (Kureshi and Sujo, 2019). Subjective norms include statements that link the influence of the social context and how it can affect the behaviour; while, perceived behavioural control represents a self-assessment of individual's capabilities and limitations that could affect the evaluated behaviour and the engagement in a particular activity (Lopez-Mosquera, 2016; Spina et al., 2023; Wauters et al., 2010). In particular, perceived control refers to the ease or difficulty of performing a particular behavior (Zhong et al., 2015).

TPB was adopted in different studies, to evaluate consumers behaviour related to several aspects such as organic products (Loera et al., 2022), honey and chicken consumption (Menozzi et al., 2015) or toward Protected Designation of Origin Certification (Menozzi, 2021). This theory was also applied to describe dairy farmers' behaviour. Borges and Lansik (2016) evaluated farmers' intention to improve natural grassland, finding that the intention of farmer was mainly moved by the perception of social pressure. In 2020 Savari and Gharechaee found that PBC, SN and ATT had a positive effect toward farmers' intention to for the safe use of chemical fertilizers. However, TPB can also be integrated with other constructs or items to enhance the capability of the model to describe human behaviour. In this case, authors indicate this strategy as Extended Theory of Planned Behaviour (Raimondo et al., 2022; Rezai et al., 2019). Indeed, in the present paper, different aspects were integrated to the standard constructs of TPB. In particular, to detect which factors can affect dairy farmers' behaviour toward the adoption of technological devices related to animal welfare, the following variables were used: Age, Education, Breeding type, the operating margin and the access to the Veterinary system. Based on these integrations on the standard TPB, the underlying theoretical base can be considered the extended TPB.

3. MATERIALS AND METHODS

3.1. Data collection

Data were collected in Sicily, specifically in Ragusa Province using a multi-section questionnaire during the last months of 2022 and early 2023 with face-to-face interviews. The province of Ragusa was chosen as the sampling area because of the high amount of milk produced and the high specialization of the farms, which have high investment capital and technical expertises. Consequently, this Province can be considered a representative area of intensive dairy farming (CLAL, 2022). To improve the reliability of the responses, the survey was administered by a trained interviewer with expertise in livestock farming and able to speak appropriately with dairy farmers.

Before the administration of the survey, a preliminary focus group was conducted with various experts in the field of cattle farming, such as dairy farmers, agronomist, public administration representant and academics. The focus group was conducted by 2 facilitators and was developed according to the question approach. This method allows to maximize the consistency of data collection and is structured in different as follow: opening questions, introductory questions, transition questions, key questions and final questions (Ruff et al., 2005). Several issues emerged such as the difficulty for entrepreneurs to obtain adequate remuneration, the lack of funds for structural investment, the need to improve the efficiency of the production system and supply chain, and new demands from consumers that include animal welfare.

These considerations were used to build the survey that was divided in four sections: Attitude toward investments in technological tools, characteristics of firms, attitude toward animal welfare that included TPB and finally socio-demographic feature of respondents. To collect data several questions were developed using both binary questions (yes or not) or in Likert scale from 1 to 5 were 1 means "I do not agree" and 5 "I agree". The last preliminary step was a pilot survey that was necessary to test the understanding level of the questions and subsequently to perform minor revision of the survey. Concerning the TPB part, the items for the constructs, included in the theory were adapted by other studies conducted on farmers' intention and behaviour (Despotović et al., 2019; Rezaei et al., 2019) and are shown in Table 1.

The latent constructs, ATT, SN, PBC and INT were measured by means of Likert scales from 1 to 5 where 1 = do not agree and 5 = agree and were built over 12 items, 3 for each construct. The stated behaviour was obtained from the first section of the survey. In particular, dairy farmers were asked if they employed 3 different technological devices that can also be used to improve the animal welfare. In particular we investigated collars, pedometers and video monitoring systems. A total of 117 dairy farmers adopted at least one of the tools investigated, then the dependent variables for the PLS-SEM, or the stated behaviour, was obtained by summing the positive answers related to the adoption of these instruments. The relations among variables are graphically reported in Figure 2.

The number of dairy farmers surveyed represents 36.22% of the total population in the province of Ragu-

Table 1. List of constructs and items derived from TPB for latent variable extrapolation.

Constructs	Mean (SD)	Items	References
ATT_1	4.863 (0.369)	Adopting animal welfare practices in my farm would lead to productive benefits	Despotović *et al.*, 2019; Pienak *et al.*, 2010 Raimondo *et al.*, 2022 Rezaei *et al.*, 2019
ATT_2	4.880 (0.351)	Adopting welfare practices would improve animal performances	
ATT_3	4.915 (0.337)	Adopting animal welfare practices can lead to professional satisfaction	
SN_1	4.932 (0.253)	People whose professional opinion I value support the introduction of animal welfare practices	
SN_2	4.923 (0.268)	People whose professional opinion I value suggest the introduction of animal welfare practices	
SN_3	3.692 (1.192)	I believe the community influences the choice of farmers to introduce animal welfare practices	
PBC_1	3.188 (1.192)	I have adequate funds and time to adopt animal welfare practices	
PBC_2	4.111 (1.007)	I can properly manage practices to improve animal welfare on the farm	
PBC_3	4.573 (0.634)	I have the technical knowledge and experience to adopt animal welfare practices	
INT_1	4.333 (0.991)	I am planning to adopt animal welfare practices this year	
INT_2	4.385 (1.024)	I plan to raise the level of animal welfare in the next 5 years	
INT_3	4.350 (1.003)	I plan to regularly increase animal welfare practices.	

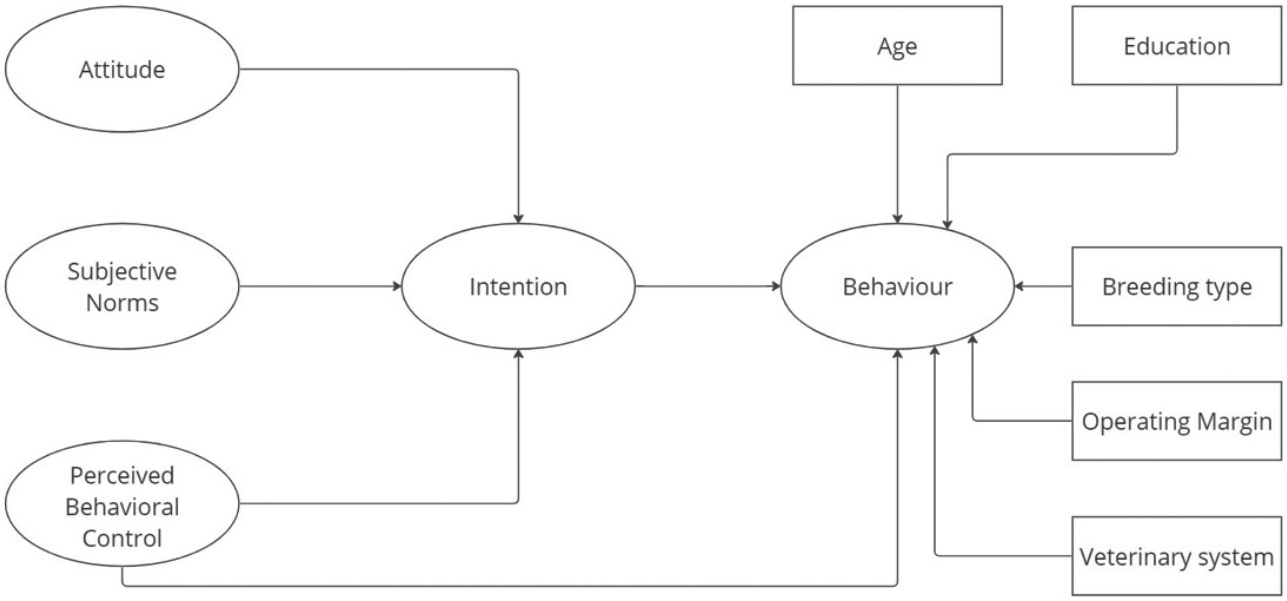

Figure 2. Graphical representations of the relations tested with the structural model.

sa. Based on the power sampling method suggested by Bartlett et al. (2001), the sample size for a population of 400 individuals considering an alpha value of 0.05 is 92. Therefore, the estimates of the models have been considered reliable and adoptable for the general population of Dairy farmers in the study area.

Data collection resulted in 117 valid surveys that were preliminary checked in the data cleaning process to assess the reliability of the answers. To deal with the research questions, some socio-demographic variables and firm characteristics were selected whose descriptive statistics are included in Table 2. These variables were adopted in the PLS-SEM model to get information related to the effect on dairy farmers' behaviour based on farmers and firms' characteristics. Among the variables used to enhance the descriptive capability of TPB, Age and Operating Margin were collected as continuous variables. Education and Breeding type were collected as categorical variables using three levels while the access of farmers at the Veterinary system as a dummy variable where 1 = yes.

Some further explanation is provided to fully understand the meaning of Veterinary system predictors. Indeed, Italian famers can have IT tools to access Italian veterinary services. If farmers can use these systems on the farm, it means that there is also a relationship with the attitude toward the use of computer systems for animal care. Consequently, this variable was adopted in the PLS-SEM model as integration of TPB constructs

3.2. Data Analysis

To address the research question, PLS-SEM was deemed as the most suitable multivariate statistical tool. The method is widely used in social sciences (Ringle et al., 2020) and is considered a useful approach when complex relationships between observed and latent variables are analysed (Sarstedt et al., 2022). Indeed, PLS-SEM is suitable for the analysis of constructs derived by validated scales, such as TPB, to evaluate implications from the adoption of theoretical theories in different case studies (Hair et al., 2019). Moreover, this multivariate method is more suitable than maximum likelihood estimators with covariance-based structural equation modeling (COV-SEM) when the structural model is complex and includes different constructs or whit limited sample size (Hair et al., 2019; Venturini and Mehmetoglu, 2019). Another important advantage in using PLS-SEM is related to the absence of distributional assumptions, such as data normality that rarely occur in social sciences (Hair et al., 2019; do Valle and Assaker, 2016). In fact, maximum likelihood estimators are less robust than PLS-SEM and could lead to abnormal results when normality is not meet (Reinartz et al., 2009). Finally, partial least squares result in higher statistical power, higher robustness, minimization of unexplained variance by maximize r square values and allows the implementation of both, constructs and single item variables (Hair et la., 2020)

PLS-SEM compute partial regressions relations in measurement and structural models by preforming dis-

Table 2. Descriptive statistics of the sample (n = 117).

Variables	Items	Coding	Frequency	Percent	Mean (SD)
Age	Age	Continuos			45.13 (13.13)
Education	Middle school or lower education	1	53	43.30	
	High School	2	47	40.17	
	University degree	3	17	14.53	
Breeding type	Cubicles for cattle	1	12	10.26	
	Permanent litter	2	94	80.34	
	Mixed	3	11	9.40	
Operating Margin	Operating Margin (€)	Continuos			16,696 (150,742)
Veterinary system	Yes	1	55	47.01	
	No	0	62	52.99	

tinct least square regression (Hair et al., 2019; Sarstedt et al., 2020). Indeed, this method is divided in measurement model that provides relations among latent variables derived by constructs and structural model. The second one, highlights the relationships among latent variables by adopting them as predictors (exogenous variables) and outcome variables (endogenous variables) (Venturini and Mehmetoglu, 2019). Constructs adopted for the analysis are considered as proxy of latent variables that are determined as linear combinations. Moreover, can be adopted for predictive purposes (Hair et al., 2020). The algorithm of PLS-SEM consists in three different parts: Iterative estimation of latent variable scores; Estimation of measurement model parameters, Estimation of structural model parameters (path coefficients) (Venturini and Mehmetoglu, 2019).

To assess goodness of fit, several indicators are used in this study. To assess the internal consistency of the construct, Cronbach alpha and Rho A were adopted whose values should be higher than 0.6 (Bland and Altman, 1997). Convergent validity was evaluated using average variance extracted (AVE) and the threshold for acceptability was 0.5. Collinearity among variables and constructs was calculated using the variance inflation factor (VIF) of which, the maximum value to consider collinearity acceptable would be 5. Finally, where the VIF values are acceptable, the variance explained by the different constructs was assessed by means of the r square value. This index is considered also as an estimation of the explanatory and predictive power of the model and was considered acceptable for value higher than 0.25 (Hair et al., 2019). Finally, the interpretation of standardized loadings was conducted for those whit value higher than 0.4 (Hair et al., 2011).

All the analyses were carried out using STATA software 17 and "plssem" package (Venturini and Mehmetoglu, 2019).

4. RESULTS

As indicated in methodology, different outcomes are provided by PLS-SEM analysis. Starting from the measurement model depicted in Table 3, the standardize loadings meet the criteria indicated by Hair et at., 2011, being higher than 0.4 except for SN3 that obtained a score of 0.374. However, since the reliability of the SN construct is high based on the alpha, rho and AVE values, the items was considered suitable to be included in the measurement model. This result indicate that all the items investigate in constructs provide a good contribution in the latent variables identified by the measurement model. This value can be interpreted as correlation between items and each related construct. The reliability of the factors was evaluated in different ways. In term of reliability, Cronbach's alpha values are higher than 0.6 for each latent variables indicating high internal consistency of the constructs. However, as indicated in literature, this indicator provides conservative value of internal consistency. Therefore, Rho A can complete the information being this coefficient more balanced than the first one (Hair et al., 2019). The values of Rho A are higher than 0.6 suggesting that each construct have adequate consistency and can be used in the structural model. Convergent validity was evaluated trough AVE that is higher than 0.5 for each construct, indicating the possibility for the latent variables to be used in the structural model.

The structural model followed the measurement one. However, the collinearity was tested using VIF analysis using each construct and items adopted in the structural model. The results of the collinearity test are shown in Table 4 and suggest that this issue does not affect the analysis and the variables are adequate for the analysis being the values of VIF lower than 5.

Moving on the structural analysis, the relations are tabulated in Table 5. The average r square obtained is

Table 3. Factor loadings and goodness of fit for the measurement model.

Items\Construct	Attitude	Subjective Norms	PBC	Intentions
ATT_1	0.648			
ATT_2	0.960			
ATT_3	0.647			
SN_1		0.929		
SN_2		0.924		
SN_3		0.374		
PBC_1			0.789	
PBC_2			0.872	
PBC_3			0.610	
INT_1				0.857
INT_2				0.927
INT_3				0.943
Cronbach alpha	*0.690*	*0.606*	*0.643*	*0.895*
rho_A	*1.240*	*0.689*	*0.696*	*0.895*
AVE	*0.587*	*0.619*	*0.584*	*0.827*

Table 4. VIF analysis for the constructs and items used in the structural model.

Constructs	Intentions	Stated-Behavior
ATT	1.146	
SN	1.176	
PBC	1.087	1.531
INT		1.708
Variables		
Age		1.486
Education		1.395
Breeding type		1.110
Operating Margin		1.162
Veterinary system		1.117

0.306, suggesting that the model that explanatory and predictive power of the analysis is sufficient. Path coefficients are indicative of the direction and the magnitude of the relations among Constructs and variables with the explained variables: Intention and stated-behaviour.

Starting with the relation with the intentions and TPB constructs, we found that only PBC has significant effect on dairy farmers' intention to adopt technological tools to improve animal welfare. Conversely, ATT and SN are not significant in the structural model. Since these latent variables are obtained starting from TPB adapted for the analysis of dairy farmers' intention and behaviour toward innovative tools, further explanations are provided.

Table 5. Structural model with path coefficients.

Constructs	Intentions	Stated-Behaviour
ATT	0.008 (0.922)	
SN	0.037 (0.661)	
PBC	0.559 (0.000)	0.211 (0.037)
INT		0.008 (0.945)
Variables		
Age		0.058 (0.558)
Education		0.065 (0.496)
Breeding type		-0.168 (0.052)
Operating Margin		0.380 (0.000)
Veterinary system		0.178 (0.040)

Note: p-values in parenthesis.

Another important information is provided by the coefficient related to ATT which is representative of dairy farmers' evaluation of the consequences of their decision. Being the coefficient close to zero, this construct seems to be unrelated with the intention. .

The structural model evaluated also the relations between TPB construct and items with dairy farmers' stated behaviour. Important outcomes are obtained by this model; in fact, INT is not significant. This result is particularly important because it indicates that there is an important gap between dairy farmers' intentions compared to the actual execution of the behaviour. PBC, on the other hand, is significant compared to the actual behaviour.

Since ATT 1 is not significant, it's also possible that the drivers of the stated behaviour lie on other aspects. So, as suggested by Spina et al. (2023), other aspects were considered in the structural models to improve researchers' ability to describe farmers behaviour. So, to get more information related to the drivers of the stated behaviour, single items variables related to farmers and firms' characteristics were included in the model. Among such predictors, Age, Education, Breeding type, Operating Margin and Veterinary system were integrated in the structural model and were found to be useful to describe dairy farmers' behaviour. In particular, Operating Margins represents the variable with the highest magnitude based on the obtained coefficient. Even if the p-value is just above the 0.05 limit, also breeding type indicates that producers that use Cubicles for cattle are more likely to adopt tools related to animal welfare. The access to the Veterinary system is positively related to the stated behaviour.

Finally, the results highlight neither age nor education is significant in the structural model, suggesting that the aspects that drive dairy farmers' choices are mostly related to the farms features rather than personal characteristics, except for self-awareness mediated by PBC.

5. DISCUSSION

The results about the significant effect of PBC on dairy farmers' intention to adopt technological tools to improve AW suggest the important role of dairy farmers' awareness in their capabilities described by this construct (Lima et al., 2018). The coefficient of PBC is positive, indicating that as self-awareness increases, intention toward the adoption of technological instruments increases (Timpanaro et al., 2023). Conversely, SN that consist in the effect of the system surrounding farmer, is not significant in predicting their intention. This result suggests that dairy farmers are little influenced by outside opinions, preferring to rely on their own knowledge in making managerial decisions (Bagheri and Teymouri, 2022; Dong et al., 2023).

Another important result is the construct ATT that seems to be unrelated with the intention. This result could suggest that dairy farmers are still unable to judge the effect on business performance in the medium to long term of the introduction of technological innovations related to animal welfare, as stated by Rutten et al. (2018) and Silvi et al. (2021).

The structural model evaluated also the relations between TPB construct and items with dairy farmers' stated behaviour. The results of this model suggest the high importance of self-awareness with respect to business investment in innovative technological instruments. In fact, investing in new technologies involves high effort by entrepreneurs in developing technical skills. As a result, a high PBC can reduce the perception of risk and encourage entrepreneurial choices toward such tools (Yang et al., 2022).

When single items variables related to farmers and firms' characteristics were included in the structural model, Operating Margins resulted as the most important variable that affect the adoption of technological tools. This result confirms what Vázquez et al., (2019) stated about agribusiness sector and it is crucial because it indicates that it is the actual availability of funds that moves dairy farmers' investments rather than intentions and SN. Moreover, also the access to the Veterinary system has significant effect on the stated behaviour. Conversely, less specialized systems such as litter and mixed systems are not related to technological innovation (Abeni et al., 2019). The access to the Veterinary system is positively related to the stated behaviour, suggesting that dairy farmers capable to use IT system to communicate with the veterinary system are more interested in animal welfare technologies contrary to other findings reporting that there is no this kind of interrelation (Kebebe et al., 2017). This variable has a twofold meaning: greater aptitude compared with IT services and greater attention to herd health aspects. The last aspect that is worthy to be considered is related to the role of entrepreneurs' characteristics.

The use of devices to improve animal welfare in agriculture, including animal husbandry, can lead to a range of benefits, including greater economic and environmental sustainability of the production process. Constant monitoring of animals can help identify health or welfare problems early, thereby reducing economic losses due to diseases or mortality. Devices that optimize feeding, waste management, and water use can contribute to reducing operating costs and minimizing the environmental impact of farming. Developing low-cost devices and accessible technological solutions for farmers is crucial to ensure that the benefits of technology are available to all, regardless of the size of the farm or available financial resources. Investing in research and development to continuously improve devices and technologies for animal welfare can lead to increasingly effective and efficient solutions, further enhancing the sustainability of the animal husbandry industry.

6. CONCLUSION

6.1. Main outcomes

The paper investigated using the extended TPB as theoretical framework and a multi variate analysis tool such as PLS-SEM dairy farmers' intention and behaviour toward the adoption of technological tools related to animal welfare. This methodological approach allowed us to meet the research questions. In particular, we found that PBC was a good predictor of intention while SN and ATT were not significant in the model. PBC and INT were used as regressors of behaviour; results indicate that a gap between behaviour and intention exists. Conversely, PBC is significant toward behaviour indicating the predominant role of self-confidence in dairy farmers' choices. TPB was integrated using dairy farmers and firms' characteristics as predictors of behaviour. Results suggest that behaviour is mainly affect by firms characteristics being age and education are not significant in the structural model. The operating margin is the driver with the highest effect in dairy farmers' behaviour indicating that the implementation of technological tools and attitudes toward innovative investments are mainly influenced by the actual availability of liquidity. Finally, also the technological specialization of the firms and IT and veterinary aspects can be important as significant predictor of behaviour.

The results of this research state the importance of developing ad hoc strategies and promoting research in

this field as crucial steps to maximizing the benefits of these technologies.

6.2. Implications

The results of this work have several implications, for academics and stakeholders in the dairy cattle sector. Considering the academic perspective, to the best of our knowledge, this is the first work using the extended TPB to describe dairy farmers' choices for technological tools related to animal welfare. Consequently, these results can provide early clues regarding this topic. In particular, the importance of TPB constructs for describing dairy farmers' intentions emerged but not as a predictor of actual behaviour. The prominent role of the operative margin was found indicating that TPB can be a good predictor for intention, but structural characteristics of firms could have an important role in describing dairy farmers' behaviour. For stakeholders, this work can help improve the characteristics of the sector. Indeed, technology investments are advisable to improve the efficiency and profitability of enterprises. Considering that the main drivers of behaviour are related to operating margin, breeding systems and the access to the IT veterinary system, policymakers could support, even though the Community Agricultural Policy, the adoption of technological tools and the acquisition of IT support for enterprise management. Such investments should be supported by appropriate training courses to improve dairy farmers' competences. Finally, since PBC is significant in the structural model, the introduction of technical training courses can also be helpful in improving the investment readiness of dairy farmers.

6.3. Limitations and future research

The main limitation of the work is the typical one for the studies involving survey area: the results are influenced by the local problems and conditions where dairy farmers conduct their activities. Consequently, the same study, if carried out in other regions, could lead to different results. However, this limitation can be mitigated by the power sampling evaluation carried out that suggested the sample size used is sufficient to make statistical inference. Another limitation of the work comes from the variables used in the model. While strengthened by such aspects the model cannot be exhaustive of behaviour, as there are multiple drivers of individuals' behaviour. In fact, only selected aspects were investigated, consequently other factors influencing dairy farmers' behaviour may play a role that was not observed in this study (i.e. entrepreneur's risk aversion, availability of funding, barriers, competition, and others). However, this limitation offers an important insight for further research. In fact, the TPB could be integrated with other constructs or single items derived from scales validated in literature or with other items that have not been considered, with the aim to increase understanding of the drivers of choice for describing behaviours. Moreover, TPB could be replaced or integrated with scales that consider other aspects such as the Norm Activation Model as the main model. Finally, the same work could be conducted in other regions and countries to assess changes in the structural model.

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